JOURNAL OF RESEARCH IN ECONOMICS, POLITICS & FINANCE

EKONOMİ, POLİTİKA & FİNANS ARAŞTIRMALARI DERGİSİ

Volume: 10 Issue: 1

2025

e-ISSN: 2587-151X

EKONOMİ, POLİTİKA & FİNANS ARAŞTIRMALARI DERGİSİ
Journal of Research in Economics, Politics & Finance

Peer-reviewed, Scientific and Quarterly
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Publisher/ Yayıncı: Economic and Financial Research Association/Ekonomi ve Finansal Araştırmalar Derneği
Contact / İletişim: epfjournal@gmail.com

Year: 2025, Volume: 10, Issue: 1, March / Yıl: 2025, Cilt: 10, Sayı: 1, Mart

ISSN: 2587-151X

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Journal of Research in Economics, Politics & Finance, 2025, 10(1): 1-26
Araştırma Makalesi / Research Article, https://doi.org/10.30784/epfad.1576481

THE DYNAMICS OF OUTPUT GAP HYSTERESIS IN TÜRKİYE

Türkiye'de Çıktı Açığı Histerezisinin Dinamikleri

Koray YILDIRIM[*], Neşe ALGAN[**] & Harun BAL[***]

Keywords:
Output Gap, Hysteresis, Structural Break, Structural VAR

JEL Codes:
E22, E32, E61

Abstract

The aim of this study is to identify the dynamics and hysteresis of the output gap. First, the existence of an output gap in the Turkish economy for the period 2005Q4:2021Q3 is determined using the Hodrick-Prescott and Baxter-King methods, and then the structural break procedure, which is widely used in the literature, is applied to detect hysteresis. The presence of a structural break supports the existence of hysteresis in the output gap. In addition, a structural VAR model is estimated with money supply, capacity utilization rate, and capital productivity variables as components of the output gap. While the empirical evidence points to the role of capacity utilization and productivity variables in explaining hysteresis, capacity utilization shocks are relatively stronger determinants of output gap hysteresis. For future studies, the effect of money supply on capacity utilization and productivity, labor productivity, etc., should be monitored. The novelty of the study is the modeling of hysteresis in a structure that includes demand-side and supply-side components. This innovation allows it to act as a guide for policymaking by taking into account the dynamic conditions appropriate to the nature of hysteresis beyond the static situation, such as the detection of hysteresis in the literature.

Anahtar Kelimeler:
Çıktı Açığı, Histerezis, Yapısal Kırılma, Yapısal VAR

JEL Kodları:
E22, E32, E61

Öz

Bu çalışmanın amacı çıktı açığı histerezis ve dinamiklerinin tespit edilmesidir. İlk olarak Türkiye ekonomisinde çıktı açığının varlığı 2005Q4:2021Q3 dönemi için Hodrick-Prescott ve Baxter-King yöntemleri ile tespit edildikten sonra histerezisin tespiti için literatürde yaygın bir şekilde kullanılan yapısal kırılma prosedürü uygulanmıştır. Yapısal kırılmanın varlığı çıktı açığında histerezisin varlığını desteklemektedir. Ayrıca çıktı açığı bileşenleri olarak para arzı, kapasite kullanım oranı ve sermaye verimliliği değişkenleri ile Yapısal VAR modeli tahmin edilmiştir. Ampirik bulgular histerezisi açıklamada kapasite kullanım oranı ve verimlilik değişkenlerini işaret ederken nispi olarak kapasite kullanım oranı şokları çıktı açığı histerezisinde daha güçlü bir belirleyicidir. Gelecek çalışmalar için para arzının kapasite kullanım oranı ve verimlilik üzerindeki etkisi, işgücü verimliliği izlenmesi gereken noktalar arasındadır. Çalışmanın yeniliği histerezisin talep yanlı ve arz yanlı bileşenlerini içerecek yapıda modellemesidir. Bu yenilik literatürde histerezisin tespiti gibi statik durumun ötesinde histerezisin doğasına uygun dinamik koşulları dikkate alarak politika yapımında rehber görevi üstlenmesine imkan sağlamaktadır.

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Received Date (Makale Geliş Tarihi): 30.10.2024 *Accepted Date (Makale Kabul Tarihi): 02.03.2025*

1. Introduction

The inability of economies to reach their potential growth level has been one of the main structural problems of economic stability since the 1929 crisis. After the permanent structural changes in economies, the business cycle fluctuations settle on a different path, and the economy moves away from its potential and cannot return to its previous level, which is hysteresis behavior. In this process, if the output gap becomes permanent, it may exhibit hysteresis-type behavior. The inefficiency of economic policy, which cannot provide a permanent solution to hysteresis in the output gap, also leads to discussions on the structure of business cycle fluctuations.

The basic explanation of real business cycle theory is that technological shocks are the main dynamic that exogenously drives business cycle fluctuations (Hansen and Wright, 1998). However, empirical studies suggest that the persistent (hysteresis) effects in business cycle fluctuations in the current period are due to shocks in the past period. In the empirical literature, an important criterion for hysteresis is the structure of resistance to the variables that influence business cycle fluctuations. The fundamentals of hysteresis behavior in business cycle fluctuations are based on adjustment time differences in the dynamics that determine output. In terms of the structural state of output, Campbell and Mankiw (1987) argue that the slow movement of output towards the steady state characterizes business cycle fluctuations. In terms of the determinants of output, Lucas (1973) argues that while aggregate demand shocks are temporary in nature, the persistence of structural shocks to real variables is determined by hysteresis. Yellen (2015) argues that the failure of productivity to recover, as a common consequence of structural recessions, becomes a component of the permanent effects on output. The results of studies in the empirical literature are also instructive for understanding the nature of permanent output effects (hysteresis). Kienzler and Schmid (2014) show that hysteresis in real output generally moves in the same direction as the business cycle fluctuations of aggregate demand shocks but exhibits a more persistent structure in supply-side dynamics. Garga and Singh (2021) argue that monetary policy inefficiency, a permanent slowdown in aggregate demand, structural deterioration in employment, and permanent effects on total factor productivity are the factors that deepen the hysteresis as dynamics that prevent output from returning to its previous path after deviating from its path.

The debate on output gap hysteresis focuses on policies that fail to address the output gap. Orphanides et al. (2000), who assessed hysteresis in terms of policy design and effectiveness, pointed out that policies implemented to resolve hysteresis may deepen it. Economic policies implemented by neglecting hysteresis may cause strong hysteresis by becoming the main dynamic of hysteresis, contrary to ensuring economic stability. Mishkin (2017) emphasized that the effectiveness of monetary policy after the crisis should be evaluated through the interaction between the financial system and the real economy. He argues that the policy response function also changes following the structural change in the economy and attributes the failure of the Taylor rule, which is not adapted to dynamic conditions, to this structure. Since it represents structural change, adapting monetary policy to new conditions in the presence of hysteresis will prevent the deepening of hysteresis by increasing the effectiveness of monetary policy. Indeed, the fact that monetary policy becomes ineffective is important evidence of the existence of a hysteresis structure. As a result, it is concluded that the detection of hysteresis effects in the output gap requires an understanding of the nature of the relationship or decoupling (Classical Dichotomy) between nominal (financial) and real (GDP) variables.

The aim of this study is to identify the existence and dynamics of output gap hysteresis and to provide guidance to policymakers. The functioning mechanism of hysteresis is evaluated through the effectiveness of monetary policy on real output and is realized as the economy moves away from its potential through capital stock, employment structure (unemployment hysteresis), and total factor productivity. It is a prominent form of hysteresis behavior in which hysteresis is monetary-based, as shocks in output follow monetary shocks, but real output does not return to its previous path with monetary policy. This structure makes monetary changes a measurement variable in terms of both the dynamics of hysteresis and the inability to resolve hysteresis. Taking into account the behavioral form of the output gap hysteresis and the structure of the Turkish economy, the motivation of the study is directed to constructing the empirical strategy based on these dynamics. In this context, after identifying the hysteresis in the output gap, the effects of money supply, capacity utilization rate, and productivity variables as output gap components on output are taken into account. The lack of such a study in the empirical literature for the Turkish economy indicates that this study will fill an important gap in the literature.

The dynamics of output and output gap hysteresis in the Turkish economy are closely related to the dynamics of important chronic problems. These relations are primarily theoretical in nature. Aydin and Esen (2017) have argued that the policies implemented to achieve full employment cause inflation. From this perspective, the inability of the economy to reach the potential output level due to structural obstacles has revealed the importance of the output gap hysteresis. At the same time, it is noteworthy that the discussions on the middle-income trap in the Turkish economy have links with the output gap. Kargi (2024) argues that the relations between financial processes and output dynamics with globalization have led to the middle-income trap situation in developing countries. As a solution to the middle-income trap of the Turkish economy, technological development and optimization of strategic capital allocation are important dynamics of potential growth. Considering these relationships, providing a comprehensive insight into the output gap hysteresis will be an important guide in policymaking in order for output to reach its potential in the Turkish economy. At the same time, the Turkish economy has been preferred in the model in order to provide important information on chronic inflation and debates on output gap hysteresis findings.

In the case of hysteresis in the output gap, the role of policy is extremely important. This is because the nature of hysteresis is such that policy errors can make policy the source of the problem rather than the solution to hysteresis. First, output gap models increase the margin of error for policymakers in quantitative terms, as they are models for estimating approximate potential (Durand and Fornero, 2024). On the other hand, it contains estimation errors for the determination of which dynamic (supply or demand) causes the output gap and the degree of impact on the output gap. Fatás and Singh (2024) show that in policies implemented for the output gap hysteresis, policies implemented with a lag become a dynamic of hysteresis beyond the dynamics from which the hysteresis originates. In addition, if output is in the form of hysteresis, monetary policy time inconsistencies can transform hysteresis into strong hysteresis.

Traditional structural break tests are widely preferred in the empirical literature to detect hysteresis effects in the output gap. However, the dynamic nature of business cycles makes it very difficult to determine whether these movements are cyclical or due to structural change. In line with this complex structure, holistic empirical strategies that take into account more economic dynamics for hysteresis will produce more effective results. For this reason, in order

to detect the structural change in output, the structural break test was used to find evidence in favor of hysteresis, following a certain tradition. After the identification of hysteresis, it is crucial to analyze the relationship between output and monetary changes, productivity, and capacity utilization rate in order to better understand its nature. Output gap hysteresis is analyzed using the structural VAR method, which is effective in detecting long-run structural changes. The clarification of the weight degrees of the components that are effective in the structural VAR output gap hysteresis will also enable the design of an effective policy mix. In addition to the fact that monetary shocks are theoretically important in determining output, the inability of monetary changes to bring output back to its previous path is also a form of hysteresis behavior. For the supply side, capacity utilization rate and productivity stand out as the dynamics driving hysteresis. Beyond proving hysteresis in the output gap, the findings shed light on many debates, such as the effectiveness/ineffectiveness of monetary policy, the weight of supply and demand dynamics, and the income distribution effects of hysteresis.

The structure of the rest of the study will be as follows: theoretical framework in the second section, literature review in the third section, empirical methodology in the fourth section, empirical findings in the fifth section, and conclusion in the sixth section.

2. Theoretical Framework

The theoretical foundations of hysteresis in economic systems date back a long way, and the empirical literature has an important place in equilibrium debates. Cross (1993) Although not mentioned by name in Alfred Marshall's Principles of Economics, hysteresis is defined as a situation in which a certain movement in production and pricing behavior does not return to its previous level. In the following period, as equilibrium discussions increased, James Tobin stated that hysteresis is nothing different from unemployment that becomes natural unemployment in the long run. Benati and Lubik (2021) argue that the debate on the existence of hysteresis in output and its components is the extent and impact of hysteresis. Indeed, the structural and specific conditions of each economy are unique. Therefore, the effectiveness of hysteresis analyses will increase with comprehensive alternative models. Based on this information, in order to obtain comprehensive and effective findings on the output gap hysteresis in the Turkish economy, the specific conditions of the economy should be taken into account in addition to the theoretical foundations.

Although hysteresis is expressed as the permanent effects of temporary shocks, its forms in economic systems vary in terms of specific conditions. Michl and Oliver (2019) show that there are behavioral forms in which the output gap, defined as the difference between real output and potential output, becomes permanent. In terms of business cycle fluctuations, business cycle fluctuations, which are expressed in many dimensions such as real income, employment, and output, move in a certain systematic (mostly cyclical) way. However, these basic components may exhibit not only a symmetric structure but also an asymmetric structure. The asymmetric structure is based on components that reach equilibrium with a time lag. In this context, the fact that business cycle fluctuations are not defined in a certain systematic way is based on these lagged components (Zarnowitz, 1991). The gap between real output and potential output, which is usually cyclical but whose trend is adjusted to a new path by the permanent effects of shocks, widens and does not return to its previous level. This structure in which the output gap becomes permanent is output gap hysteresis.

The output gap hysteresis is formulated by adding a persistence parameter to the output gap. In the basic definition of the output gap, Y_t is real output and Y_t^* is potential output.

$$Output\ gap\ =\ Yt\ -\ Yt*\qquad(1)$$

The output gap is modeled as hysteresis by adding a persistence parameter and a hysteresis-sensitive output gap form.

$$Lt\ =\ \rho\ Lt-1\ +\ y(\ Yt-1\ -\ Y*t-1\ )\qquad(2)$$

Where y is the hysteresis-sensitive output gap, ρ is the persistence parameter, and Lt is the hysteresis term including persistent effects. By including the hysteresis-free potential output, $\bar{Y}_t^*$, the equation is rearranged to obtain the output gap equation including hysteresis.

$$Yt\ =\ Yt\ -\ (\ \bar{Y}\ +\ Lt\ )\qquad(3)$$

The output gap hysteresis equation implies that the output gap hysteresis is a function of the output gap, output sensitive to persistent effects, and time. Here, the degree of output gap hysteresis is determined by the coefficient of the persistence parameter and the sensitivity of output to persistent effects. The degree of hysteresis determines the path of output in the return of real output to its potential point after the temporary shock. As another form of hysteresis, there are also 'strong hysteresis' conditions in which output persists on the path to which it was adjusted after the shock. Different degrees of output gap hysteresis forms are visualized in Figure 1.

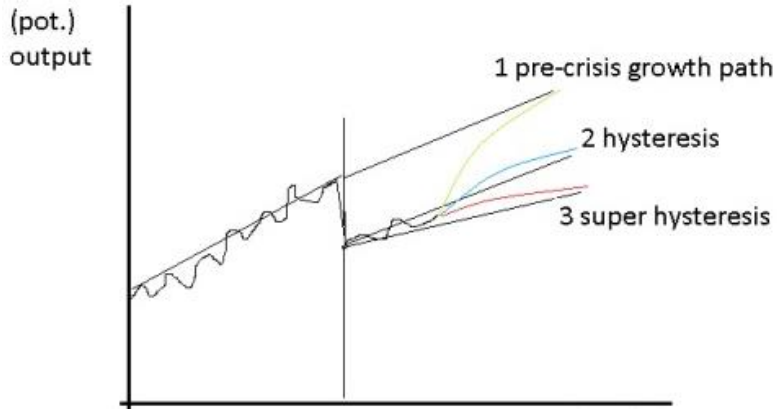

Figure 1. Hysteresis by Resilience Levels

There are different forms of hysteresis in the output gap according to the degree of resilience. As visualized in Figure 1, Van Aarle (2016) defines output path number 1 as the output path that adjusts to its previous path after a temporary shock, output path number 2 as the output path that adjusts to its previous path after a while even if there are permanent effects, and output path number 3 as the strong hysteresis that exhibits persistence in the path it was adjusted after temporary shocks.

Models in which the degree of output gap hysteresis is determined by specific interactions between the structural conditions and dynamics of economies come to the fore. When these relationships are evaluated in terms of theoretical foundations, the importance of monetary policy in aggregate demand shocks is theoretically recognized. As it is known, in Classical

microeconomics, partial equilibrium is formed by the price mechanism, while in Walrasian equilibrium, relative prices are formed by the balance between all markets (Mankiw, 1989). These models do not mention the existence of money in the formation of employment, output, and relative prices. According to the Classical view, markets are shaped in this way by the neutrality of money, while this is rejected in the Keynesian view. Since wages and prices are inelastic in the Keynesian view, the Classical Dichotomy and the neutrality of money disappear. The explanation of the Keynesian view at this point is that when there is an unexpected decrease in the money supply, the temporary decrease in the relative prices of goods encourages producers to reduce the quantity supplied. The real business cycle theory accepts the Classical Dichotomy. However, the fact that fluctuations in real output appear to be related to a nominal variable such as money supply raises doubts about the Classical Dichotomy. On the other hand, the real business cycle theory assumes that the real variable is the cause and the monetary variable is the effect, and the direction of the relationship is accepted as from output to money supply (King and Plosser, 1982). At the same time, as a counter view, the theoretical basis has been formed that demand shocks have a more permanent effect on output (Ball and Onken, 2022). In this debate, the fact that the real business cycle theory takes a view closer to the endogeneity of the money supply provides an exception to the complete disconnect between the financial system and the real economy. Moreover, beyond the disconnect/interaction between the financial system and real dynamics, there are specific factors, such as total factor productivity and its components, and labor market structure and its components, that determine hysteresis.

The existence and direction of the relationship between fixed investment and growth have been widely analyzed, and although no definitive conclusion has been reached, important evidence has been found on the process of this relationship. Blomström et al. (1996), while determining the existence of the effect of fixed investments on growth, also identified the existence of a different mechanism. After increases in fixed investments, growth also accompanies these increases. However, increases in growth mobilize fixed investments before fixed investments mobilize growth. It is observed that this structure is made possible by transferring the increase in per capita income to fixed capital investments along with growth. On the other hand, as studies supporting the effect of fixed investments on growth, Pollard (1964) attributes the start of the Industrial Revolution in England to the fact that there was a lot of capital stock in England at that time, and the existence of this relationship in the historical process is accepted. On the other hand, Fedderke (2004) argues that the functioning of this mechanism also depends on the stability of output. Investments are adversely affected by an increase in output volatility. A decline in investments, on the other hand, leads to a slowdown in output, revealing the existence of a cyclical process that feeds each other in a positive and negative sense. Analyzing this process in terms of hysteresis, the effects of crises last longer as a result of the mutual interaction of deterioration in investments with deterioration in output.

Although the hysteresis structure is historically based on the labor market model (Blanchard and Summers, 1986), the fact that hysteresis effects in employment are closely related to total factor productivity (Fatás and Summers, 2016) provides a comprehensive perspective on the theoretical foundations of hysteresis. Moreover, the relationship between productivity and long-run output makes productivity important in terms of hysteresis. According to Girardi et al. (2020), the traditional approach, which accepts the view that aggregate demand is important only in the short run, recognizes that aggregate demand tends to

adjust to potential output. The functioning of this mechanism is dominated by the view that investments are highly sensitive to interest rates. On the other hand, the Taylor Rule is followed in the interest rate policy that ensures the adjustment between actual and potential output, which is widely used in the current system and expressed as the New Consensus. The effective adjustment of the interest rate policy to the full employment equilibrium level will be possible with the full use of capital, flexibility in labor-capital substitution, and flexible real wages. However, according to the New Keynesian view, the institutional rigidity of real wages makes the effects of economic shocks more permanent. In other words, there is stronger empirical evidence that productivity shocks have a greater impact on the emergence and deepening of the hysteresis structure. Furlanetto et al. (2025), when decomposing the structure of output fluctuations into supply-side and demand-side, make important points about hysteresis effects by re-evaluating empirically the traditional view that sees fluctuations due to demand shocks as temporary. While the transmission mechanism in hysteresis effects takes place through employment and investment, there are uncertain areas regarding output per worker (productivity). The degree to which firms are affected by adverse shocks varies according to their productivity, and in the case of a decline in employment, the increase in productivity with demand that stimulates production may increase the error rate in the measurement of policy responses. The persistence of deterioration in productivity in post-crisis periods and the fact that this situation is mostly caused by demand-side shocks is a form of hysteresis behavior.

Dosi et al. (2018) argue that the insider-outsider model is not the only explanation for the impact of hysteresis on output. Declining investment rates as a result of a decline in aggregate demand due to rigidities in the industrial system, a decline in innovation, a deterioration in the quality of labor, and the market moving away from perfect competition are all determinants of output performance. It is well known that the labor wedge, which is the difference or discrepancy between the marginal rate of substitution (preference for work and leisure) and the marginal product of labor, has increased significantly during recessions, particularly during the Great Depression. Wage and price rigidities are considered to be the main factors in the emergence of this structure. However, other rigidities such as adjustment costs and habit formation in the labor market are also indirect diffusion dynamics. Finally, it is widely accepted that the hysteresis effects in potential GDP deepen the hysteresis by spreading to the supply side through the process starting from the demand shock (Gali et al., 2007; Inaba et al., 2020).

The unique structure of supply-side and demand-side dynamics that cause hysteresis may lead to different dynamics in the hysteresis process. Michl (2018) argues that expectations have an important role in wage bargaining and price determination as mechanisms affected by demand-side policies. Although there is usually persistence in forecast errors arising from worker error and firm error models, it does not indicate a hysteresis structure. However, if expectations are not adjusted according to new conditions after a demand shock and remain constant, it will have permanent effects on output, employment, and real wage levels. On the other hand, the hysteresis process, which is based on a supply shock, is driven by factors such as a decline in capital accumulation, a decrease in labor force qualifications, and a slowdown in the rate of technological diffusion as a result of recessions (Mourougane, 2017). Problems in these dynamics, which cause structural distortions on the supply side, may also exhibit permanence. Indeed, the fact that temporary shocks to supply dynamics have lasting effects on potential output reflects supply-side hysteresis. Therefore, in hysteresis, supply-side dynamics should be evaluated over a longer period than demand-side dynamics.

3. Literature Review

Historically, Hicks attributed the main dynamics of deviations from equilibrium to changes in the interest rate and the value of money. Keynes drew attention to fluctuations in demand in explaining cyclical movements in output. In explaining these cyclical movements, driven by fluctuations in demand and resulting in low growth and high unemployment, Keynes referred to deviations from Classical long-run equilibrium. Burns and Mitchell, on the other hand, characterized these fluctuations in the business cycle as periodic cycles and defined these movements as a necessity of their nature (Cerra et al., 2020).

The phenomenon of hysteresis, which in the empirical literature was expressed as a deviation from the cyclical movements of macroeconomic variables, was also empirically observed in the output gap. The relationship between hysteresis, which is expressed in the persistence of the output gap, and financial crises is widely observed in the empirical literature as well as in the theoretical underpinnings (Redmond and Van Zandweghe, 2016; Romer and Romer, 2017; Blanchard, 2018). Although the view that unemployment, which was a product of the systematic relationship between the financial system and the real economy, was solved by the dynamics of the financial system (money supply, interest rate) was accepted, the view that this process was an equilibrium mechanism has been supported by the experience of resistant output declines in developed economies (Solow, 2000). These long-term effects of financial crises on supply dynamics, starting from the demand structure, were called hysteresis (Ball, 2014). Another situation that increases the importance of hysteresis in terms of business cycle fluctuations is path dependence. Dutt (1997) argues that path dependence manifests itself in the fact that shocks that change the initial conditions in business cycle fluctuations have permanent effects and do not return to the initial conditions with favorable shocks. On the other hand, the deepening of hysteresis in the case of a second negative shock, while the effects of negative shocks persist, increases the importance of timing and historical processes in policymaking.

The structural situation and policy choices of economies are also important for the output gap. The disinflationary policy implemented in the German economy in the 1980s to control inflation made the output gap permanent (Fritsche and Logeay, 2002). The size of the output gap also determines the effectiveness of the policies implemented. A large gap between real and potential output requires a longer period of policy effectiveness. In this process, not neglecting the inflation target will prevent hysteresis in the output gap (Calvert Jump and Levine, 2021). The policy choice for the output gap is also important in terms of hysteresis. Tervala and Watson (2022) find that the most effective policy instrument for the output gap is public investment expenditure.

3.1. Monetary Policy and Hysteresis

Based on Friedman's views, Ball (2009) analyzes the short- and long-run movements of employment, one of the main components of output, for 20 advanced economies and reaches the same conclusions as Friedman. Although the current situation of the developed economies in the 1980s pointed to the validity of the Classical Dichotomy, this structure was not different from hysteresis.

Acharya et al. (2022) argue that the size of shocks is also a determinant of the impact of monetary policy shocks on output, with temporary shocks having permanent effects. The fact

that temporary shocks caused more than one steady-state unemployment in the employment dimension occurs when the labor force loses skills and employment is affected at a level that cannot be recovered spontaneously. Therefore, the reduction in output through employment in a tight monetary policy as a demand-side policy caused a permanent deterioration on the supply side. Bernanke and Mihov (1998) found that the effect of restrictive monetary policy on GDP can last up to 10 years. It can be said that the real economy, which cannot gain the necessary momentum from an expansionary monetary policy, was subject to hysteresis effects. In fact, the results of monetary policy show that hysteresis cannot be assessed only with a supply-side approach but is also related to demand-side policies.

Fontana and Palacio-Vera (2007) argue that the traditional inflation-targeting policy is based on the principle of monetary policy neutrality in the long run and has no effect on output and employment. However, the new consensus is that in the case of hysteresis, output moves independently of aggregate demand and time dynamics and exhibits different trends and equilibrium states, which raises the need for alternative policies to the traditional view in the literature. In this context, a flexible monetary policy that can be adjusted to changing conditions would be the appropriate policy option for hysteresis. Ball (2015) argued that the traditional view that recessions have a short-term impact on output and employment, as experienced in the 2008 crisis, has been challenged. Although recessions cause output and employment to fall, it is accepted that expansionary policy is the appropriate policy in a strong economy to prevent output and employment from returning to their previous path through asymmetric behavior. At this point, an aggressive expansionary monetary policy, which in the case of hysteresis was referred to as a high-pressure economy, would push inflation above expectations. In this case, the cost of returning to the targeted level of inflation would be to raise unemployment above the natural rate. This process will again mobilize the dynamics of hysteresis. Therefore, the view that a gradual expansionary policy is the optimal policy for hysteresis has begun to prevail in the empirical literature.

IMF (2009) Output losses after a recession are not inevitable, but the output gap can be reduced through expansionary monetary and fiscal policies. Following an aggressive expansionary policy after a recession allows output and growth to return to their previous trend more successfully before structural distortions spread through the economy (Ma et al., 2020). Indeed, more aggressive expansionary policies would be appropriate in the case of hysteresis, where the recovery in output has a resilient structure. In conclusion, based on the empirical literature, monetary policy should be conducted according to certain principles in the case of hysteresis. The roadmap for monetary policy in hysteresis is to implement monetary policy in a way that does not cause delays, to implement it aggressively at a level of capacity utilization that does not cause inflation, and to gradually adjust the size of the expansion after the process that causes inflationary effects.

3.2. Capacity Utilisation Rate and Hysteresis

Although the hysteresis literature focuses mainly on absolute changes, such as the persistence of output after a temporary shock or its adjustment to its previous path, income and capital distribution effects are extremely important. In fact, it is the evolution of wage profit and per capita capital that makes income and capital distribution important for output hysteresis. Amadeo (1986) argues that there are two main views that are prominent in sectoral models for

the supply side. The first is the existence of an inverse relationship between wage and profit rates, and the second is the inverse relationship between capital accumulation and the per capita capital ratio. In a high-growth environment with increased capital accumulation, a smaller share of output is allocated to consumption, while if investment is covered by profits, this results in low real wages. The validity of these relationships under the assumption of constant capacity utilization is generally accepted. However, a change in capacity utilization affects all these dynamics and ultimately output. Looking at these dynamics in more detail, Rowthorn (1995) argues that in recessionary periods the NAIRU also rises with the increase in idle capital. This process leads to an increase in profits as capacity utilization rises with the decline in the capital stock. This is due to the fact that production is covered by the increase in existing potential output, as opposed to the participation of labor in the employment of new capital. In fact, it is the rate of capacity utilization that determines these relationships.

Although it is an important determinant of capacity utilization for potential and real output, it has not been given sufficient attention in hysteresis discussions. However, its widespread use in the recent literature is evidence of its importance. Based on the relationship between capacity utilization and business cycle fluctuations, Setterfield and Avritzer (2020) argue that changes in actual capacity utilization are necessary in hysteresis models. Di Domenico et al. (2024) concluded that aggregate supply is influenced by aggregate demand in the long run. More specifically, transitory shocks are found to have a temporary effect on unemployment and capacity utilization, while they have resilient permanent effects on productive capacity and labor force participation. Bassi et al. (2022) find evidence of hysteresis behavior in the capacity utilization rate across sectors in the US economy. However, as the capacity utilization rate at full employment differs for these different sectors, this paves the way for the relative interpretation of hysteresis effects. Bassi (2024) finds evidence of permanent hysteresis in the capacity utilization rate in many EU economies after the 2008 global crisis. Here, capacity utilization adjustments also determine the effectiveness of monetary policy for hysteresis based on inflationary pressures.

3.3. Productivity and Hysteresis

The traditional view that business cycle fluctuations caused by supply and demand shocks move around a certain trend is supported by empirical studies (Tervala, 2021). Therefore, how to model potential output has been questioned more in the literature. In empirical studies, it is among the common results that demand shocks cause hysteresis in output starting from total factor productivity. Other studies in this direction are Adler et al. (2017) and Anzoategui et al. (2019). In the New Keynesian view, recessions cause a short-term decline in consumption, while in the case of hysteresis, consumption falls permanently, leading to further welfare losses. Therefore, the social cost of hysteresis becomes important in terms of restoring demand to its previous level. Blanchard and Summers (1986) empirically proved that the time trend of many economic variables with hysteresis structure is non-stationary. In the European unemployment hysteresis, along with unemployment, total factor productivity also exhibited a hysteresis behavior by not returning to the mean. On the other hand, the fact that productivity shocks have the same effect as positive supply shocks makes productivity an important dynamic in measuring hysteresis effects and determining effective policy.

Blanchard et al. (2015), who tested the persistent effects of recessions in 23 countries over the last 50 years, found the presence of hysteresis in the vast majority of them. The impact of recessions on output mainly spreads through the employment and total factor productivity (TFP) channels, causing deviations in output. Jordà et al. (2020) empirically prove that monetary shocks cause hysteresis in output and total factor productivity. Engler and Tervala (2018) show that the recession in the euro area caused a 4% and 0.9% deviation in output and TFP, respectively. Anzoategui et al. (2019) found that the recession in the US economy reduced productivity by 5%, emphasizing that TFP is the most important dynamic in hysteresis. In terms of the relationship between hysteresis and capacity utilization rate, Köberl (2011) argues that the non-inflationary capacity utilization rate (NAIRCU), which is defined as the capacity utilization of a firm without price adjustment pressure, is effective in measuring the performance of the economy. NAIRU is used as an effective measure of labor costs and the output gap. Although most empirical studies find that it has a constant trend, Bassi (2019) observes that NAIRCU has a time-varying trend. Deviations in GDP can create permanent shocks in total factor productivity if chronically underutilized capacity moves with inflation. If NAIRU remains below full capacity output, demand-side expansionary policies will not create inflationary pressures until full capacity. The fact that temporary demand shocks have permanent effects, in other words, hysteresis effects, results in a spillover to the supply side through the total factor productivity channel. As a matter of fact, adjusting demand-side expansionary policies in recessionary periods in a way not to trigger inflationary acceleration will provide stability in economic activity without deepening hysteresis effects. Approaching hysteresis from the perspective of technological development, Li et al. (2015) argue that technological progress is considered the most important trigger in economic development. Since technological progress is a slow-moving process due to its nature, it is important in terms of hysteresis that there is no time inconsistency in the policies implemented by the governments. Total factor productivity, which reacts with a delay to policies implemented with a delay, will cause distortions in the supply structure. At this point, policies implemented on time by encouraging the innovative production system and improving the adaptation to the innovative production system will be the optimum policy option.

Summers (2014) argues that the future potential of the economy depends on current conditions. Moreover, the hysteresis situation in which economic recovery does not lead to an improvement in total factor productivity is followed by a reduction in capital investment and labor input. After the 2008 World Crisis, labor and capital decreased more than total factor productivity decreased, which better explains why potential output in the US fell to around 5%. Since interest rates have reached lower limits, limiting the room for maneuvering in monetary policy, healthy growth policies have become the more reasonable option for the solution to the recession.

Standard unit root tests (Brunello, 1990; Mitchell, 1993) have been used for hysteresis, which was first examined in unemployment dynamics in economic systems. The presence of a unit root implying a structural break may be misleading in some cases. Structural shocks such as oil shocks, which can be effective on a global scale, cause structural changes in macroeconomic variables. In standard unit root tests, estimation is made without taking into account the endogeneity of structural breaks. In order to compensate for this limitation of standard unit root tests, the Zivot-Andrews test was developed in which structural breaks are endogenous. However, even if structural breaks are endogenous, there are specific conditions for output gap

hysteresis. Tests with endogenous structural breaks based on the standard unit root test have some limitations due to the specific conditions of the Turkish economy. For the Turkish economy, the presence of a unit root or unit root with a structural break in output implies a trend change. This trend change in output is interpreted as the persistence of structural shocks in the economy. The fact that output interacts with all macroeconomic variables increases the likelihood that structural changes will spread gradually to the whole economy in the long run beyond the increase in costs on the supply side. For this reason, the Leybourne et al. (1998) smooth transition structural break test developed for gradual transitions instead of sharp structural breaks will produce effective results for the output gap hysteresis in the Turkish economy.

The hysteresis literature in the Turkish economy has focused on unemployment. Akcan (2019) finds that there is hysteresis in youth and general unemployment rates in the Turkish economy, which is supported by the findings obtained from standard and structural break unit root tests. Tekin (2018) states that in the Turkish economy, the long-run effects of unemployment shocks lead to an increased unemployment path, validating the concept of unemployment hysteresis. Additionally, Ozturk (2020) finds that hysteresis behavior is evident not only in unemployment rates but also in the labor force participation rate in the Turkish economy. These results obtained on the basis of unemployment indicate a permanent deterioration in the dynamics of the employment structure. Since unemployment and employment are components of output, it proves that output in the Turkish economy may have a permanent trend deviation. Therefore, the output gap hysteresis should be comprehensively analyzed for the Turkish economy. Accordingly, the motivation of this study includes the determination of the output gap hysteresis in the Turkish economy as well as the determination of the dynamics and the extent of the hysteresis. Output gap hysteresis is a topic that has not been analyzed in the empirical literature for the Turkish economy. While the study contributes to the literature in this respect, it follows a comprehensive path in terms of the variables used (monetary change, capacity utilization, productivity) and the empirical strategy (smooth transition structural break, SVAR model). In this context, the study provides a new perspective for policymakers by extending the limited empirical contributions on output gap hysteresis in the literature.

4. Data and Methodology

The empirical method of the study is designed to determine the dynamics of the output gap hysteresis and to provide suggestions for policymaking. The variables to be used in the study are defined as gross domestic product (GDP), money supply (M3), capacity utilization rate (CUR), and capital productivity (PRODUCTIVITY), and time series are constructed with the data obtained from the CBRT (CBRT/EVDS) system for 2005Q4:2021Q3 (t=64). The defined time series are visualized in Figure 2.

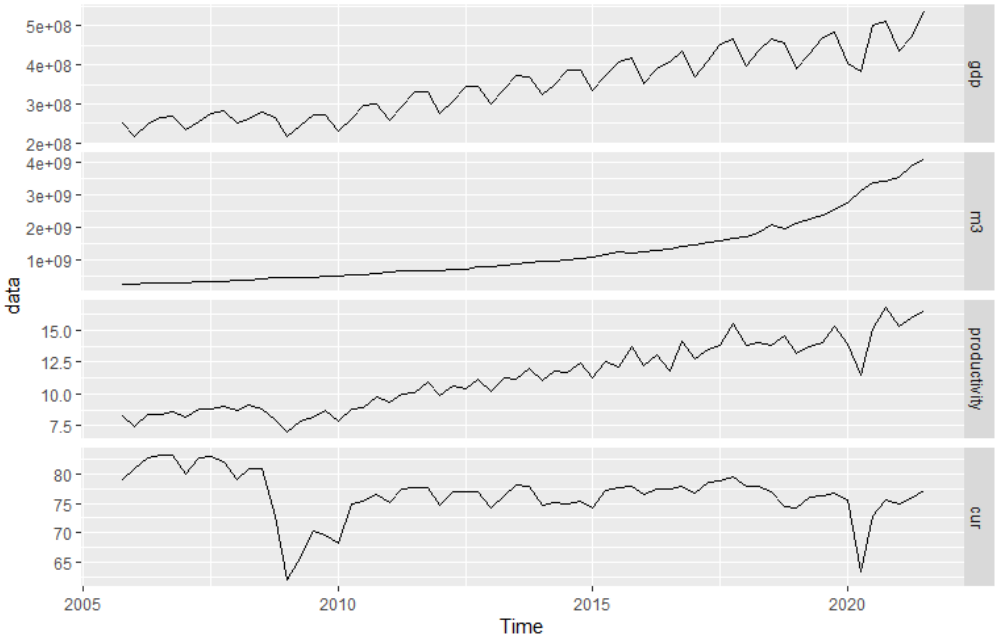

Figure 2. Developments in Variables

In order to evaluate the output gap hysteresis, the output gap in the Turkish economy will be determined by the Hodrick-Prescott (HP) and Baxter-King (BK) methods. The persistence of the trend change in output after a temporary shock or the level of resistance to output components (money supply, capacity utilization rate, productivity) in case output returns to its previous path requires specific analyses to understand the nature of hysteresis. Accordingly, the smooth transition structural break test will be applied to detect permanent trend changes in output, and the structural VAR method will be applied to measure the response of output to its components. For the structural VAR method, the model specification conditions are met as a result of the data processing processes suggested by the logarithmic transformation, Kruskal Wallis seasonality test, and stationarity (Augmented Dickey-Fuller, Phillips-Perron) tests.

4.1. Hodrick-Prescott and Baxter-King Method Output Gap Estimates

The Hodrick-Prescott (HP) filter is widely used in the estimation of the output gap (Hodrick and Prescott, 1997). The estimation method of the HP filter is estimated by minimizing the variance of GDP based on the values of the two main components of GDP: trend and cyclical movement. The HP filter method is based on estimating the output gap from the difference between the actual GDP and the predicted GDP by weighting the linearised GDP series with the help of a logarithm with trend growth. Another frequency filter method is the Baxter-King (BK) filter method. The BK filter has an important advantage over the HP filter. The strength of the BK filter is that it provides a symmetric estimation of real data by taking weighted averages of GDP data and reducing data loss (Iacobucci and Noullez, 2005). On the other hand, the BK filter method has a disadvantage. In the moving average technique, the same number of initial and final observation data are needed for the observation to be estimated.

Therefore, a certain number of observations from the beginning and end of the series are lost (Oomes and Dynnikova, 2006).

4.2. Smooth Transitions Structural Break Test

It is a structural break test developed by Leybourne et al. (1998), which also takes into account non-linearity. The strength of the smooth transition structural break test is that it can detect structural breaks in nonlinear time series while measuring soft breaks instead of hard breaks. The smooth transition structural break test is estimated with the help of the logistic smooth transition function defined as St instead of hard and sudden breaks modeled with the help of a dummy variable in other structural break tests. The logistic smooth transition function is presented below.

$$St\ (\gamma, \tau)\ =\ [\,1\ +\ exp\ \{-\lambda\ (t\ -\ \tau\ T)\}] - 1 \tag{4}$$

Since it tests a nonlinear structure in the estimation phase, the nonlinear ECM method is used, and error terms are obtained. The models from which the error terms are obtained have three different structures. Model A takes into account the smooth transition break in the level, Model B takes into account the smooth transition break in the trend, and Model C takes into account the smooth transition break in both level and trend. The estimation equations obtained for Model A, Model B, and Model C are given below.

$$yt\ =\ \alpha 1\ +\ \alpha 2\ St\ (\lambda, \tau)\ +\ \nu t \tag{5}$$

$$yt\ =\ \alpha 1\ +\ \beta 1t\ +\ \alpha 2\ St\ (\lambda, \tau)\ +\ \nu t \tag{6}$$

$$yt\ =\ \alpha 1\ +\ \beta 1t\ +\ \alpha 2\ St\ (\lambda, \tau) + \beta 2t\ St\ (\lambda, \tau)\ +\ \nu t \tag{7}$$

Structural break in level is detected by Model A, structural break in trend is detected by Model B, and structural break in level and trend is detected by Model C. The interpretation of the estimation results is made with the help of hypothesis tests. While the hypothesis H0: $\delta=0$ accepts the existence of a unit root with a structural break, the alternative hypothesis H1: $\delta < 0$ is interpreted as stationary with a structural break.

4.3. Structural VAR Model

Due to the dynamic structure of vector autoregressive-based models, it is difficult to detect long-run relationships. In standard VAR models, this problem leads to the deterioration of long-run relationships with the increase in the number of variables as well as the decrease in the efficiency of estimation. The structural VAR (SVAR) model, which was developed to overcome this deficiency of vector autoregressive models, can make effective forecasts even in models with a large number of variables by eliminating the restriction in matrix form. The superiority of structural VAR-based models stems from the reduced form achieved with the restriction in matrix form (Dungey and Pagan, 2000). While all variables affect each other throughout the time series in the standard VAR model, only independent variables have an effect on the dependent variable in the restricted form estimation. Kilian (2013) also argues that with the historical decomposition function, the extent to which the share of independent variables in the structural change in the dependent variable is realized can be effectively determined. Therefore, the effectiveness of the structural VAR technique in measuring the

hysteresis in the output gap determined the empirical method of the study. While defining the structural VAR model, Amisano and Giannini's (2012) and Zivot's (2000) studies are taken as references.

Considering the variable and data scale of the study, a four-variable structural VAR form is defined. Equation (8) shows the estimation equation obtained from the matrix form.

$$Byt = \square 0 + \Gamma 1 yt - 1 + \varepsilon t \quad (8)$$

The restricted form of the vector autoregressive structural VAR is obtained by multiplying equation (8) by B^{-1} and solving Yt in terms of Y_{t-1} and ε_t. In this way, the matrix form is obtained by restricting Y_t (9), and different forms is obtained.

$$yt = B - 1 \square 0 + B - 1 \Gamma 1 yt - 1 + B - 1 \varepsilon t \quad (9)$$

As seen in Equation 6, matrix B is obtained from the reduced form. The structural VAR form with four variables is visualized in equation (10).

$$A(1) - 1B = \begin{bmatrix} 1 & 0 & 0 & 0 \\ * & 1 & 0 & 0 \\ * & * & 1 & 0 \\ * & * & * & 1 \end{bmatrix} \quad (10)$$

5. Empirical Findings

In line with the empirical strategy of the study, firstly, output gap estimation is analyzed with the help of the HP filter and BK filter. The output gap estimation results of the HP filter and BK filter are presented in Figure 3.

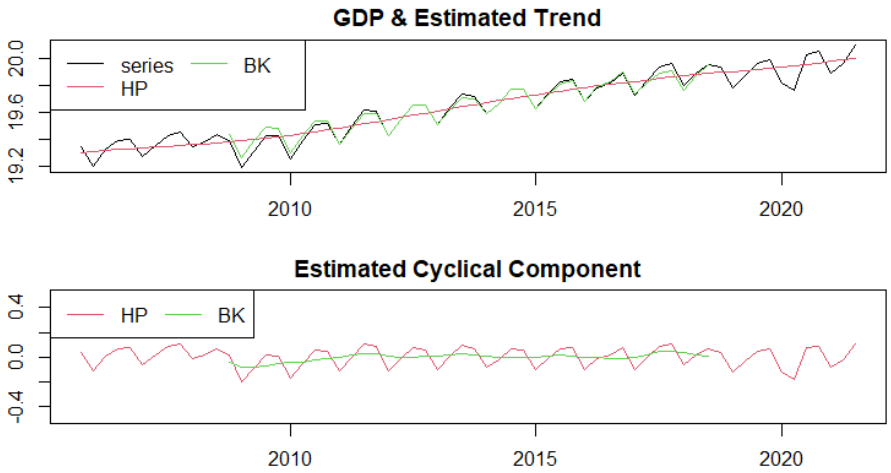

Figure 3. Output Gap Estimation Result Of HP Filter And BK Filter

HP and BK filter results indicate the existence of an output gap. Due to the 2008 World Crisis, output deviated from its trend, and its effect continues throughout the time series. This situation proves the existence of hysteresis effects in the output gap. Another method to detect hysteresis is the smooth transition structural break test. Cremaschini and Maruotti (2023) argue that due to the structural nature of output, trend changes are endogenous to gradual changes when they do not involve a sharp change. Moreover, the strength of the smooth transition

structural break test, which is estimated by internalizing the structural break in hysteresis models, emerges at this point. Smooth transition structural break test results are presented in Table 1.

Table 1. Smooth Transition Structural Break Results

Model	Observation Range	t statistics	Critical Value %1	Result
Model A	50<T<100	-3.26***	-5.09	Smooth break
Model B	50<T<100	-2.55***	-5.77	Smooth break
Model C	50<T<100	-3.40***	-6.13	Smooth break

Note: Leybourne et al. (1998) critical values. ***, ** and * represent 1%, 5% and 10% level respectively. Model A Smooth transition in level ($S2\alpha$), Model B Smooth transition in trend ($S\alpha(\beta)$), Model C Smooth transition in level and trend ($S\alpha\beta$)

Smooth transition structural break estimation results support the existence of a structural break for GDP. Model C, which includes structural breaks in the level and trend, is the more efficient model in terms of hysteresis. Model C results indicate the existence of hysteresis in the output gap.

The interaction between the output gap and the components of the output gap allows not only for determining the existence of hysteresis but also for assessing the degree of influence of these determinants (money supply, capacity utilization rate, productivity) on the hysteresis in output gap hysteresis. These relationships are evaluated by the structural VAR method. In this sense, structural VAR model outputs are an important guide for policy makers.

The matrix form used in the structural VAR model estimation and the coefficients of the variables obtained as a result of the estimation are presented in equation (11).

$$\begin{bmatrix} \text{GDP} \\ \text{PRODUCTIVITY} \\ \text{CUR} \\ \text{M3} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ -1.218636 & 1 & 0 & 0 \\ 0.042380 & -0.592309 & 1 & 0 \\ -0.089520 & 0.312658 & -0.255454 & 1 \end{bmatrix} * \begin{bmatrix} \varepsilon\text{GDP} \\ \varepsilon\text{M3} \\ \varepsilon\text{CUR} \\ \varepsilon\text{PRODUCTIVITY} \end{bmatrix} \quad (11)$$

Since the structural VAR (SVAR) model has an autoregressive structure, the coefficients cannot be interpreted. Therefore, impulse-response function analysis, structural decomposition, and historical decomposition function will be used to explain the structure of output gap hysteresis.

Impulse response analysis (Figure 4) is used to determine the extent to which one unit standard deviation shocks in the independent variable affect the dependent variable. In terms of the response of output to explanatory variables, capacity utilization rate shocks have a positive effect on output, while productivity shocks have a negative effect on output. Money supply shocks do not have a statistically significant effect on output.

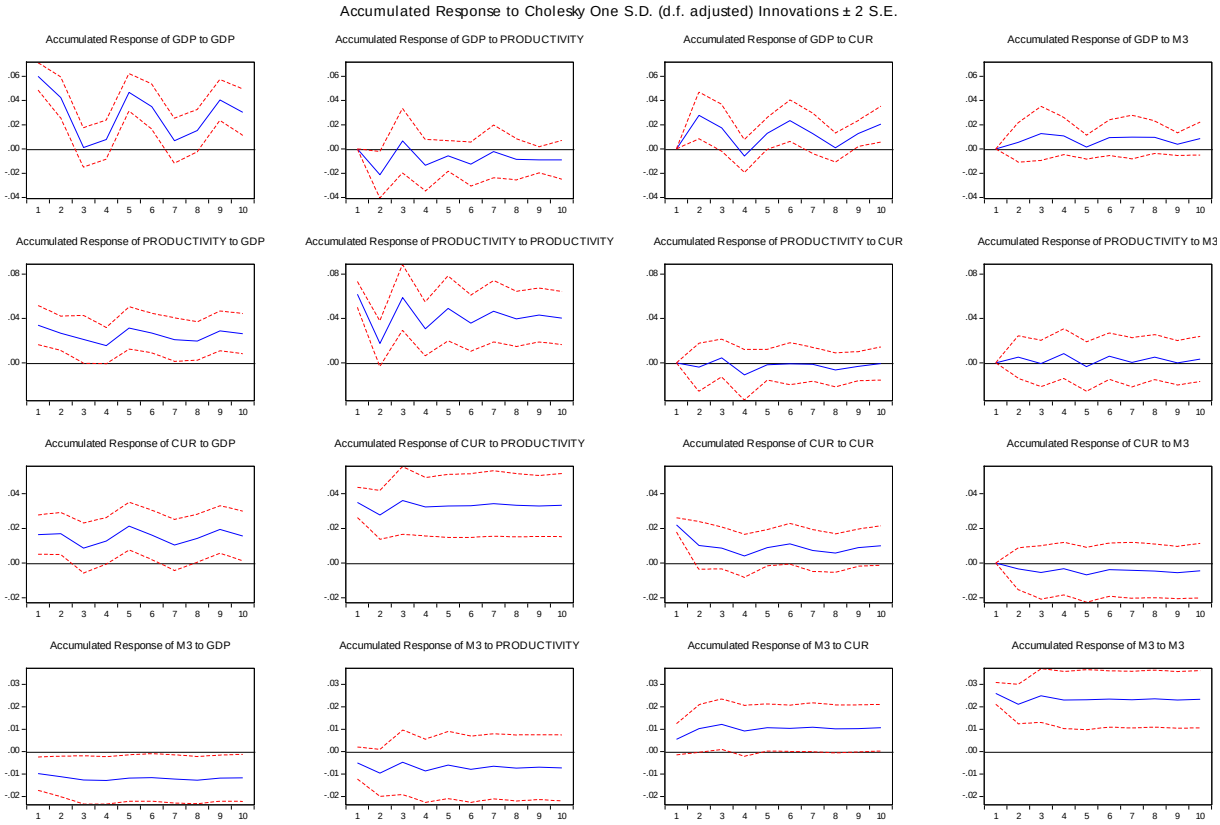

Figure 4. Impulse Response Analysis

Structural variance decomposition measures the explanatory power of independent variables for the dependent variable. According to the variance decomposition results (Table 2), the capacity utilization rate and productivity explain the output at the highest rates of 17.27% and 14.23%, respectively. The money supply does not have a significant effect at the rate of 2.14%.

Table 2. Structural Variance Decomposition (GDP)

Period	Standard Error	GDP	Productivity	CUR	M3
1	0.059975	100.0000	0.000000	0.000000	0.000000
2	0.071788	75.72026	8.830622	14.87700	0.572116
3	0.088296	71.83666	15.91796	11.17686	1.068520
4	0.093753	64.19280	18.76284	16.04914	0.995223
5	0.103902	66.29120	15.83809	16.27997	1.590747
6	0.105598	65.41324	15.74274	16.76035	2.083672
7	0.110267	66.45318	15.33621	16.29795	1.912660
8	0.111385	65.67443	15.37420	17.07685	1.874515
9	0.114945	66.49460	14.43763	17.05478	2.012998
10	0.115749	66.33747	14.23789	17.27682	2.147822

VAR-based models are frequently used to analyze structural changes in time series models. However, when the time series exhibits non-linear behavior, the effective analysis technique may also change. Historical decomposition becomes effective in nonlinear models due to structural breaks along the time series. Historical decomposition is used to identify the

contribution of shocks in independent variables throughout the time series to the structural change in the dependent variable (Wong, 2017). The historical decomposition function will give more effective results on which variable shocks are responsible for the structural change in output, which exhibits non-linear behavior due to hysteresis effects. The historical decomposition function enables the identification of the common effect of all shocks in past periods for a given time point. According to the results of the historical decomposition function, capacity utilization rate and productivity shocks have the highest cumulative effect on the structural change in output, while money supply shocks do not have a significant effect.

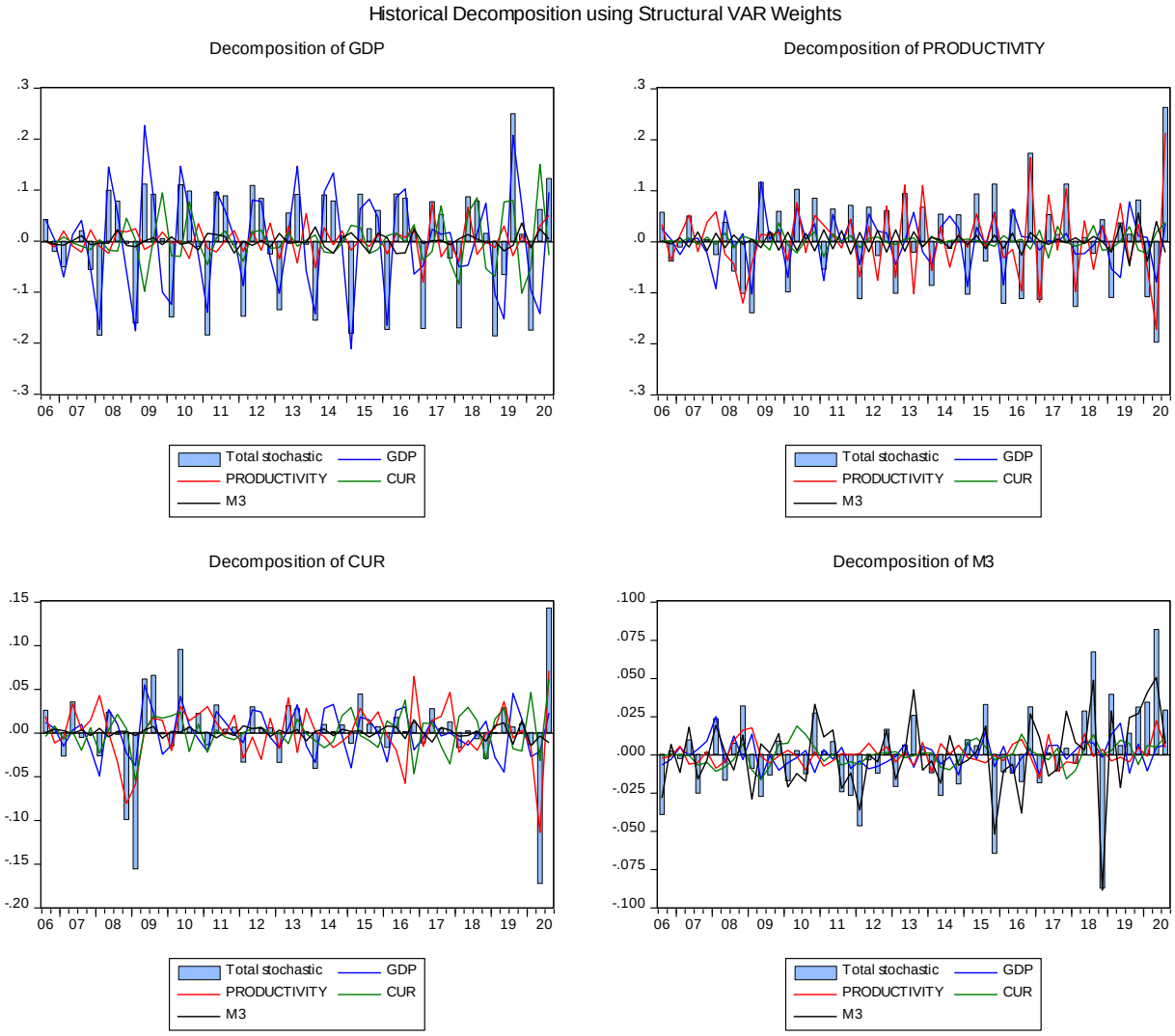

Figure 5. Historical Decomposition

The hysteresis in the output gap may be highly effective in the fact that the dynamics that cause hysteresis also undergo structural changes, as output undergoes structural changes and does not return to its previous path. Therefore, the persistence of the breaks in the capacity utilization rate and productivity in the Turkish economy explains the hysteresis in the output gap to a great extent. This can be observed in the course of capacity utilization rate and productivity in Figure 1. Due to the 2008 World Crisis, productivity experienced a significant

break, and its effect lasted for a long time. However, productivity, which returned to its old path in the long run, had an effect on the output gap hysteresis, but it was temporary. Similarly, in support of our findings, Clavijo-Cortes (2022) concluded that when productivity shocks are accompanied by output shocks, permanent effects on output deepen. On the other hand, the break in the capacity utilization rate, on the other hand, exhibits a more resilient structure and does not return to its previous path throughout the time series and even falls permanently after the trend deviations in 2008 and 2018. In this context, the capacity utilization rate stands out as the strongest dynamic in explaining the strong hysteresis in the output gap. The importance of the capacity utilization rate for the output gap hysteresis is its relationship with monetary policy. Parigi and Siviero (2001) show that changes in the capacity utilization rate in response to monetary policy adjustments also adjust inflationary pressures. The capacity utilization rate that can be adjusted in this way can expand the room for maneuvering of central banks in policies implemented for output growth. This process also provides central banks with a favorable position to set policy boundaries in the fight against inflation. On the other hand, empirical studies show that monetary expansion that is not reflected in output also points to hysteresis. Borio and Hofmann (2017) argue that the demand expansionary policies implemented in the US, the Euro area, and the UK after the 2008 World Crisis were insufficient to return the output that deviated from its trend to its former path. In this context, the effect of monetary easing on output in the Turkish economy remains limited (inability to return output to its previous path) and supports the empirical findings in terms of hysteresis.

As is known, the effects of the 2008 World Crisis were more severe and permanent than expected (Stiglitz, 2018). In the case of secular stagnation, which is defined as the persistence of the effects of the crisis by acquiring a resilient structure, the massive redistribution of income and wealth from lower-income groups to higher-income groups results in a weakening of aggregate demand. As can be seen in Figure 1, the fact that the increase in money supply does not lead to a change in output despite a significant acceleration is evidence of the weakening aggregate demand due to the redistribution of income and wealth to upper-income groups in secular stagnation.

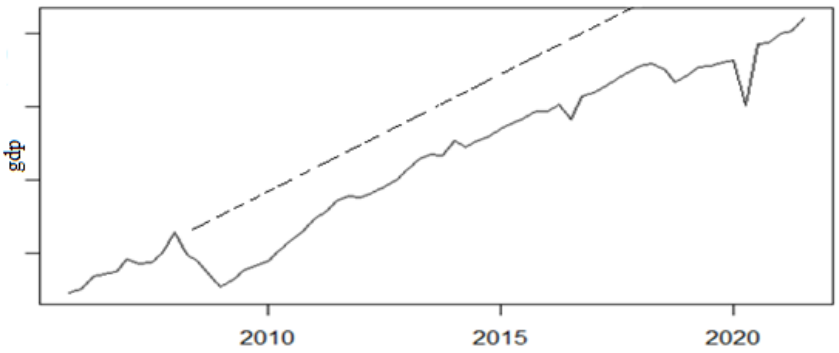

Figure 6. Turkish Economy Output Path

Figure 6 shows the path of Turkish economic output after the 2008 World Crisis. The dashed line represents the expected output path without the impact of the 2008 World Crisis. The fact that output did not return to its previous path after the crisis can be interpreted as secular stagnation. The fact that output does not return to its previous path despite the monetary

policy developments by exhibiting a resilient structure points to strong hysteresis as defined in the empirical literature. This structure of output in the Turkish economy is in line with the findings in the empirical literature (Ball, 2014; Lavoie, 2018; Eo and Morley, 2022), and it is concluded that the strong hysteresis structure is valid in output.

6. Conclusion

The difference between potential output and actual output, which is defined as the output gap, and its hysteresis form (becoming permanent) is a dynamic that determines economic stability on policy effectiveness. In addition, output gap hysteresis and its solution proposals are the guide to healthy growth in terms of explaining the inflationary pressures that have become a chronic problem in the Turkish economy and suggesting policies. The empirical literature analyzes the relationship between output and dynamics such as money supply, productivity, and capacity utilization rate in order to identify hysteresis in the output gap. In the case of hysteresis in the output gap, the movement in output ceases to be cyclical and adapts to a different path in the form of structural change. At this point, monetary policy developments are insufficient to return output to its previous path. On the other hand, since productivity and capacity utilization rates do not return to their previous levels and are the main dynamics of the structural change in output, they can provide important information in output gap hysteresis. Taking these variables into account, the output gap hysteresis of the Turkish economy for the 2005Q4:2021Q3 period is analyzed through money supply, capacity utilization rate, and productivity variables. The empirical setup of the study aims to identify the output gap with the Hodrick-Prescott and Baxter-King methods. In order to detect the persistence of output deviation from its trend, in other words, hysteresis, the smooth transition structural break test is used to detect hysteresis in output, while the structural VAR method aims to provide important information to policymakers for output gap hysteresis through the interaction/response of output to its components.

In the first stage, the Hodrick-Prescott and Baxter-King methods are used to determine the existence of an output gap. According to the smooth transition structural break test, the detection of a structural break in output proves the existence of hysteresis. The structural VAR model estimated with output, money supply, capacity utilization rate, and productivity variables yielded satisfactory results for the existence of output gap hysteresis. In terms of money supply, the fact that money supply does not have a significant effect on output indicates hysteresis behavior on theoretical grounds. The fact that the long-run change in the level of money supply is insufficient to return output to its previous path is another important finding that proves the existence of hysteresis. In the hysteresis dimension, this situation is among the results commonly found in the empirical literature. Productivity and capacity utilization rate variables are important determinants of output gap hysteresis. According to the structural decomposition and historical decomposition function, capacity utilization rate and productivity are the two main variables in terms of hysteresis. While the permanent adjustment of the capacity utilization rate to a lower path after shocks explains the basis of the strong hysteresis in the output gap, the fact that shocks to productivity are compensated in the long run and adjusted to the old path reveals the importance of output in the hysteresis structure. As a matter of fact, taking into account capacity utilization rate and productivity changes in order of importance as determinants of output in policymaking will increase policy effectiveness.

The study contributes to the empirical literature in several aspects. The study first analyzes the output gap hysteresis for the Turkish economy. Its contribution to the hysteresis literature is that, in addition to identifying the output gap, it uses the smooth transition structural break test, which is more appropriate to the nature of business cycle fluctuations, and analyzes the output gap hysteresis through its interaction/response with output components (money supply, capacity utilization rate, productivity). The empirical strategy designed in this way has enabled the identification of hysteresis and its dynamics, leading to important key findings for policymaking. Another important contribution of the study is that it provides information on which dynamics should be emphasized in policymaking in terms of hysteresis and to what extent. In this context, based on the empirical findings, it is extremely important in terms of hysteresis that the money supply should not be tightened more than necessary in a way to slow down output in money supply changes, and that the money supply should be adjusted quickly in expansionary policies so as not to cause inflationary pressures. Because actual output that does not move towards its potential with expansionary policies will cause inflation. Here, the central bank's room for maneuver in policy implementation is determined by the flexibility of the capacity utilization rate. Moreover, calculating the marginal change effect of monetary policy on the capacity utilization rate at different levels will increase the effectiveness of demand-side expansionary policy. Increasing productivity is another important dynamic in eliminating the hysteresis behavior in the output gap. Increasing productivity is also associated with an increase in the capacity utilization rate, which underlines the importance of productivity. More specifically, increasing new products and services and more flexible working models in terms of the labor market will increase the capacity utilization rate. Since the Turkish economy is open to foreign markets, domestic and foreign demand developments are determinant for the capacity utilization rate. More specifically, if expenditure-shifting policies are not adjusted effectively during exchange rate fluctuations, the appreciated local currency will shift demand to foreign markets, thus preventing the incentive to increase production capacity.

Although the study uses output, money supply, capacity utilization rate, and productivity variables in the output gap hysteresis, it has some limitations. In terms of productivity, labor productivity is neglected in the empirical model by taking capital productivity into account. While employment and investments decrease permanently in recessions driven by demand shocks that are effective in the long term, while output per worker is not significantly affected (Furlanetto et al., 2025), in Turkey, as a developing economy, employment shows sharper changes and more production factors are included in production during the expansion period. For this reason, the productivity of the labor force specifically participating in production in the Turkish economy will also determine total factor productivity. In future studies, monitoring labor productivity at different employment levels will increase policy effectiveness.

Declaration of Research and Publication Ethics
This study which does not require ethics committee approval and/or legal/specific permission complies with the research and publication ethics.

Researcher's Contribution Rate Statement
The authors declare that they have contributed equally to the article.

Declaration of Researcher's Conflict of Interest
There is no potential conflicts of interest in this study.

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Ekonomi, Politika & Finans Araştırmaları Dergisi, 2025, 10(1): 27-43
Journal of Research in Economics, Politics & Finance, 2025, 10(1): 27-43
Araştırma Makalesi / Research Article, https://doi.org/10.30784/epfad.1576857

PORTFOLIO CONSTRUCTION WITH POSTMODERN PORTFOLIO THEORY FRAMEWORK*

Postmodern Portföy Teorisi Çerçevesinde Portföy Oluşturma

Erdi BAYRAM** & **Rabia AKTAŞ*****

Abstract

This study includes alternative portfolio construction approaches consistent with the Modern Portfolio Theory (MPT) and Postmodern Portfolio Theory (PMPT). We propose a weighting strategy based on Sharpe and Sortino optimization, and unlike MPT, we create PMPT portfolios using downside metrics, such as downside risk, downside beta, and downside capital asset pricing model (D-CAPM). Portfolios consist of stocks in the Borsa Istanbul Participation 30 Index (XK030), with the stocks in the portfolio having been revised according to screening periods. In addition, we created an equally weighted portfolio and used XK030 as a benchmark for comparative analysis. The sample period covers 527 trading days between May 6, 2022, and June 28, 2024. The results show that the Sharpe portfolio consistently follows the benchmark index throughout the observation period. Sortino outperforms both the benchmark and conventional market index in some specific periods when the market has an upward trend, especially. This study provides evidence that the MPT and PMPT approaches and measures can be used in asset allocation and portfolio management. Investors can manage their assets and balance portfolio weights by implementing the models in different market conditions.

Keywords:
Postmodern Portfolio Theory, Downside Risk, Portfolio Optimization, Participation Index

JEL Codes:
C61, G11, G17

Öz

Bu çalışmada Borsa İstanbul Katılım 30 endeksinde yer alan pay senetleriyle Sharpe ve Sortino oranlarının maksimizasyonuna dayalı alternatif ağırlık belirleme stratejileri kullanılmış, modern portföy teorisi ve postmodern portföy teorisiyle uyumlu portföyler oluşturulmuştur. Sharpe portföyü için geleneksel risk ölçütleri, Sortino için aşağı yönlü metrikler kullanılarak ağırlıklar hesaplanmış ve elde edilen ağırlıklarla 6 Mayıs 2022 – 28 Haziran 2024 tarihleri arasındaki dört endeks izleme döneminde 527 işlem günü için portföy getiri serileri oluşturulmuştur. Ayrıca eşit ağırlıklı portföyler ve Katılım 30 endeksi karşılaştırma ölçütü olarak kullanılmıştır. Analiz sonuçları Sharpe getiri serisinin endeksi yakından izlediğini, Sortino portföyünün ise piyasanın yükseliş trendine girdiği spesifik periyotlarda hem karşılaştırma endeksinin hem de geleneksel piyasa endeksinin üstünde performans sergilediğini göstermektedir. Bu çalışma MPT ve PMPT yaklaşımlarının ve ölçütlerinin varlık tahsisi ve portföy yönetiminde uygulanabilirliğine ilişkin kanıtlar sunmaktadır. Ayrıca çalışma yatırımcıların farklı piyasa koşullarında ilgili modelleri kullanarak varlıklarını yönetebileceğini ve portföylerini dengeleyebileceğini göstermektedir.

Anahtar Kelimeler:
Postmodern Portföy Teorisi, Aşağı Yönlü Risk, Portföy Optimizasyonu, Katılım Endeksi

JEL Kodları:
C61, G11, G17

* This study is derived from the first author's Ph.D. Thesis entitled "Essays on Participation Finance System and Stock Market Analysis" completed under supervision of the second author at Manisa Celal Bayar University Graduate School of Education.

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Received Date (Makale Geliş Tarihi): 31.10.2024 *Accepted Date (Makale Kabul Tarihi): 06.01.2025*

1. Introduction

It is important for investors to manage the uncertainty arising from market conditions. A common strategy is to minimize risk through diversification. Optimal allocation through diversification differs according to market conditions, investors' risk preferences, and the risk-return trade-off. The fundamental approach in MPT, an efficient portfolio, has the highest reward for a given level of risk or the lowest risk for a given reward (Wilmott, 2001). Markowitz's mean-variance model is the core of MPT, and variance is a fundamental measure of risk in this model (Markowitz, 1970). Today, we use standard deviation as a risk measure in financial markets. On the other hand, portfolio risk depends on the correlation between the assets comprising the portfolio. Beta, the coefficient of systematic risk, is accepted by investors as the sensitivity of a financial asset to market returns. Beta is included as a risk measure in the CAPM formula developed by William Sharpe and his contemporaries (Petzel, 2022). The market premium for tolerating an asset's volatility relative to a benchmark, which is the return on a risk-free investment, is measured using the CAPM (Chen, 2016).

Even though the standard deviation is a powerful volatility measure, it does not reflect asymmetric risk (See PMPT Framework heading). Nevertheless, indicators and risk measures of MPT, such as the Sharpe ratio, are still useful for portfolio management. In contrast, empirical studies show that downside risk measures are feasible for investors to capture negative conditions. Estrada (2002, 2007) provides empirical evidence that downside risk metrics and D-CAPM enable more accurate asset pricing. Moreover, according to Estrada, the findings on downside risk measures are consistent with investors' loss aversion in behavioral finance literature. In this respect, PMPT overcomes the limitations of MPT that do not reflect investors' perceptions. As a matter of fact, it is significant for investors to understand how sensitive the portfolio is to downside risk. Investors neglect upside risk because the risk measure is associated with potential earnings.

Relevant studies such as Yıldız and Erzurumlu (2018), Yıldız et al. (2022) emphasize the advantages of PMPT to MPT; nonetheless, this is a remarkable finding from their empirical studies based on forecasts of expected returns. Although many studies utilize downside risk measures across different indices, the existing literature regarding stock selection, asset allocation, and portfolio construction with a downside risk framework for Borsa Istanbul is still developing. The main motivation of this study is to construct portfolios using the PMPT framework, that is, the downside risk framework, and to compare them with MPT portfolios, equally weighted portfolios, and the market index. The secondary motivation of this research is to propose an alternative weighting method for the participation index based on the PMPT approach and tools. Accordingly, we created and compared the Sortino, Sharpe, and EW portfolios for 527 trading days and four periods using the XK030 daily stock returns. There are many empirical studies on Borsa Istanbul (Istanbul Stock Exchange) that focus on conventional indices such as BIST 30 and BIST 100. Acar (2020), Bayat and Yiğiter (2021), and Yıldız's (2021) research can be given as examples. Therefore, we conducted a study on alternative index that interest to different segments in the Turkish capital market. In the context of this, we created and compared the Sortino, Sharpe, and EW portfolios for 527 trading days and four periods using the XK030 daily stock returns.

The XK030 is a thematic index (the Turkish Islamic Index) and companies' shares in the index are specified following the screening process. The stocks included in the index are

reviewed according to the qualitative and quantitative criteria. In other words, participation indices comprise companies that comply with specific rules. We provide the screening process steps of the Borsa Istanbul Participation Indices in Annexes.

As it is known, the Sharpe ratio is a simple metric that shows the risk-return trade-off and indicates risk in terms of total volatility. The ratio can typically be followed by investors who want to minimize the total risk of the portfolio. The Sortino ratio is a downside risk-oriented metric that is suitable for investors with low-risk tolerance. In this study, we construct portfolios using the Sharpe and Sortino ratio optimization methods, consistent with MPT and PMPT measures. In addition, we create equally weighted portfolios (EW) and include the participation XK030 as a benchmark. In the first section, we introduce the PMPT framework, its measures, and tools. The literature review is followed by an explanation of the data and methods. The final section presents our findings and results.

2. PMPT Framework

The fundamental risk measures of the MPT have certain limitations. One such limitation is the use of the standard deviation as a risk measure based on the symmetricity of the return distribution. Rom and Ferguson (1994, 2001) introduced the PMPT framework under the title "Comes of Age," stating that an MPT's risk measure does not reflect investors' perception of risk. In fact, they emphasize that investors do not accept movements above the target return, known as upside volatility, as risk. Rather, investors consider that risk the possibility of a positive return (Riddles, 2001). Harlow (1991) argues that it is meaningful to use downside risk metrics because they are consistent with investors' risk perceptions. On the other hand, Nawrocki (1999) states that an investor's total wealth affects the tendency of risk aversion. Some researchers argue that downside risk is an appropriate measure of risk, but investors should also track total risk depending on the time horizons (Nawrocki, 1999: 23). As an asymmetric measure of risk, downside volatility is related to the minimum acceptable return or the target return (Figure 1).

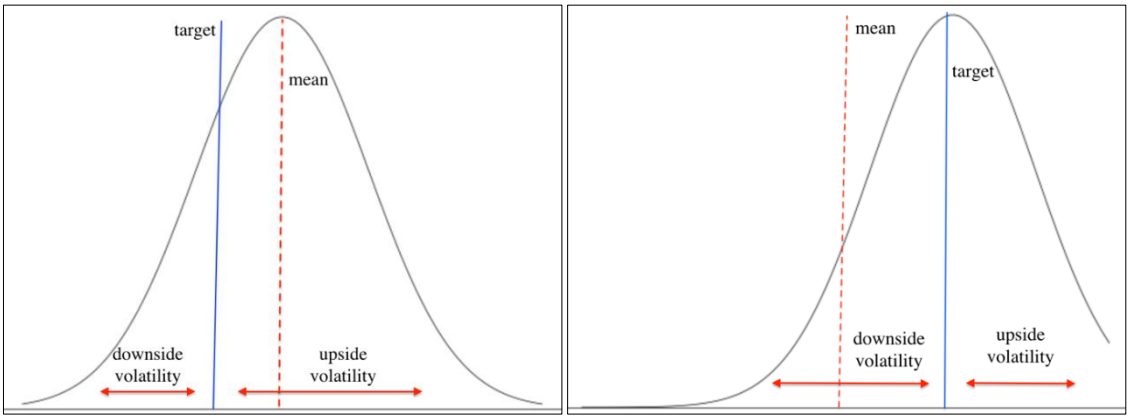


Figure 1. Downside Volatility in Symmetric and Skewed Distribution
Source: Rigamonti, 2020.

Under the symmetric distribution shown in Figure 1 (left side), the risk is reduced by minimizing deviations from the mean. However, return series are generally not symmetrically

distributed and risk cannot be measured fairly by minimizing the deviation (right side). In other words, if returns have a skewed distribution or if targets (benchmark) are not equal to the mean, minimizing the total risk is not equivalent to minimizing the downside risk. In this respect, the PMPT's heuristic approach is suited to estimating the downside volatility for investors (Rigamonti, 2020). Downside deviation (σ_d) is a measure of downside volatility and is calculated using Equation 1.

$$\sigma_d = \sqrt{\frac{\sum_{i=1}^{n} \min(0, r_i - r_t))^2}{n-1}} \tag{1}$$

where r_i denotes the return of stock and r_t denotes the target return or minimum acceptable return (MAR). r_i can be computed using Equation 7.

The downside deviation is in the denominator of the Sortino ratio, which is the fundamental performance metric of PMPT. According to Chen (2016), downside deviation is the natural starting point for the pursuit of a single risk measure reflecting both volatility and skewness. As shown in equations 2 and 3, unlike the Sharpe ratio, Sortino focuses on the between the return and MAR (Sortino and Van der Meer, 1991; Sortino and Price, 1994).

$$sharpe = \frac{r_i - r_f}{\sigma} \tag{2}$$

where r_f denotes the risk-free rate and σ denotes standard deviation.

$$sortino = \frac{r_i - r_t}{\sigma_d} \tag{3}$$

where r_t denotes the target return.

PMPT's other risk metric is downside beta, which is a coefficient that measures the sensitivity of stocks to the market when the markets show a downward trend. Downside beta differs from traditional beta calculated as the covariance between stock returns and market returns divided by the variance of market returns. There are different calculation techniques for downside beta. In this study, we used the formula given by Charoenwong and Ng (2013), based on the approach of Bawa and Linderberg (1977).

$$\beta_d = \frac{E[(r_i - r_f)\min(r_m - r_f, 0)]}{E[\min(r_m - r_f, 0)]^2} \tag{4}$$

where r_m denotes market return. The numerator represents the covariance of stock returns and negative returns of the market portfolio. The denominator shows the square of the negative returns of the market portfolios. The use of downside beta in the CAPM formula transforms into a special form called D-CAPM (Equation 5).

$$E(r_i) = r_f + \beta_d(r_m - r_f) \tag{5}$$

where $r_m - r_f$ denotes excess return.

In the PMPT, the volatility skewness ratio indicates the distribution of the return series volatility. This ratio is obtained by dividing the upside variance of the distribution of the return series by the downside variance (Equation 6):

$$s_v = \frac{\frac{1}{n-1}\sum_{i=1}^{n} \max(0, r_i - t)^2}{\frac{1}{n-1}\sum_{i=1}^{n} \min(0, r_i - t)^2} \quad (6)$$

where t denotes target return. If the ratio is equal to 1, it indicates a symmetric distribution, and if $s_v > 1$ positive skewness, $s_v < 1$ negative skewness. We evaluated the ratio for the XK030 using data from 500 trading days. The index was negatively skewed (0.93196), meaning that the downside volatility of the series was higher than the upside volatility.

3. Literature Review

Relevant literature can be classified into two groups. The first group includes empirical research testing the PMPT in different markets. These studies have examined the ability of PMPT tools to explain stock returns. Artavanis et al. (2010) tested the explanatory power of PMPT risk measures (semivariance and downside beta). Researchers estimated cross-sectional linear simple regression and cross-sectional bivariate regression for the two periods and obtained different results in the London Stock Exchange and Euronext Paris. Tahir et al. (2013) empirically tested the CAPM and D-CAPM in the Karachi Stock Exchange by implementing the Fama-MacBeth procedure. El-Masry and El-Mosallamy (2016) examined the explanatory power of CAPM and D-CAPM in conventional and Islamic funds risk-adjusted performance. Rasool et al. (2018) investigated the explanatory power of the downside risk framework in four South Asian markets. On the other hand, Raza (2018) conducted a study on the Pakistan Stock Exchange with totally different results. Yıldız and Erzurumlu (2018) tested the explanatory power of downside risk metrics for stock returns in Borsa Istanbul with local and global single-factor models. Yıldız et al. (2020) conducted a comparative analysis of the CAPM and D-CAPM risk parameters, which better explain stock returns. Table 1 presents the findings of the studies.

Table 1. Summary of Findings (1)

Author(s)	Sample	Findings
Artavanis et al. (2010)	London Stock Exchange, Euronext Paris	Downside risk measures are found to be more effective for stocks. In contrast, there is no difference between downside beta and conventional beta for portfolios.
Tahir et al. (2013)	Karachi Stock Exchange	D-CAPM is a convenient model explaining risk-return trade-off.
El-Masry and El-Mosallamy (2016)	21 mutual funds in Saudi Arabia	D-CAPM is a more applicable measure for emerging markets.
Rasool et al. (2018)	Four South Asian Countries	D-CAPM is better pricing model as compared to standard CAPM for emerging equity markets.
Raza (2018)	Pakistan Stock Exchange	Despite the observation of negatively skewed behavior, the conventional model (CAPM) demonstrates better explanatory power for expected returns compared to D-CAPM.
Yıldız and Erzurumlu (2018)	Borsa Istanbul (Istanbul Stock Exchange)	D-CAPM provides more explanatory power than the CAPM. Downside risk metrics are considerable for emerging markets.
Yıldız et al. (2022)	Developed and Emerging markets	Downside betas are superior to CAPM betas in explaining stock returns.

The results of these studies show applicable PMPT measures for investment and risk management in different markets. The second group includes studies on portfolio selection, asset allocation, and optimization based on downside risk metrics and PMPT tools. Galloppo (2010) presented a resampling method in portfolio management, using Markowitz and PMPT models in three indexes. Geambaşu et al. (2013) emphasized that the PMPT method produces better empirical outcomes complying with the theoretical framework. Todoni (2015) proposed a new method and used the multiplier method and Sortino ratio to calculate risk-adjusted return in emerging markets including Romania, Hungary, the Czech Republic, Bulgaria, and Poland. In another remarkable study, Garcia (2019) introduced a portfolio selection model that allows investors to simultaneously evaluate average stock returns, downside risk, and ESG criteria. Jankova (2019) analyzed the risk-return of two investment portfolios using the MPT and PMPT approaches. Nassar and Ephrem (2020) proposed allocation strategies using the Sortino ratio to balance risk and return in DJIA. Yıldız (2021) utilized the alpha from CAPM and D-CAPM approaches as a criterion for stock selection and reported that the results from through applying on Borsa Istanbul 30 Index. Bayat and Yiğiter (2022) analyzed portfolio performance constructed by MPT and downside measures in the Borsa Istanbul 100 Index. May and Yeing (2022) developed a stock selection strategy based on Sortino. Table 2 presents the findings of the studies.

Table 2. Summary of Findings (2)

Author(s)	Sample	Findings
Galloppo (2010)	EUX50, SP100, SPMIB40	Resampling method in PMPT models such as tracking error minimization, mean absolute deviation minimization, and shortfall probability improved portfolio performance.
Geambaşu et al. (2013)	Bucharest Stock Exchange	PMPT increases the investor's ability to manage risk under different market conditions.
Todoni (2015)	Five emerging markets in Europe	The author used the Sortino ratio, and the multiplier method to analyze the risk-adjusted return performance of the markets, were obtained different results for indices.
Garcia et al. (2019)	Dow Jones Industrial Average (DJIA)	Socially responsible portfolios that were constructed using mean return, downside risk metrics and ESG criteria outperformed the benchmark. The researchers used the Sortino ratio to determine the optimal portfolio.
Jankova (2019)	Prague Stock Exchange	Portfolios constructed with the PMPT provide lower risk and more diversification.
Nassar and Ephrem (2020)	Dow Jones Industrial Average (DJIA)	Asset allocation based on Sortino ratio is highly efficient in different market conditions.
Yıldız (2021)	Borsa Istanbul (Istanbul Stock Exchange)	The results produced by asset pricing models indicate no difference between risk minimization and portfolio diversification.
Bayat and Yiğiter (2022)	Borsa Istanbul (Istanbul Stock Exchange)	Researchers constructed a portfolio using MPT and downside metrics. The findings indicated that the alternative portfolio has a reduced risk compared to the MPT portfolio.
May and Yeing (2022)	Malaysia Stock Market	Sortino portfolios outperformed than Treynor and Jensen's Alpha portfolios.

These findings show that the PMPT framework can be used to construct portfolios, particularly the Sortino ratio. The results of the studies focusing on emerging markets are very encouraging. Some researchers such as Galloppo (2010) and Nassar and Ephrem (2020) have

produced better results in developed markets. In this respect, we believe that this study contributes to relevant literature. Additionally, the application of PMPT to the Borsa Istanbul Participation Index will be important for future comparative studies.

4. Data and Methodology

This study used daily stock return data calculated using closing prices from November 15, 2021, to June 28, 2024. The beginning date is determined by the period when the index was calculated by Borsa Istanbul (The first value date of Participation 30 Index by Borsa Istanbul is 10/01/2021). Closing price data were collected from Refinitiv Eikon Datastream. The daily returns (r_i) were calculated using Equation 7.

$$r_i = \frac{p_t}{p_{t-1}} - 1 \tag{7}$$

where p_t denotes the closing price at time t.

Table 3. Stocks in Participation 30 Index

Stock Numbers	Index Period I (May-September 2022)	Index Period II (October 2022-April 2023)	Index Period III (May -September 2023)	Index Period IV (October 2023-June 2024)
1	AKSA	AKSA	AHGAZ	AKSA
2	AKSEN	AKSEN	AKSA	AKSEN
3	ARDYZ	ALBRK	AKSEN	ALBRK
4	ASELS	ASELS	ALBRK	ASGYO
5	BASGZ	BASGZ	ASELS	ASELS
6	BERA	BERA	ASTOR	BIMAS
7	BIMAS	BIMAS	BERA	CWENE
8	BIOEN	CIMSA	BIMAS	DOAS
9	CCOLA	DOAS	CIMSA	ENJSA
10	DOAS	EGEEN	DOAS	EREGL
11	EGEEN	EREGL	EGEEN	GESAN
12	EREGL	GOZDE	ENJSA	GUBRF
13	GENIL	GUBRF	EREGL	ISMDR
14	GOZDE	ISDMR	GESAN	KLSER
15	GUBRF	JANTS	GUBRF	KRDMD
16	ISDMR	KRDMD	ISDMR	KARSN
17	JANTS	KONTR	KRDMD	KONTR
18	KORDS	KORDS	KONTR	MAVI
19	KRDMD	MAVI	KORDS	ODAS
20	OTKAR	ODAS	ODAS	OYAKC
21	PGSUS	OTKAR	OYAKC	PGSUS
22	PRKAB	OYAKC	PGSUS	PENTA
23	PSGYO	PGSUS	SASA	SASA
24	SASA	SASA	SNGYO	SMRTG
25	THYAO	SNGYO	SMRTG	TKFEN
26	TKFEN	TUPRS	TKFEN	TUKAS
27	TRGYO	THYAO	TUPRS	TUPRS
28	TRILC	TTRAK	THYAO	THYAO
29	TTRAK	VESBE	TTRAK	VESTL
30	VESBE	YYLGD	VESBE	YEOTK

Source: Borsa Istanbul, 2024.

The research sample consists of 52 companies on the XK030. Four periods were included in the study considering the index screening periods (Table 3). The stock weights in the portfolio for each period were calculated based on the previous period. For example, the weights from October 2022 to April 2023 index period were calculated using return data from May 2022 to September 2022. This calculation was based on Sharpe and Sortino's optimization. Then, the daily portfolio returns for the period were calculated using the weights. Following this method, daily portfolio returns were calculated for 527 trading days between May 6, 2022, and June 28, 2024. In short, we constructed the Sharpe and Sortino portfolios. In addition, we include EW portfolios and XK030 returns as a benchmark index for comparison. All computations were conducted using MS Excel and MS Excel Solver functions.

Sharpe and Sortino's portfolios were created using the ratio-maximizing method. In Sharpe ratio (Sortino ratio) optimization, expected returns $E(r_i)$ were calculated based on the CAPM (D-CAPM) formula. Turkey's 2-year bond yield (TR2YT=XX) was used as the risk-free rate (r_f). The target return (r_t) was 1% over the risk-free rate. To simulate index weighting (w_i), constraints were added to models. The objective function and constraints of the model are presented below.

Sharpe ratio objective function as follows:

$$maximize\ \left(\frac{E(r_p) - r_f}{\sigma}\right) \tag{8}$$

Sortino ratio objective functions as follows:

$$maximize\ \left(\frac{E(r_p) - r_t}{\sigma_d}\right) \tag{9}$$

where $E(r_p)$ denotes the expected return of the portfolio. It is calculated using Equation 10.

$$E(r_p) = \sum_{i=1}^{n} E(r_i)\, w_i \tag{10}$$

The constraint of optimization as follows:

$$\begin{gathered} subject\ to \sum_{i=1}^{n} w_i = 1 \\ 0.001 \le w_i \le 0.1, \forall i \end{gathered} \tag{11}$$

Portfolio returns for 527 trading days were calculated using the weights obtained after the Sharpe and Sortino optimization process steps. We update the stock weights in the portfolios for each period. Actual return of the portfolios (r_p) calculated by multiplying the daily realized return of each stock (r_i) by its weight (w_i) in the portfolio (Equation 12).

$$r_p = \sum_{i=1}^{n} r_i w_i \tag{12}$$

We calculate the Normalized Herfindahl Index (NHI) coefficient to measure portfolio concentration. NHI is a normalized form of the HI index. It ranged from 0 to 1. A coefficient close to 0 indicates a fair distribution, whereas a value close to 1 implies high concentration (Equations 13 and 14).

$$HI = \sum_{i=1}^{n} w_i^2 \tag{13}$$

$$NHI = \frac{HI - 1/n}{1 - 1/n} \tag{14}$$

Here, n denotes the number of stocks (Busse et al., 2006).

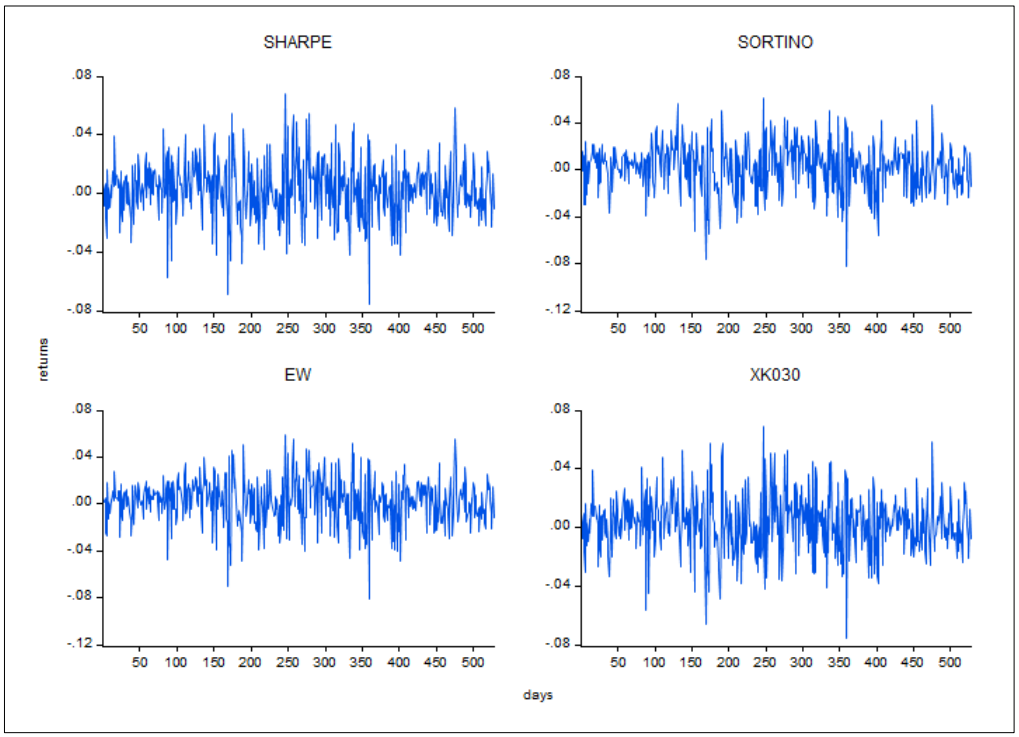
5. Findings and Results

The stock weights and concentration coefficients of the Sharpe and Sortino portfolios are presented in Table 4 according to the outputs of the optimization models solved under the specified objective function and constraints. Daily portfolio returns were computed for 527 days, from May 6, 2022, to June 28, 2024, using weights of four periods. Equally weighted portfolio returns are calculated for the same data range. The XK030 was used as the benchmark. Below, we provide model outputs, graphs, statistics, and estimates.

Table 4. Stock Weights

Stocks	Period I (Estimation Data Range: 11/16/2021 – 04/29/2022)		Period II (Estimation Data Range: 04/05/2022 – 09/30/2022)		Period III (Estimation Data Range: 11/01/2022 – 04/28/2023)		Period IV (Estimation Data Range: 05/03/2023 – 09/29/2023)	
	Sharpe	**Sortino**	**Sharpe**	**Sortino**	**Sharpe**	**Sortino**	**Sharpe**	**Sortino**
1	4.44%	10.0%	4.48%	7.06%	0.10%	10.0%	2.13%	0.10%
2	1.50%	10.0%	3.50%	10.0%	3.96%	10.0%	0.77%	0.10%
3	1.07%	6.64%	0.10%	0.10%	1.16%	0.10%	0.10%	10.0%
4	10.0%	0.10%	9.83%	3.23%	1.98%	10.0%	0.10%	10.0%
5	0.81%	0.10%	1.33%	0.10%	5.78%	10.0%	7.63%	0.10%
6	2.13%	10.0%	1.84%	10.0%	0.61%	10.0%	10.0%	10.0%
7	8.58%	0.10%	10.0%	0.10%	1.81%	0.10%	0.26%	0.10%
8	0.84%	0.10%	0.10%	8.40%	9.17%	10.0%	2.35%	0.10%
9	7.02%	4.73%	2.62%	10.0%	4.04%	0.10%	2.56%	2.96%
10	0.10%	10.0%	1.27%	2.39%	2.14%	0.35%	6.22%	0.10%
11	1.35%	10.0%	10.0%	0.10%	0.10%	0.10%	2.87%	0.10%
12	9.90%	0.10%	1.49%	0.10%	0.10%	2.27%	4.48%	9.84%
13	0.52%	10.0%	4.66%	3.30%	10.0%	0.10%	2.39%	0.10%
14	0.10%	7.80%	1.87%	0.10%	0.10%	0.10%	1.00%	9.94%
15	6.75%	0.15%	2.01%	3.92%	4.23%	9.46%	3.38%	0.10%
16	1.18%	10.0%	4.98%	0.10%	2.96%	0.10%	0.49%	0.10%
17	2.03%	0.10%	2.26%	10.0%	2.89%	0.10%	2.81%	10.0%
18	1.32%	7.57%	1.57%	0.10%	2.29%	1.78%	0.32%	0.10%
19	8.38%	1.06%	1.00%	0.10%	3.12%	0.10%	3.05%	0.10%
20	2.34%	0.10%	0.10%	10.0%	4.13%	0.10%	4.75%	3.43%
21	4.88%	0.10%	2.53%	5.16%	3.06%	0.10%	7.06%	4.01%
22	0.10%	0.46%	0.77%	5.50%	5.41%	0.10%	0.47%	9.06%
23	0.10%	0.10%	5.74%	0.10%	9.59%	0.10%	8.14%	0.10%
24	8.53%	0.10%	10.0%	0.10%	0.10%	0.10%	1.61%	2.80%
25	10.0%	0.10%	0.10%	0.10%	0.10%	6.20%	2.29%	0.10%
26	2.89%	0.10%	0.10%	0.15%	1.47%	0.10%	0.33%	0.10%
27	0.20%	0.10%	10.0%	0.32%	8.96%	1.74%	10.0%	3.15%
28	1.72%	0.10%	3.72%	0.10%	9.25%	6.61%	10.0%	10.0%
29	1.11%	0.10%	0.67%	0.10%	1.29%	10.0%	1.46%	0.10%
30	0.10%	0.10%	1.37%	9.18%	0.10%	0.10%	0.97%	3.21%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
NHI	0.037	0.057	0.034	0.049	0.031	0.057	0.030	0.053

Graph 1 provides the distribution graphs of the portfolio returns created using the stock weights in Table 4.



Graph 1. Return Distribution of Portfolios

Table 5 provides the descriptive statistics of the portfolio returns. Statistically, it was observed that the series did not follow a normal distribution. The distributions were skewed to the left and asymmetric. The market index had the highest mean value, whereas Sortino had the highest median value.

Table 5. Descriptive Statistics

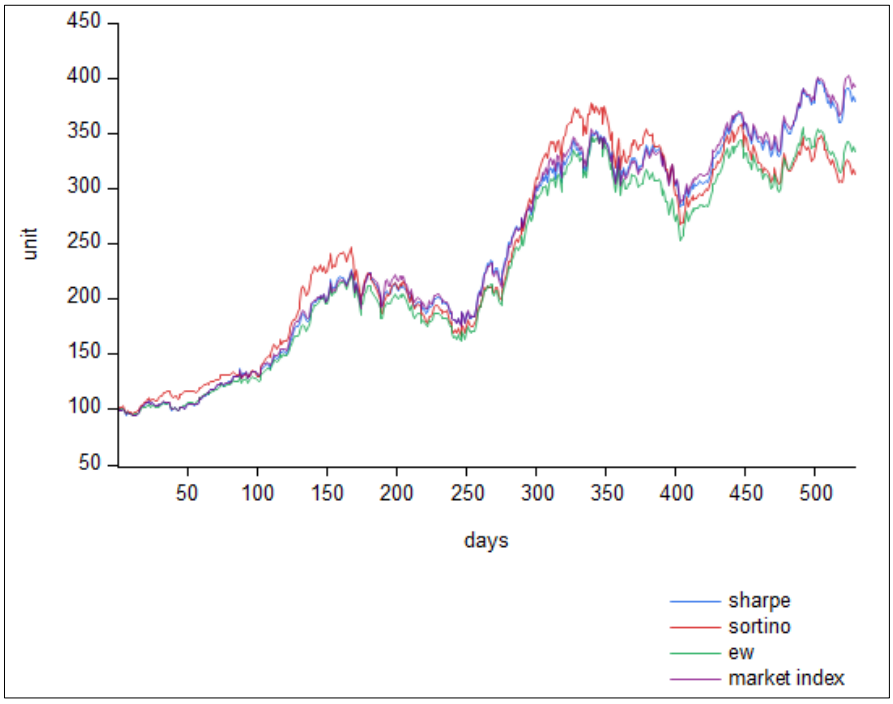
	Sharpe	Sortino	EW	Market Index
Mean	0.002722	0.002370	0.002475	0.002785
Median	0.003615	0.004289	0.003676	0.003570
Max	0.067744	0.061911	0.058943	0.069182
Min	-0.075513	-0.081938	-0.081326	-0.076167
Std. Dev.	0.019379	0.019967	0.019196	0.019545
Skewness	-0.122535	-0.368082	-0.326061	-0.052068
Kurtosis	3.914699	3.844606	3.975223	3.952751
Jarque-Bera	19.69080	27.56419	30.22178	20.17045
Prob.	0.0000	0.0000	0.0000	0.0000
Observation	527	527	527	527

Table 6 presents the correlation coefficients of the portfolios. It can be observed that there is a high correlation between Sharpe and the market index and a relatively lower correlation between Sharpe and Sortino. The Sharpe portfolio returns converge to the benchmark index.

Table 6. Correlation Matrix of Portfolios

	Sharpe	Sortino	EW	Market Index
Sharpe	1.000	0.889	0.959	0.989
Sortino	0.889	1.000	0.945	0.889
EW	0.959	0.945	1.000	0.952
Market Index	0.989	0.889	0.952	1.000

Graph 2 shows the return trends for the four portfolios starting with an investment simulation of 100 units over 527 trading days. Sortino diverged significantly from the benchmark index and others in a positive (upward) direction during some periods. This divergence is particularly evident in the 28-81, 131-172, 301-353, and 358-378 trading day intervals.



Graph 2. Compound Return of Portfolios

According to Graph 2, Sharpe diverges positively (upward) and negatively (downward) from the market index in some periods, and the two portfolios are similar in terms of return performance. In other words, the Sharpe follows the market index by excluding exceptional circumstances. The Sortino moves with the market index for short periods, while markets exhibit a downward trend but then diverge in a negative direction from the market. In the relevant periods, Sortino repeated similar tendencies in different ranges. During the downside market period, Sortino underperformed the market index. On the other hand, the EW portfolio underperforms the other portfolios for 478 trading days. In the examined period, the highest return reached by portfolios were as follows: 399.00 units for the Sharpe on the 501st trading day, 378.09 units for the Sortino on the 338th trading day, 355.00 units for the EW 490th trading day, 401.94 units for the market index 523rd trading day. Table 7 provides the risks, returns, and coefficients of variation (CV) of the portfolios for the 150-day periods.

Table 7. Return, Risk and CV of Portfolios

	Sharpe	Sortino	EW	Market Index
(1-150)				
Return	0.48%	0.57%	0.47%	0.48%
Risk	2.34%	2.46%	2.30%	2.35%
CV	4.87	4.35	4.88	4.93
(151-300)				
Return	0.22%	0.18%	0.22%	0.23%
Risk	2.24%	2.32%	2.24%	2.23%
CV	10.01	13.18	10.03	9.54
(301-450)				
Return	0.11%	0.06%	0.08%	0.11%
Risk	1.98%	2.19%	2.07%	1.97%
CV	18.04	37.95	26.41	18.71
(451-527)				
Return	0.11%	-0.09%	0.04%	0.14%
Risk	3.98%	3.20%	3.56%	3.99%
CV	36.07	-37.23	89.23	27.75

Note: Return and risk values are averages daily.

Sharpe is close to the market index in terms of portfolio performance over the 527-day period. In the first period (1-150), Sortino outperforms the other portfolios. After the second period, Sortino underperformed when the market showed a downward trend. Sharpe portfolio generally shows more stability; nevertheless, there are specific periods in which the Sortino portfolio outperforms both the participation market index (XK030) and the Borsa Istanbul 100 conventional market index (XU100). Additionally, it is seen that the participation market index underperformed Sharpe, Sortino, and EW in some periods. In general, portfolio performance varies according to market conditions. (See Annexes for a comparison of constructed portfolios and market indices.)

6. Conclusion

In this study, we constructed Sharpe and Sortino portfolios using stocks in the XK030. To construct a portfolio, we optimized the Sharpe and Sortino ratios under specified constraints and obtained stock weights. We computed portfolio returns using weights for each period and created a portfolio return series covering 527 trading days. Additionally, we created an EW portfolio and used XK030 as a benchmark for comparative analysis. We further employed XU100 as a conventional market index for a comparison (See Annexes). The results of the study show that the Sharpe portfolio consistently follows the benchmark index. It can be said that the MPT portfolio totally reflects both upward and downward market trends. During the sample period, Sortino outperformed the benchmark index when the market showed an upward trend (See Annexes). According to participation and conventional market trends, it could be concluded that Sortino achieved higher returns in a bullish market regime while underperforming the market index during the correction movements. We argue that investors and analysts could adopt the weighting and portfolio construction method based on PMPT as a strategy to provide excess returns (market outperformance) during a market upturn. On the other hand, they could recognize Sharpe convergence as a strategy to avoid losses during a market downturn. For instance, if we consider the Sharpe and Sortino portfolios as ETFs throughout the examined period, fund managers would achieve higher returns with Sortino ETF in periods of

increasing stock prices (See Graph 2 and Annexes). In addition, they can manage various assets, not just stocks, by implementing them in the model and balancing their weights.

Many studies in the literature indicate that D-CAPM estimates higher expected returns; hence, the approach may be effective for stock selection and weighting during upward trends. It would be beneficial to concentrate on stocks with high expected returns. This study provides evidence that the PMPT approach to portfolio management is feasible and can be used in combination with MPT tools. Professionals should take positions according to different market conditions using alternative portfolio construction strategies. For instance, a strategy of index-tracking can be utilized for loss aversion during market correction movements. To obtain an excess return, professionals may focus on stocks with higher expected returns, ignoring risk. The findings from our models, including MPT and PMPT approaches align with different market dynamics.

As shown in Table 5, the concentration in the Sortino is higher than that in Sharpe. It is possible to state that Sharpe is better diversified than Sortino. The concentration of stocks in Sortino indicates the overweighting of specific stocks, which can have an impact on the overall performance of the portfolio. We observed that the EW generally underperforms except for the last 47 trading days. In this respect, it can be stated that investors and analysts must consider dynamic portfolio management. PMPT metrics, such as downside risk, downside beta, D-CAPM, and Sortino ratio, can be used for portfolio construction and weighting strategies. Additionally, this study proves that outperforming market returns can be obtained by using alternative portfolio construction strategies. Some findings of this study diverge from the existing literature. For instance, Jankova (2019) found that PMPT provided better diversification and less risk. On the contrary, we obtained more aggressive portfolios when we utilized PMPT methods for estimation. Furthermore, our diversification could not exceed that of MPT. On the other hand, the findings of Yıldız's (2021) research are noteworthy and partially align with our study in terms of the semi-variance approach does not outperform the mean-variance in reducing risk with diversification. Yıldız (2021) found the two approaches do not differ significantly. However, we observed some important differences in portfolio construction. Moreover, our research offers more dynamic outcomes than the study conducted by Bayat and Yiğiter (2022) from the same viewpoint.

This study shows that alternative index simulations are also applicable for portfolio management in addition to market capitalization-based indexation. Naturally, our study has limitations and includes only evidence from a specific period under examination. In future studies, researchers could work on different stock markets or indices. In this way, they could compare the findings and results with those of our study. In terms of portfolio management topics, such as PMPT and behavioral portfolio theory, they are remarkable areas for further research.

Acknowledgements
We would like to thank the journal editor and reviewers for their valuable suggestions. Additionally, we are grateful to Prof. Dr. Koray Kayalıdere and Assoc. Prof. Dr. Selim Baha Yıldız from Manisa Celal Bayar University for their constructive comments for this study.

Declaration of Research and Publication Ethics
This study, which does not require ethics committee approval and/or legal/specific permission complies with the research and publication ethics.

Researcher's Contribution Rate Statement
The authors declare that they have contributed equally to the article.

Declaration of Researcher's Conflict of Interest
There are no potential conflicts of interest in this study.

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Annexes

Table 1. Steps of Screening Process

Stocks that are not traded in the BIST Stars Market, BIST Main Market or Sub-Market at the start of the index period are excluded. In other words, the status of the market in which the companies are traded is taken into consideration**.**
Companies are excluded if they are ethically problematic, negatively affect people and other living beings, have a negative impact on their mental and physical health, and are intensive in money trading and interest-bearing transactions. The activities are as follows: Alcoholic beverages (both production and trade) Narcotic substances except for medical purposes (both production and trade) Gambling and gambling-related activities Pigs and their products (both production and trade) Financial transactions with interest Publication contrary to morality and Islamic values Entertainment, hotel management and similar activities that are not in accordance with Islamic values Activities that impose substantial harm on the environment and living beings Biological/genetic activities to change human nature Tobacco products that are harmful to health (production, wholesale trade and distribution)
Shares with certain privileges, such as profit or liquidation rights or usufruct shares, are excluded.
Companies that ignoring Islamic values, supporting acts that violate human rights and humanitarian values, in particular inherent right to life, are excluded. (Companies are also excluded if they are found guilty in these issues.)
Companies are excluded if they are considered directly contrary to the Participation Finance Principles are excluded.
In the screening of financial ratios, companies' links to sectors rated as completely inappropriate in their interest-bearing assets and liabilities are limited to certain reference values to ensure compliance with the index. Quantitative screening values as are follows: Revenues obtained from non-permissible activities / Total revenues < 5.00% Interest-bearing assets / higher of market value or total assets < 33.00% Interest-bearing debts / higher of market value or total assets < 33.00%

Source: Borsa Istanbul, 2024.

Table 2. Computation Results of Optimization Parameters

Period	CAPM	D-CAPM	σ	σ_d	r_f	r_t	Sharpe	Sortino
1	0.34%	0.33%	2.40%	1.54%	0.0805%	0.0813%	0.11	0.16
2	0.27%	0.28%	1.54%	0.85%	0.0683%	0.0690%	0.13	0.25
3	0.12%	0.13%	2.15%	1.34%	0.0377%	0.0396%	0.04	0.07
4	0.63%	0.70%	2.29%	1.07%	0.0580%	0.0586%	0.25	0.60

Graph 1. Comparative Graphs of Portfolios

Ekonomi, Politika & Finans Araştırmaları Dergisi, 2025, 10(1): 44-57
Journal of Research in Economics, Politics & Finance, 2025, 10(1): 44-57
Araştırma Makalesi / Research Article, https://doi.org/10.30784/epfad.1581224

DOES TRADE OPENNESS AFFECT ENERGY SECURITY? EMPIRICAL EVIDENCE FROM TÜRKİYE

Ticari Açıklık Enerji Güvenliğini Etkiler mi? Türkiye'den Ampirik Bulgular

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Keywords:
Energy Security
Trade Openness
Energy Policy
Trade Policy

JEL Codes:
O13, O24, P28, Q27, Q43

Abstract

Trade openness can create advantageous and disadvantageous situations for national economies. The impacts of trade openness on energy security are also crucial for policymakers, especially in countries dependent on fossil resources. This study aims to identify the link between trade openness and energy security and to prove that trade openness is one of the determinants of energy security for the Turkish economy. In the study, long-run analysis was carried out using cointegration analysis based on time series analysis. We used Türkiye's annual data for the period 1980-2018. Empirical findings point to a long-run relationship between the variables. According to the estimation results, trade openness increases the energy security risk. This result shows that increasing trade openness increases energy security risk due to the scale effect. We can say that the scale and composition effects dominate the relationship between openness and energy security for Türkiye. As can be seen from the study's empirical results, there is a significant relationship between trade openness and energy security in Türkiye, both in the short and long run. In this context, policymakers need to implement energy policies and trade policies simultaneously and with consideration for each other.

Anahtar Kelimeler:
Enerji Güvenliği
Ticari Açıklık
Enerji Politikaları
Ticaret Politikaları

JEL Kodları:
O13, O24, P28, Q27, Q43

Öz

Açıklık, ulusal ekonomiler için avantajlı ve dezavantajlı durumlar yaratabilir. Açıklığın enerji güvenliği üzerindeki etkileri, özellikle fosil kaynaklara bağımlı ülkelerde, politika yapıcılar için hayati öneme sahiptir. Bu çalışma, ticari açıklık ile enerji güvenliği arasındaki bağlantıyı belirlemeyi ve ticaret açıklığının Türkiye ekonomisi için enerji güvenliğinin belirleyicilerinden biri olduğunu kanıtlamayı amaçlamaktadır. Çalışmada, zaman serisi analizine dayalı eşbütünleşme analizi kullanılarak uzun vadeli analiz yapılmıştır. Türkiye'nin 1980-2018 dönemine ait yıllık verileri kullanılmıştır. Ampirik bulgular, kullanılan değişkenler arasında uzun vadeli bir ilişkiye işaret etmektedir. Tahmin sonuçlarına göre, ticari açıklık enerji güvenliği riskini arttırmaktadır. Bu sonuç, ölçek etkisi nedeniyle artan ticari açıklığın enerji güvenliği riskini artırdığını göstermektedir. Türkiye için açıklık ile enerji güvenliği arasındaki ilişkide ölçek etkisi ve bileşik etkinin baskın olduğu söylenebilir. Çalışmanın ampirik sonuçlarından görüleceği üzere, Türkiye'de ticari açıklık ile enerji güvenliği arasında hem kısa hem de uzun dönemde önemli bir ilişki mevcuttur. Bu çerçevede politika yapıcıların enerji politikaları ve ticaret politikalarını eşanlı ve birbirini gözeterek yürütmesi önem arz etmektedir.

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Received Date (Makale Geliş Tarihi): 10.11.2024 *Accepted Date (Makale Kabul Tarihi): 11.02.2025*

1. Introduction

Energy security has a critical role in sustainable economic development. Recently, energy security policies have gained remarkable importance all over the world. Energy security policies are carried out in parallel with sustainable development goals. The main reason is that energy has become one of the most crucial production factors. Energy security is defined as a country's ability to provide uninterrupted access to energy resources at affordable prices (Deese, 1979). As the level of development in economies increases, the energy demand also increases. With the increase in energy demand in countries that are not rich in energy resources, energy security risks also increase. An increase in energy security risk will negatively affect the macroeconomic balance of a country.

The stagflation periods that emerged after the two major oil shocks in the 1970s brought the importance of energy to the world's agenda. After the oil shocks, the concept of energy security began to be discussed frequently in the economic literature. The oil crises emphasized the central role of energy in economic, social, and military security. Ensuring a stable oil supply has become a national security issue for many countries (Le and Park, 2021). Energy security is closely related to countries' social, cultural, political, economic, and military security (Deese, 1979). Strategies for energy security may have consequences that will affect national and international security.

In the literature, the "four A's of energy security (availability, accessibility, affordability, and acceptability" are often used when explaining the concept of energy security (Cherp and Jewell, 2014). However, the factors determining energy security are i) supply-demand balance, ii) prices, iii) accessibility, and iv) sustainability. The first of these is the element that creates the energy security problem. The energy security problem that arises in countries that consume much more energy than they produce is one of the most critical security problems in the country. According to the data of the Energy Institute (2023), only 15 to 20 countries in the world export energy, primarily oil and gas, while the rest depend on imports. Affordability, accessibility, and sustainability form a trilemma. Problems in these three elements increase the risk of energy security.

While per capita energy consumption in Türkiye was 37.2 Gj in 1990, it reached 68.4 Gj in 2012 and 82.2 Gj in 2022 (Energy Institute, 2023). However, Türkiye's dependency on energy imports is around 75%. As a developing economy, Türkiye's energy demand is expected to increase rapidly in the coming period. Within the framework of numbers, the concept of energy security is one of Türkiye's priorities.

Energy demand has increased rapidly in the last 50 years due to the increase in the world population, technological advancement, liberalization of trade, rapid growth of developing Asian countries, etc. It is expected that this value will continue to increase in the future. The notion of energy security, about the reliable supply of energy, has gained significant traction in academic circles. Numerous investigations have been undertaken to explore the elements that influence energy security.

Many studies in the literature examine the effects of trade openness on energy consumption. Although this effect is significant, the energy security risk that this effect poses is another critical point that should be emphasized for developing countries. Does this relationship between energy consumption and trade openness also exist between energy security and trade openness? This

question needs to be investigated. Although the relationship between energy consumption and trade openness is essential, the direct relationship between energy security and trade openness will produce more meaningful results in terms of policymaking. The distinctive contribution of this study, in comparison to existing literature, lies in its empirical demonstration of the relationship between energy security and trade openness.

It is stated in the literature that trade openness affects energy demand through scale effect, technical effect, and composition effect (Nasreen and Anwar, 2014; Qamruzzaman and Jianguo, 2020). Trade openness also impacts energy security through similar channels. One of these is the increase in production brought about by trade openness to the outside world (Shahbaz et al., 2014). This situation is called the scale effect. If greater trade openness stems from the export channel, it means more production of export goods. More production means more energy consumption and impacts energy security. If this channel works through imports, imports have various effects on energy consumption and energy security. If the increase in imports is directed towards imports of intermediate goods, it will lead to a rise in domestic production and will impact energy security. If the increase in imports is due to a surge in consumer goods, it will directly affect energy consumption and security. If trade openness causes technology transfer to the country, this effect is called the technical effect (Zeren and Akkuş, 2020). As a result of the technical effect, energy consumption may decrease, or renewable energy consumption may increase with the decrease in energy intensity and increase in energy efficiency in the country. This effect will have a positive impact on energy security. The composition effect refers to the phenomenon whereby a shift from the agricultural sector to the industrial sector leads to an initial rise in energy consumption, as the industrial sector is characterized by its high energy demands during the process of economic development. The composition effect causes a decrease in energy consumption when the transition from the industrial sector to the service sector is made (Arrow, 1962).

Due to the composition effect, the relationship between trade openness and energy security differs across developed and developing countries. There are also different impacts on energy exporting and energy importing countries. For example, if increasing trade openness in energy-exporting countries leads to more energy exports, it can positively affect energy security. In energy-importing countries, increasing trade openness may negatively affect energy security as it will mean more energy imports.

Another channel through which trade openness impacts energy security is the price channel. In countries with high trade openness, foreign prices directly affect domestic prices. In countries with high trade openness favoring imports, macroeconomic problems may arise due to foreign price fluctuations. Especially in recent times, fluctuations in energy prices have played a destabilizing role in economic stability.

Within the framework of these explanations, the primary purpose of this study is to prove the link between trade openness and energy security. We also argue that trade openness is one of the determinants of energy security. The subsequent sections of the study are structured as follows. The second section will present a review of the existing literature, followed by model specification in the third section, empirical findings in the fourth section, and concluding remarks in the final section.

2. Literature Review

There is a complex relationship between energy security, energy consumption, and renewable energy consumption. Trade openness is related to all of these. The interplay between energy consumption and energy security can yield two distinct results. An escalation in energy consumption that relies on fossil fuels will adversely impact energy security for nations that depend on energy imports. Conversely, an increase in energy consumption derived from renewable sources is likely to enhance the energy security of countries that rely on energy imports. The effect of trade openness varies in these two cases. Enhancing trade openness could lead to a rise in energy consumption as a result of the scale effect, potentially undermining energy security. The rise in trade openness has the potential to positively impact energy security by increasing renewable energy production through technical effects. In their study, the relationship between renewable energy - energy security and trade openness - renewable energy was proven by Ibrahiem and Hanafy (2021). Renewable energy plays a multidimensional role in the economy. Certain measures contribute to energy security; promote diversification in energy consumption, and lower production expenses by decreasing the costs associated with fossil fuels utilized in the production process (Qamruzzaman and Jianguo, 2020).

We describe the literature review in two categories. The first is studies on the relationship between energy security and trade openness. Studies generally focus on the relationship between energy consumption/demand and trade openness. However, some studies focus on the relationship between different types of security and trade openness. Examples of studies focusing on the relationship between food security and trade openness include Dithmer and Abdulai (2017); Fusco et al. (2020); Sun and Zhang (2021); and Gnedeka and Wonyra (2023).

Numerous studies exist in the literature examining the correlation between trade openness and energy consumption. However, there is no consensus in these studies. We categorize these studies into three groups. Examples of studies that find that trade openness positively affects energy consumption/demand are Sadorsky (2011), Nasreen and Anwar (2014), Shahbaz et al. (2015), Sohag et al. (2015), Koengkan (2018), Topcu and Payne (2018), Alkhateeb and Mahmood (2019), Qamruzzaman and Jianguo (2020), Zeren and Akkuş (2020). In their study, Qamruzzaman and Jianguo (2020) found that the relationship between trade openness and energy consumption was positive in some country groups and negative in some country groups. Examples of studies that found that the relationship between trade openness and energy consumption/demand is negative are Managi et al. (2009), Shahbaz et al. (2013b), Sbia et al. (2014), Al-Mulali and Ozturk (2015), Qamruzzaman and Jianguo (2020). Examples of studies that identify a causal relationship between trade openness and energy consumption are Dedeoğlu and Kaya (2013), Shahbaz et al. (2013a), Sebri and Ben-Salha (2014), Shahbaz et al. (2014), Yang and Zhao (2014), Shahbaz et al. (2015), Rasoulinezhad and Saboori (2018), Tiba and Frikha (2018), Nepal et al. (2021), Odhiambo (2021). Shahbaz et al. (2015) found a positive and bidirectional causality relationship between trade openness and energy consumption in their study.

Only a single study was identified in the existing literature that specifically examined the connection between energy security and trade openness. Le and Park (2021) state that trade openness is among the factors determining energy insecurity. Le and Park (2021) use the concept of energy insecurity, the opposite of energy security, in their study of 139 countries. They find that trade openness has a negative effect on energy insecurity. This research posits that the degree

of trade openness serves as a significant factor influencing energy security. We use energy security variables to support this claim. Although this is not the focus of their study, Ibrahiem and Hanafy (2021) note that there is causality from trade openness to energy security. The research centers on examining how energy security and environmental quality influence the adoption of renewable energy sources. However, they used trade openness as a control variable and found a causal relationship between energy security and trade openness.

The second group is the literature on the determinants of energy security. Examples of literature on the determinants of energy security include Kruyt al. (2009); Erdal (2015); Franki and Viskovic (2015). When examining these studies, the determinants of energy security include economic factors such as energy prices, energy supply and demand, energy imports, renewable energy consumption, and factors such as CO2 emissions, global climate deterioration, and low-carbon generation technologies. Our study argues that trade openness is one of the determinants of energy security. One of the studies claiming that trade openness is one of the determinants of energy security is the article by Akinyemi et al. (2017). However, Akinyemi et al. (2017) claim this relationship without using an energy security variable in their study.

Studies in the literature examine the relationship between trade openness and energy consumption in Türkiye. However, no study has been found that focuses directly on the relationship between trade openness and energy security. Examples of studies examining the relationship between trade openness and energy consumption in Türkiye are Korkmaz (2018), Zeren and Akkuş (2020), Emeç and Yarbaşı (2018), and Çetin and Çınar (2021). Korkmaz (2018) concluded that trade openness for Türkiye and financial openness for Italy positively affect energy consumption. Zeren and Akkuş (2020) and Çetin and Çınar (2021) confirmed the positive relationship between trade openness and energy consumption in their studies. Emeç and Yarbaşı (2018) found bidirectional causality between trade openness and energy consumption in their study. These studies examined the relationship between energy use and trade openness. It can be said that this study is the first study focusing on the relationship between trade openness and energy security for Türkiye.

3. Model Specification

The annual data set used in econometric estimations covers the period between 1980 and 2018, depending on the data availability. Information about the variables used in the models is given in Table 1.

Table 1. Summary Explanations of Variables

	Definition	Explanation	Source
ensec	Energy Security Risk	Energy security risk index (Taking the natural logarithm)	Global Energy Institute
enpri	Crude Oil Price	(Taking the natural logarithm)	Energy Institute
open	Trade Openness	Ratio of export and import to GDP	World Bank
gdp	Per capita GDP	(Taking the natural logarithm)	World Bank

ensec is an index calculated by the Global Energy Institute (2024) that shows the energy security risk. The increase in the values of this index indicates that the energy security risk increases. *enpri* shows the price of a barrel of crude oil in dollars at current prices, representing

energy prices. *enpri* were obtained from the Energy Institute (2023), Statistical Review of World Energy report. *open* and *gdp* were sourced from the World Bank's World Development Indicators (World Bank, 2024). Trade openness is defined here as the ratio of the sum of imports and exports to GDP. *gdp* represents GDP per capita in $ at current prices.

The descriptive statistics of the variables are reported in Table 2. The Jarque-Bera test shows all variables are normally distributed at a 5 % level. In Table 3, the Variance Inflation Factor (VIF) values were calculated to detect the multicollinearity problem between the independent variables. Generally, a VIF value exceeding 10 indicates a multicollinearity problem between the variables (Gujarati and Porter, 2009: 340). The VIF values reported in Table 3 indicate that there is no multicollinearity problem in the model.

Table 2. Summary Statistics

	ensec	enpri	open	gdp
Mean	6.98	3.53	0.44	8.44
Median	6.96	3.34	0.50	8.36
Maximum	7.14	4.71	0.60	9.43
Minimum	6.79	2.54	0.30	7.12
Std. Dev.	0.08	0.69	0.09	0.73
Skewness	0.13	0.36	-0.40	-0.11
Kurtosis	2.29	1.71	2.01	1.66
Jarque-Bera	0.83	3.21	2.37	2.68
Probability	0.65	0.20	0.30	0.26
Obs.	39	39	39	39

Table 3. Multicollinearity Test Results

Variables	Coefficient Variance	Uncentered VIF	Centered VIF
gdp	0.000930	579.9856	4.970945
open	0.029832	49.97436	2.891889
enpri	0.000675	77.84541	2.551070

The models to be used in econometric analyses are shown below.

$$ensec_t = \alpha_1 + \beta_1 enpri_t + \beta_2 open_t + \beta_4 gdp_t + \varepsilon_t \quad (1)$$

The first step in assessing the relationship between trade openness and energy security is determining whether the series has unit roots. We use the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests to determine whether the series in question has a unit root (Dickey and Fuller, 1979, 1981; Phillips, 1987; Phillips and Perron, 1988). If the series is found to have a unit root or be I(1), we will continue our investigation by applying cointegration tests. We employ the Johansen multivariate cointegration technique, as Johansen (1988) and Johansen and Juselius (1990) suggested. In this study, we employ a vector error correction model to estimate the model's short-run and long-run coefficients.

4. Empirical Findings

The prominent research question of this study is, "Is trade openness a determinant of energy security?" Based on this research question, the first of the main results we expect to obtain from the empirical application of the study is to determine that trade openness is one of the determinants

of energy security. The second main result we expect to obtain is the direction of the relationship between trade openness and energy security. As we stated before, these two variables have many channels of influence. We are looking for an answer to the question: which is more dominant in Türkiye: scale effect, technical effect, and composition effect? If trade openness increases energy security risk, the scale effect will dominate. Because increasing trade in developing countries brings economic growth, energy demand increases with increasing economic growth, and rising energy demand increases the risk of energy security. If trade openness reduces energy security risks, the technical effect dominates. The energy efficiency of developing countries increases with technology transfer from developed countries. Thus, energy demand decreases, and decreasing energy demand reduces energy security risk. In addition, energy consumption is likely to increase in industrializing economies, which is likely to increase the risk of energy security. This result is referred to as the composition effect in the literature. The positive relationship between trade openness and energy security risk may arise due to the scale effect and composition effect, and there is no clear way to separate the two, as in Cole's (2006) study.

Before the estimation of equation 1, we applied the unit root tests. Table 4 presents the unit root test results of the variables used in the model. The ADF unit root test shows that all variables are not stationary at their levels but stationary at first differences, implying all variables are integrated of order one, i.e., I(1). According to Perron (1989), the power of ADF tests decreases in the presence of structural breaks.

Table 4. Unit Root Tests

Series	ADF	PP
ensec	-1.38(0)	-1.21(6)
Δensec	-5.74(0)***	-6.59(18)***
enpri	-0.96 (0)	-0.96 (0)
Δenpri	-5.67 (0)***	-5.66 (2)***
open	-1.82 (0)	-1.60 (13)
Δopen	-7.67 (0)***	-10.95 (16)***
gdp	-0.77 (0)	-0.76 (1)
Δgdp	-6.09 (0)***	-6.09 (1)***

*** indicates rejection of the null hypothesis of non-stationary at the 1% level.
PP is the Phillips-Perron, and ADF is the Augmented Dickey-Fuller tests. The proper lag order for the ADF test is chosen by considering Akaike Information Criteria (AIC) and white noise of residuals, represented in parenthesis. The bandwidth is chosen for PP tests using the Newey–West method, and spectral estimation uses the Bartlett kernel, represented in parenthesis.

Zivot and Andrews (1992) criticized Perron's (1989) exogenous breakpoint assumption and developed a new unit root testing procedure that allows for an estimated break in the trend function (Zivot and Andrews, 1992). Table 5 shows the Zivot-Andrews (ZA) unit root test results. Three models are used in this test: Model A contains a single break in level, Model B contains a single break in slope, and Model C contains a single break in both slope and level. Test results indicate that all series are integrated in the same order, I(1).

Table 5. Zivot-Andrews Unit Root Test

	Level			First Difference		
Series	**ZA_I**	**ZA_T**	**ZA_B**	**ZA_I**	**ZA_T**	**ZA_B**
ensec	-4.159	-3.422	-4.604	-6.457***	-6.034***	-6.332***
Time Break	1990	1999	1990	1989	1991	1999
Lag Length	0	0	0	0	0	0
enpri	-3.53	-2.987	-2.987	-6.418***	-6.168***	-6.303***
Time Break	2004	2004	2004	2009	2006	1999
Lag Length	0	0	0	0	0	0
open	-4.869*	-3.937	-4.849	-5.269**	-4.571**	-5.305**
Time Break	1994	2002	1994	1998	1997	1994
Lag Length	0	0	0	2	3	2
gdp	-2.943	-3.203	-3.412	-6.648***	-6.737***	-7.289
Time Break	2003	2012	2004	2009	2006	2003
Lag Length	0	0	0	0	0	0

*, **, *** indicate significance at the 10%, 5%, and 1% level, respectively. ZA_I represents the model with a break in the intercept; ZA_T is the model with a break in trend; ZA_B is the model with a break in both the trend and intercept.
The 1%, 5%, and 10% critical values for the Model A are -5.34, -4.93, -4.58, respectively.
The 1%, 5%, and 10% critical values for the Model B are -4.80, -4.42, -4.11, respectively.
The 1%, 5%, and 10% critical values for the Model C are -5.57, -5.08, -4.82, respectively.
The 1%, 5%, and 10% critical values for the ADF and PP tests are -3,61, -2,94, and -2,60, respectively.

According to unit root test results, the condition for the Johansen cointegration technique is satisfied, and therefore, short and long-run analyses can be performed. Performing the cointegration tests, we determined the lag length as 2 according to the AIC criterion and used the model that includes the constant. In the cointegration test, we used the dummy variable we created for 1994 and 2001 to account for the structural break. The crises of 1994 and 2001 are the biggest crises seen in the Turkish economy. Due to the failure to ensure monetary and fiscal discipline, high inflation, and high interest rates, along with the deterioration of the balance of payments and exchange rate shocks, these crises brought about significant changes in the Turkish economy. Many institutional arrangements, especially the central bank's independence, were made after the 2001 crisis, and structural measures were taken to control inflationary trends. The trace and max eigen statistics results for the dependent variable, *ensec, are* presented in Table 6.

Table 6. Cointegration Test Results

Hypothesized No. of CE(s)	**Trace Statistic**	**0.05 Critical Value**	**Prob.**	**Hypothesized No. of CE(s)**	**Max-Eigen Statistic**	**0.05 Critical Value**	**Prob.**
r = 0*	57.157	47.856	0.005	r = 0*	29.382	27.584	0.029
r ≤ 1	27.774	29.797	0.084	r ≤ 1	16.088	21.132	0.220
r ≤ 2	11.687	15.495	0.172	r ≤ 2	8.265	14.265	0.352
r ≤ 3	3.422	3.841	0.064	r ≤ 3	3.422	3.841	0.064

*denotes rejection of the hypothesis at the 5% level
The model that includes the constant in the cointegration equation was used. The optimum lag length was determined as 2 according to the AIC criterion.

Cointegration test results show that there is a cointegration relationship between the variables. Therefore, a vector error correction model will be estimated to investigate short-run and long-run relationships between variables. The prediction results of the ECM model are shown

in Table 7. In Table 7, it is estimated that 23.9 percent of the short-run imbalance will be eliminated in the long-run. Table 7 also presents the cointegration equation showing the long-run coefficients of the variables affecting energy security. Accordingly, *open, enpri* and *gdp* have a positive impact on *ensec*. The positive relationship between trade openness and energy security risk indicates that the scale effect and composition effects are more dominant in Türkiye. This result has been realized within the framework of our expectations for Türkiye. In Türkiye, where the industrialization process continues and has rapid growth potential, the increasing energy demand due to increasing trade negatively affects energy security. The positive relationship between energy prices and energy security risk is an expected result, too. Increases in energy prices make energy imports more complex, and the energy security risk increases. The positive relationship between income and energy security risk confirms the dominance of the scale effect channel. With increasing trade, economic growth occurs, energy demand increases, and energy security risk increases with growing energy demand.

Table 7. Short-Run and Long-Run Test Results

	Short-Run Estimates		**Long-Run Estimates**
$\Delta(ensec_{t-1})$	0.313*	$open_{t-1}$	1.083***
	(0.169)		(0.364)
$\Delta(ensec_{t-2})$	0.098	$enpri_{t-1}$	0.124***
	(0.172)		(0.042)
$\Delta(open_{t-1})$	-0.377**	gdp_{t-1}	1.010***
	(0.151)		(0.057)
$\Delta(open_{t-2})$	-0.920***		
	(0.154)		
$\Delta(enpri_{t-1})$	-0.043		
	(0.026)		
$\Delta(enpri_{t-2})$	-0.034		
	(0.032)		
$\Delta(gdp_{t-1})$	0.059		
	(0.054)		
$\Delta(gdp_{t-2})$	-0.113*		
	(0.066)		
Error Correction Term	-0.239***		
	(0.074)		
Constant	0.017		7.309
	(0.009)		
Dum1994	0.054		
	(0.034)		
Dum2001	0.020		
	(0.042)		
Obs.	36		
R^2	0.731		
F Test	5.944		
Autocorrelation LM Test (2) (p-value)	0.165		
Breusch-Pagan-Godfrey Test (p-value)	0.525		

*, **, *** indicate significance at the 10%, 5%, and 1% level, respectively. Standard errors are represented in parentheses

As a result of the empirical findings, we prove that trade openness is one of the determinants of energy security for Türkiye. No other study has proven the relationship between trade openness

and energy security for Türkiye. We develop the findings of Korkmaz (2018), Zeren and Akkuş (2020), and Çetin and Çınar (2021), who examined the relationship between trade openness and energy consumption for Türkiye and found a positive relationship to include energy security. We also contribute to the work of Akinyemi et al. (2017) by including the energy security variable.

Contrary to the finding of Le and Park (2021), who used the concept of energy insecurity, that trade openness negatively affects energy insecurity, the finding that trade openness increases energy security risk is essential for this study. We also improve the work of Ibrahiem and Hanafy (2021), which identified causality from trade openness to energy security in terms of the degree and direction of the relationship.

The diagnostic test results reported at the bottom of Table 7 show that the residuals are not serially correlated and heteroscedastic at the 5 percent level. Cusum and Cusum of square tests shown in Figure 1 and Figure 2 show the parameter stability in the models.

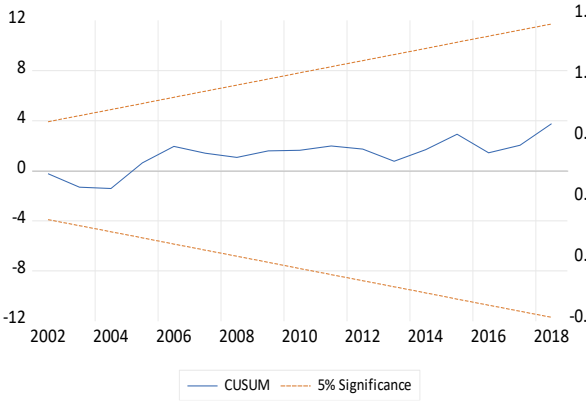

Figure 1. CUSUM test.

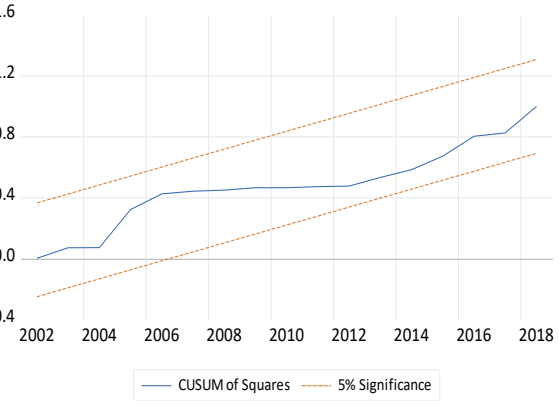

Figure 2. CUSUM of squares test.

5. Conclusion

Energy security has a critical role in sustainable economic growth and development. For this reason, energy policies should be designed within the framework of sustainable development goals. In recent years, many studies have emerged in the literature investigating the relationship between trade openness and energy consumption or demand. In addition, examining the impact of trade openness on energy security, which is a direct policy indicator, will guide policymakers.

In this study, we examined whether trade openness impacts energy security in the Turkish economy. We used time series analysis to explore the relationship. In the study, we took into account structural breaks for Türkiye. We analyzed the impact of trade openness on energy security in Türkiye with the cointegration and error correction model. The study's findings highlight that trade openness significantly influences energy security in Türkiye.

This study used an econometric model for variables assumed to be effective in determining energy security. Energy security was taken as a dependent variable in econometric model estimations. Empirical results show that there is a long-run relationship between energy security and the explanatory variables, which are trade openness, GDP per capita, and energy price.

The estimation results of the error correction model created to analyze the short and long-run dynamics between the variables show that an increase in trade openness, energy prices, and GDP per capita positively affects energy security. According to the error correction term, 23.9 percent of the short-run imbalance will be eliminated in the long-run. This result shows that the error correction mechanism is working.

This study indicates a significant relationship between trade openness and energy security in the short and long run, and the permeability between energy and trade policies is relatively high. According to these results, policymakers should simultaneously design energy and trade policies.

The limitation of this study is the short period during which the analysis was conducted. This situation is due to the restrictions on the accessibility of the data. Another limitation of the study is that the results obtained are valid within the method's scope. Future studies can conduct analyses with more extended data sets and methodological developments.

Declaration of Research and Publication Ethics

This study which does not require ethics committee approval and/or legal/specific permission complies with the research and publication ethics.

Researcher's Contribution Rate Statement

The authors declare that they have contributed equally to the article.

Declaration of Researcher's Conflict of Interest

There is no potential conflicts of interest in this study.

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Ekonomi, Politika & Finans Araştırmaları Dergisi, 2025, 10(1): 58-91
Journal of Research in Economics, Politics & Finance, 2025, 10(1): 58-91
Araştırma Makalesi / Research Article, https://doi.org/10.30784/epfad.1588423

FORECASTING THE INFLATION FOR BUDGET FORECASTERS: AN ANALYSIS OF ANN MODEL PERFORMANCE IN TÜRKİYE

Bütçe Tahmincileri için Enflasyon Tahmini: Türkiye'de YSA Modeli Performansının İncelenmesi

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Keywords:
Budget Forecasting, Inflation Forecasting, Artificial Neural Network

JEL Codes:
C53, E27, H68, E31

Abstract

The reliability of budget revenue and expenditure forecasts depends on the accuracy of inflation forecasts. Without realistic inflation forecasts, it is not possible to produce sound budget forecasts. This study aims to guide budget forecasters in Türkiye by providing accurate inflation forecasts. The analysis utilizes data from the 2005–2023 period. The basket exchange rate (USD and Euro), unemployment, imports, exports, budget revenues and expenditures, interest rates, industrial production index, money supply, general price index, and minimum wage are forecasted using Holt-Winters, ARIMA, SARIMA, Prophet, LSTM, and Hybrid models. These forecasts are then used as inputs in ANN, SVR, RF, and GBM models to forecast monthly inflation. The results indicate that the forecasts generated with ANN are significantly more realistic than those presented in Türkiye's budget law and the Medium-Term Program. The study demonstrates that ANN can be an effective tool for budget forecasters in accurately forecasting inflation and, consequently, improving budget forecasts. The findings are further evaluated through a comparative analysis with forecasts from institutions such as the IMF, OECD, Central Bank, and the European Union. To support future academic research, inflation forecasts for 2025, along with forecasts for independent variables, are also included in the study.

Anahtar Kelimeler:
Bütçe Tahmini
Enflasyon Tahmini
Yapay Sinir Ağları

JEL Kodları:
C53, E27, H68, E31

Öz

Bütçe gelir ve harcama tahminlerinin güvenilirliği, enflasyon tahminlerinin doğruluğuna bağlıdır. Gerçekçi enflasyon tahminleri olmadan sağlıklı bir bütçe tahmini yapmak mümkün değildir. Bu çalışma, Türkiye'de bütçe tahmincilerine enflasyon tahminleri konusunda rehberlik etmek amacıyla hazırlanmıştır. Çalışmada, 2005-2023 dönemine ait veriler kullanılmıştır. Döviz kuru sepeti (Dolar ve Euro), işsizlik, ithalat, ihracat, bütçe gelir ve harcamaları, faiz oranı, sanayi üretim endeksi, para arzı, genel fiyat endeksi ve asgari ücret, Holt-Winters, ARIMA, SARIMA, Prophet, LSTM ve Hibrit yöntemleriyle tahmin edilmiştir. Daha sonra bu tahminler kullanılarak YSA, SVR, RF ve GBM yöntemiyle aylık enflasyon tahminleri üretilmiştir. Sonuçlar, çalışmada YSA ile edilen tahminlerin, Türkiye'nin bütçe kanunu ve orta vadeli programda yer alan enflasyon tahminlerinden daha gerçekçi olduğunu göstermektedir. Çalışma, YSA yönteminin bütçe tahmincileri tarafından enflasyonu doğru tahmin etmek için etkili bir araç olarak kullanılabileceğini ortaya koymaktadır. Bulgular, IMF, OECD, Merkez Bankası ve Avrupa Birliği tahminleriyle karşılaştırmalı analiz yoluyla değerlendirilmiştir. Gelecek akademik araştırmaları desteklemek amacıyla, 2025 yılına ilişkin bağımsız değişkenler ve enflasyon tahminleri de çalışmaya dahil edilmiştir.

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Received Date (Makale Geliş Tarihi): 20.11.2024 Accepted Date (Makale Kabul Tarihi): 25.03.2025

1. Introduction

Inflation is a critical element for sound fiscal policy and economic stability. Accurate inflation forecasting plays a crucial role in the formulation of reliable budget forecasts. To allocate resources, manage public debt, and configure fiscal policy, governments use budget forecasts as their primary tool. Misforecasting inflation can lead to high discrepancies between the planned and actual public expenditures and revenue collection, thereby reducing the effectiveness of fiscal policy. For instance, unforeseen inflationary shocks can significantly distort budget forecasts, especially for government expenditure on wages, pensions, tax revenue, and entitlement programs (Bretschneider and Gorr, 1992). Governments will tend to overspend budgeted amounts when inflation is under-forecasted, thereby generating fiscal deficits. Excess inflation forecasting results in over-contracting of the budget, which is most likely to injure economic growth (Allan, 1965).

Inflation forecasting has been extensively studied in the literature since it is of great significance for monetary and fiscal policy. The conventional econometric models such as Autoregressive Integrated Moving Average (ARIMA), Vector Autoregressive (VAR), and Phillips Curve-Based (PC) approaches have conventionally formed the basis of inflation forecasting (Stock and Watson, 1999, 2003). However, these models are prone to fail in describing the dynamic and complex character of inflation, particularly in periods of economic crises and structural adjustment. More recently, Machine Learning (ML) techniques, particularly Artificial Neural Networks (ANN), have gained prominence due to their ability to model nonlinear relationships and detect advanced patterns in massive data sets (Moshiri and Cameron, 2000; Nakamura, 2005). Some comparative studies have established the superior predictive performance of ANN models in inflation forecasting relative to traditional statistical methods (Choudhary and Haider, 2012; Medeiros et al., 2021).

Despite such advancements, there is controversy surrounding the effectiveness and validity of other methods of inflation forecasting. Some literature captures the failure of econometric models to uncover dynamic economic relations (Atkeson and Ohanian, 2001; McKnight et al., 2020). Others point out that while ML methods such as ANN, Long Short-Term Memory (LSTM), and hybrid models improve accuracy, their use in policymaking is limited by data availability and computational expense (He et al., 2012; Garcia et al., 2017). Considering these controversies, this study aims to investigate the performance of ANN models in inflation forecasting specifically for budget forecasters, who require timely and realistic models for fiscal planning.

The purpose of this study is to constitute a comprehensive analysis of the performance of ANN regarding its forecasting purposes concerning inflation in Türkiye and whether it as a tool could be reasonably used by budget forecasters. In the literature, this study fills a gap by extending the applications of ANN in fiscal planning through inflation forecasting. Unlike previous studies that concentrate on short-term inflation forecasting or central bank decision-making, this study corresponds with the needs of budget planners relating to inflation forecasting based on leading macroeconomic indicators available at the time of preparing the budget. In this regard, a more realistic assessment of the application of ANN for actual fiscal practice can be portrayed.

Türkiye provides a particularly good example of inflation forecasting due to its history of chronic inflation and macroeconomic turmoil. Since the second half of the 20th century, Türkiye has had repeated episodes of high inflation, currency devaluations, and foreign debt crises that

have posed gigantic challenges to fiscal planning (Kara, 2024a). The latest inflationary pressures, fueled by exchange rate instability and global commodity price shocks, have served to reinforce the imperative of accurate inflation forecasting. Unusually high inflation rate volatility has often led to substantial disparities between forecast and actual budget outcomes, with a need for a quest for better forecasting tools.

The most elementary issue addressed in this study is the uncertainty for budget planners in inflation forecasting. The budgeting process in Türkiye is extremely complicated due to the very high volatility of the economic variables. Fluctuations in primary macroeconomic determinants such as exchange rates, unemployment, imports, exports, interest rates, and money supply directly affect inflation forecasts. Thus, the use of models that generalize traditional methods and are better able to capture complex economic relationships is central to improving forecast accuracy. The approach employed in this study presents a new solution, in that it not only adheres to the process employed by budget forecasters but also produces more plausible forecasts.

The methodology of the research applied here is a two-stage process for enhancing the accuracy of inflation forecasting. In the first stage, various forecasting methods were applied to independent variables, and the models yielding the most accurate results were selected. Specifically, the Holt-Winters, ARIMA, Seasonal ARIMA (SARIMA), Prophet, LSTM, and Hybrid models were evaluated, and the most reliable forecasting techniques were identified. In the second stage, these forecasts were used as inputs for an ANN model to forecast inflation. Also, ANN's performance was compared with some other ML techniques.

In Türkiye, budget forecasters typically rely on the most recent macroeconomic data available when preparing budget forecasts for the following year. This study replicates that process by utilizing data up to September 2023 to generate inflation forecasts through December 2024. By simulating the workflow of budget forecasters, the study establishes a realistic forecasting framework.

This paper is structured as follows: Section 2 reviews the relevant literature on inflation forecasting, discussing both traditional and ML-based methodologies. Section 3 presents the dataset and methodology, detailing the forecasting models used for independent variables and inflation. Section 4 discusses the results, comparing ANN-based forecasts with government and other institutional forecasts. Section 5 outlines policy recommendations based on the findings, emphasizing the integration of ANN models into budget forecasting frameworks. Finally, Section 6 concludes with a discussion of the study's implications for future research and policymaking in inflation forecasting for budgetary applications.

2. Literature Review

Advanced methodologies have been developed and tested in inflation forecasting, and performance has varied according to the broader economic environment, horizon, and coverage of available data. Traditional econometric techniques like ARIMA, VAR, and PCs have long constituted the foundation with an extremely stable base for describing inflationary processes. However, with more complex economic systems and the availability of large datasets, more advanced techniques like ML algorithms and hybrid models have evolved. These techniques have been unearthing new channels for modeling inflation dynamics and, as such, offer possible

enhancements in forecasting accuracy during times of economic turbulence or structural change periods.

While most of the traditional models usually take their basis on a group of pre-specified economic relations, ML algorithms like ANN, Random Forests (RF), and Least Absolute Shrinkage and Selection Operator (LASSO) are flexible in that the model can learn from the changes in the economic environment through the fact that they focus more on pattern identification in big data. Meanwhile, hybrid approaches have also been applied, which integrate elements from both traditional econometrics and modern ML to siphon the strengths of each method. Hence, much of the recent literature has concentrated on investigating the relative performance of these methodologies, thus highlighting their strengths, weaknesses, and the most appropriate areas of economic application.

The contributions of Stock and Watson are particularly significant. Their studies of the predictive performance of different models, particularly their (2003) and (2004) works, present evidence that many models feature higher out-of-sample forecasting errors than a simple Autoregressive (AR) model of inflation for the United States (U.S.). In a follow-up study, Stock and Watson (2007) provided further empirical evidence reinforcing the earlier finding that univariate models often outperform multivariate approaches in the U.S. context. Their earlier work (1999) highlighted the effective use of PC analysis for inflation forecasting, where strong predictive performance was demonstrated. However, in their subsequent research (2008), they revisited this approach and noted that the efficacy of PC models is not consistent over time, identifying the episodic nature of its forecasting success.

The examination of PC has been expanded in numerous studies. Atkeson and Ohanian (2001) demonstrated that in the U.S., forecasts relying on simple averages of past inflation outperformed those produced by PC models. However, McKnight et al. (2020) presented an alternative model rooted in the New Keynesian PC, applied to both the U.S. and the Eurozone, which surpassed the accuracy of traditional Random Walk (RW) approaches. In a similar vein, Kapur (2013) employed an augmented version of the PC to forecast inflation in India, yielding highly accurate results.

ANN has emerged even more into focus in forecasting inflation during recent years, especially with a high degree of noticeability in many comparative analyses. For instance, Choudhary and Haider (2012), amongst others, have tested the performance of ANN and AR in terms of forecasting in 28 OECD countries. According to them, ANN outperformed AR in almost half of the cases, while the AR forecast was superior in almost a quarter of the cases. Similarly, Haider and Hanif (2008) applied ANN in inflation forecasting in Pakistan. They showed that ANN outperformed both AR and ARIMA with a significant difference in accuracy. Nakamura (2005) expanded upon such findings by showing that ANN improved upon univariate autoregressive models for the U.S. While such cases of success pervade, higher performance by ANN is not absolute or categorical. He et al. (2012) tested within their paper the forecasting of U.S. inflation and discovered that while ANN held much potential, results were most effectively obtained by ARIMA-GARCH.

This followed other concepts of the subsequent ANN models. Moshiri and Cameron (2000) applied their research in Canadian inflation where they compared the results of using the Back-Propagation Artificial Neural Networks (BPN) with ARIMA, VAR, and Bayesian VAR (BVAR). The researchers found that the BPN has made equivalent forecasts to the traditional models and,

at times, outpaced traditional models, especially where economic variables experienced instability. Almosova and Andresen (2023) forecasted the U.S. inflation with LSTM Recurrent Neural Networks and compared it with AR, ANN, SARIMA, and Markov-Switching. Their findings determined that while LSTM outperformed AR, ANN, and Markov-Switching, it did not differ from SARIMA, which evidences that though there are obvious advantages to ANNs, they cannot claim to be superior to all statistical methods in general. Following up, Barkan et al. (2023) tested the Hierarchical Recurrent Neural Network (HRNN) model against other models such as the PC, VAR, and RW. The results indicated that the proposed model of HRNN outperformed all the other methods significantly.

ML techniques have also become popular and are among the most preferred and utilized inflation forecasting techniques. They are great since they are capable of handling huge amounts of data, and simulate complex dependencies, and because of these, they are among the best economic forecasting techniques. For example, Araujo and Gaglianone (2023) used ML for inflation forecasting in Brazil, comparing it with traditional techniques such as RW, Autoregressive Moving Average (ARMA), VAR, and PC against the emerging ones such as RF and ANN. The findings indicated that ML models, especially RF, outperformed the other traditional techniques. Likewise, Medeiros et al. (2021) conducted an extensive study for the U.S. based on heterogeneous models like RF, LASSO, Ridge Regression (RR), Principal Component Factors, and even advanced techniques like Boosted Factors and Complete Subset Regressions. The analysis also validated that RF always provided the best forecasts.

In a similar vein, the study by Ülke et al. (2018) considered a comparison between ML methods comprising K-nearest Neighbors (k-NN), ANN, and Support Vector Machine (SVM) against traditional models comprising AR, Auto Regressive Distributed Lag (ARDL), VAR, and Naive in forecasting U.S. inflation. The results of the study indicated that the best performer in the forecasting of core personal consumption expenditure inflation was the model that used SVM, while core consumer price index inflation was performed better by ARDL.

Beyond these advanced models, many studies have compared classical models, ARIMA, VAR, AR, SARIMA, SVM, LASSO, and Bayesian approaches to understand their relative strengths and weaknesses. For example, Bos et al. (2002) compared the performance of the Autoregressive Fractionally Integrated Moving Average (ARFIMA) and ARIMA in U.S. inflation forecasting. Their results showed that ARIMA outperformed in point forecast accuracy, although ARFIMA generated more sound multi-step forecast intervals. This stresses that one has to trade off for both short-run accuracy and long-run predictability. Moser et al. (2007) examined forecasting methods for Austria using factor models, VAR, and ARIMA. They concluded that the factor models resulted in better forecasts among these models. Furthermore, they stress that combining factor models with VAR yielded even better forecast quality.

In a study conducted by Doguwa and Alade (2013) in Nigeria, it was found that in comparison to SARIMA with Exogenous Variables (SARIMAX), better forecast accuracy was produced by the SARIMA model. Also, a multi-scope study on the US data by Gil-Alana et al. (2012) suggests that Survey-Based Expectations models outperform the conventional models of AR, VAR, ARMA, and ARFIMA.

A similar evaluation of models including RW, ARIMA, AR, ARDL, VAR, and BVAR in Pakistan by Hanif and Malik (2015) established that the most plausible forecast was provided by the ARDL model. Likewise, in a study carried out on inflation forecasting in Pakistan by Bokil

and Schimmelpfennig (2005), the results showed that the Leading Indicators Model forecasts were more accurate than the forecasts made by VAR and ARIMA models.

For the U.S., Groen et al. (2013) forecasted inflation using the Bayesian Regression model, contrasting it with RW, AR, RR, and PC models. Their results indicated that the Bayesian model resulted in more accurate short-term forecasts. Wright (2009) also investigated inflation forecasting in the U.S., evaluating a Bayesian model with counterparts such as AR, ARMA, RW, and those from the Survey of Professional Forecasters and Blue Chip. Once more, the Bayesian model proved to be the most reliable option.

Garcia et al. (2017) examined inflation forecasting in Brazil using various methods, including RW, Complete Subset Regression (CSR), AR, LASSO, FOCUS, and RF. They found that LASSO and FOCUS excelled in the short term, while Adaptive LASSO performed best in the long term. Cumulatively, CSR proved to be the most successful, and the average of all models yielded even better results.

Inoue and Kilian (2008) introduced bagging predictors for inflation forecasting in the U.S. Their results showed that bagging predictors outperformed equally weighted forecasts, median forecasts, Adaptive Regression by Mixing, and Bayesian forecast averages. However, they found performance parity between bagging and other advanced models like Bayesian shrinkage, RR, and iterated LASSO. Tang and Zhou (2015) applied SVM-based models (Fixed-SVM, PSO-SVM, GA-SVM) and BPNN to inflation forecasting in China. Among these, the PSO-SVM model emerged as the most accurate.

In addition to the commonly used methods, several studies have employed more unconventional approaches to inflation forecasting, demonstrating the versatility and innovation in this field. For instance, Sbrana et al. (2017) utilized the Moments Estimation Through Aggregation method to forecast inflation in the Eurozone, demonstrating that this novel approach produced highly accurate forecasts. Hauzenberger et al. (2023) examined inflation forecasting for the U.S. using sophisticated dimension reduction methods, revealing that these approaches were competitive with traditional linear models based on principal components. Notably, the Autoencoder and squared principal components emerged as the most successful in generating accurate forecasts.

Faust and Wright (2013) conducted an extensive survey on inflation forecasting methods in the U.S. They discovered that a simple glide path forecasting from the current inflation rate performed as well as, if not better than, model-based forecasts for long-term inflation rates, particularly in the long run. Theoharidis et al. (2023) applied a Variational Autoencoders and Convolutional LSTM Networks (VAE-ConvLSTM) model to inflation forecasting in the U.S. Their results, compared with models like RR, LASSO, RF, Bayesian Methods, Vector Error Correction Model (VECM), and Multilayer Perceptron, revealed that the VAE-ConvLSTM approach produced more accurate forecasts.

While the current literature is mostly focused on inflation forecasting in various countries, the body of research for Türkiye has also contributed significantly to the explanation of inflation processes, both with traditional econometric models and newer ML approaches. To this end, efforts have been made to forecast inflation in Türkiye with a range of approaches, each yielding some insight into the performance of competing forecasting techniques in the country's specific economic context.

One of the earlier studies, Meçik and Karabacak (2011) forecasted inflation using the ARIMA method and the results were consistent with the actual rates of inflation. Erilli et al. (2012) studied the forecasting of inflation in periods of crisis using Fuzzy Regression in Türkiye, noting that this technique gave very high forecasting accuracy. A more thorough assessment was carried out by Öğünç et al. (2013), who applied numerous models comprising univariate models, decomposition cases, time-varying parameter models based on PC, as well as VAR and BVAR models. Their analysis showed that the model allowing the use of more economic data has better predictive capabilities than the RW model and also found improvement in forecast accuracy by using multiple forecasts.

Bayramoğlu and Öztürk (2017) compared ARIMA with the Grey System model. The result indicated that ARIMA was more convenient in the forecast of the Producer Price Index, while the Grey System model had more appropriate forecasts in the Consumer Price Index. Similarly, another study by Kızılkaya (2017), using the ARIMA model, showed that it outperformed official forecasts. More recently, Özgür and Akkoç (2022) compared ML techniques (RR, LASSO, ADALASSO, and Elastic Net) with traditional models like VAR and ARIMA. The results indicated that Elastic Net produced the best forecasts. More recently, Nas et al. (2024) investigated the performance of several ML models and found the decision tree model to outperform both the RF and multilayer sensor models.

The extensive body of research on inflation forecasting demonstrates that the literature in this field is both vast and methodologically diverse. Studies aimed at identifying the determinants of inflation are equally comprehensive and traced back even further in economic research. However, given the breadth of this literature, it is not feasible to discuss all contributions in detail. Nonetheless, it is essential to highlight some of the most notable recent studies. For instance, Lim and Sek (2015) identify GDP growth, money supply, government spending, and imports as key determinants of inflation across 28 countries. Similarly, Deniz et al. (2016) find that while the specific drivers of inflation vary across industrialized and emerging economies, exchange rates, output gaps, money supply, budget balances, real wages, and GDP growth play significant roles. Čaklovica and Efendic (2020) further emphasize the importance of economic openness, unemployment, real wages, institutional factors, and external variables, such as food and oil prices, in shaping short-term inflationary dynamics within EU28 countries. More recently, Jakšić (2022) identified exchange rates, commodity prices, interest rates, and wage levels as being major inflation drivers for economies situated in Central, Eastern, and Southeastern Europe. For Türkiye, Kara (2024b) finds that inflation is greatly affected by government expenditures, while government revenues have little or no effect on inflation. Fiscal policy effects are also noted by Kinlaw et al. (2023), who identify public spending as the key inflation driver in the U.S. Lastly, Martins and Verona (2023) show that both supply shocks and inflation expectations provide significant contributions to U.S. inflation, whereas unemployment makes only a small contribution. These contributions reinforce the multifactor character of inflation dynamics as well as the necessity for incorporation in inflation forecast equations of an elaborate set of macroeconomic variables.

3. Data Set

The data set includes the most important macroeconomic variables in the budget forecasting process in Türkiye (Table 1). The variables are chosen carefully to represent the actual

conditions and limitations budget forecasters have in Türkiye. The methodology of the study included utilizing data up to September of the current year to generate forecasts up to December of the subsequent year. This procedure is consistent with the time frame utilized by budget planners in Türkiye. By repeating this same process, the aim was to improve the accuracy of inflation forecasts, which has always been one of the most challenging issues for budget forecasters.

Table 1. Data Definitions

Variable	Explanation	Acronyms	Source	Period
Exchange Rate	Monthly Dollar & Euro Basket Exchange Rate Average	BSK	Central Bank of the Republic of Türkiye	January 2005 – September 2023
Interest Rate	Central Bank's Overnight Interest Rate's Monthly Average	INT		
Money Supply	M3 Money Supply on A Monthly Basis	MSP		
Industrial Production Index	Monthly Industrial Production Index	IPI		
General Price Index	General Price Index on A Monthly Basis	GPI	Istanbul Chamber of Commerce	
Unemployment	Monthly Unemployment Rate	UNP	Turkish Statistical Institute	
Export	Monthly export amount (USD)	EXP		
Import	Monthly Import amount (USD)	IMP		
Wage Growth	Net Minimum Wage on A Monthly Basis	WGH		
Government Budget Expenditure	Monthly Government Budget Expenditure	EXT	Ministry of Treasury and Finance of the Republic of Türkiye	
Government Budget Revenue	Monthly Government Budget Revenue	REV		

The selection of the variables in this study is guided by both economic theory and usefulness to budget forecasters. Inflation forecasting models tend to be founded on a combination of monetary policy indicators, labor market conditions, and real economic activity. To this degree, key macroeconomic determinants of inflation are included in the dataset to provide theoretical consistency and empirical robustness. The selection of these specific variables is not arbitrary but follows from both their demonstrated applicability to inflation dynamics and availability in the budget forecasting procedure. Because budget forecasters operate under time pressure and only utilize officially published data, the indicators selected represent the most relevant and realistically obtainable set of variables for inflation forecasts.

By incorporating key monetary, fiscal, and real sector variables, the study not only aims to maximize the realism of inflation forecasts but also to enable methodological comparability with economic theory. The choice of variables is consistent with conventional models of inflation, such as the Quantity Theory of Money, the Phillips Curve, and cost-push models of inflation, thereby complementing the empirical and theoretical foundations of the study. Moreover, this advanced

technique guarantees that the forecasting model remains applicable in a policy context, where institutional constraints and availability justify the use of economic forecasts.

This structural framework of forecasting enables budget forecasters to generate higher-accuracy forecasts from theoretically sound and empirically accessible variables. Therefore, the study enhances the accuracy and reliability of inflation forecasts, making them stronger in fiscal planning and decision-making in the economy.

4. Methodology

In the analysis, four forecasts of independent variables were made using the following methods: Holt-Winters, Prophet, ARIMA, SARIMA, and LSTM. Also, a mean of these methods was computed in order to create a forecast which is called the Hybrid model. All these forecasts were then incorporated for forecasting inflation in an ANN. To evaluate the robustness of the ANN model, its performance was compared with other ML techniques, including RF, SVR, and Gradient Boosting Machines. Various error indicators were applied to assess the accuracy of all models. The following sections provide a detailed explanation of these methods.

4.1. Holt-Winters

The Holt-Winters Method was developed by Holt (1957) and Winters (1960) to model trend and seasonal components in time series. In this method, separate smoothing coefficients are used for level, trend, and seasonality to generate forecasts. This method can be applied in two different model structures: additive and multiplicative. The multiplicative model is suitable for situations where seasonal fluctuations vary in proportion to the series' average level. Initial values are determined through regression analysis or decomposition techniques, while the optimal values of the α (level), β (trend), and γ (seasonality) coefficients are optimized to minimize the Mean Square Error (Erişoğlu and Erişoğlu, 2022).

4.2. Prophet

The Prophet method, developed by Facebook's Data Science Team, is an open-source ML model used for time-series forecasting. Unlike traditional time-series methods, Prophet performs well even with missing and outlier data. One of its key advantages is the curve-fitting technique that allows users to make forecasts with the help of Bayesian-based intuitive parameters (Kayran and Uzun Araz, 2023). The general equation of the Prophet is:

$$y(t) = g(t) + s(t) + h(t) + \varepsilon(t) \quad (1)$$

The core equation of the Prophet model comprises a trend function g(t), a seasonal component s(t), a holiday effect h(t), and an error term ε(t). Prophet's intuitive and user-friendly approach makes time-series analysis more accessible, enabling even users with limited statistical knowledge to perform effective forecasting (Taylor and Letham, 2018).

4.3. ARIMA

ARIMA model, introduced by Box and Jenkins (1976), is a widely used statistical method for time-series forecasting. ARIMA captures both AR and MA components while incorporating

differencing (I) to make a non-stationary series stationary. The model is denoted as ARIMA (p, d, q), where p represents the number of lagged observations in the AR component, d indicates the number of differencing operations applied to achieve stationarity, and q refers to the number of lagged forecast errors in the MA component. The general mathematical representation of an ARIMA model is:

$$\Phi_p(B)(1-B)^d y_t = \theta_q(B)\varepsilon_t \quad (2)$$

In equation B is the backshift operator, $\Phi_p(B)$ represents the AR polynomial, $\theta_q(B)$ denotes the MA polynomial, and ε_t is a white noise error term (Box and Jenkins, 1976). The optimal values for p, d, and q are typically selected using criteria such as the Akaike Information Criterion (AIC) to minimize forecast errors and improve model accuracy.

4.4. SARIMA

The SARIMA model is an advanced statistical model used for forecasting time-series data that exhibit seasonality. The SARIMA model, which is an extension of the ARIMA model developed by Box and Jenkins (1976), consists of seven parameters: The first three (p, d, q) represent the non-seasonal component of the trend, while the remaining four parameters (P, D, Q, s) define the seasonal component. Here, p represents the degree of AR term, d represents the degree of differencing, and q represents the degree of MA. Among the seasonal parameters, P represents the degree of seasonal AR, D represents the degree of seasonal differencing, Q represents the degree of seasonal MA, and s represents the number of steps in a seasonal cycle (Malki et al., 2022). The mathematical formula of the SARIMA model is:

$$f(B)\Phi(B^S)(1-B)^d(1-B^S)^D y_t = c + q(B)\Theta(B^S)\varepsilon_t \quad (3)$$

In the equation, $\Phi(B^S)$ represents the seasonal AR parameter, while $\Theta(B^S)$ denotes the seasonal MA parameter. For the model to be applied, the non-seasonal parameters p, d, q and the seasonal parameters P, D, Q along with the seasonal period s, must be specified. The most used metric for selecting the optimal SARIMA model is the AIC, which assesses the model's forecasting accuracy. The model with the lowest AIC value is considered to provide the best fit. The formula for AIC is as follows:

$$AIC = -2\log(L) + 2k \quad (4)$$

In the equation, k represents the total number of parameters estimated in the SARIMA model. L indicates the maximum likelihood function for the model. This criterion is an important measure used to increase the accuracy of the SARIMA model (Malki et al., 2022).

4.5. LSTM

LSTM is a type of Recurrent Neural Network (RNN) widely used in time-series forecasting. LSTM was developed to address the vanishing gradient problem commonly encountered by traditional RNNs, which can cause the model's learning process to slow down or even halt. By learning long-term dependencies, LSTMs overcome this challenge (Yadav et al., 2020). LSTM consists of three main gates. Input Gate: Determines whether the new input will be stored in memory; Forget Gate: Functions to discard irrelevant information and Output Gate:

Selects which information will be presented as output (Siami-Naimi et al., 2019). The fundamental computational formula of LSTM is as follows.

$$i_t = \sigma(W_i.[h_{t-1}, x_t] + b_i) \quad (5)$$

The output of the input gate is represented by i_t, and similarly, the input value is calculated using weights W_i and bias b_i. This gate determines which new information should be added to the cell state.

$$f_t = \sigma(W_f.[h_{t-1}, x_t] + b_f \quad (6)$$

Here, f_t is the output of the forget gate; W_f is the weight matrix; h_{t-1} is the previous cell state; x_t is the current input; and b_f is the bias value of the gate. This gate determines the extent to which previous information should be forgotten.

$$\widetilde{C_t} = \tanh(W_C.[h_{t-1}, x_t] + b_C \quad (7)$$

$$C_t = f_t * C_{t-1} + i_t * \widetilde{C_t} \quad (8)$$

The updated cell state C_t is determined by the effects of the outputs from the forget and input gates:

$$o_t = \sigma(W_o.[h_{t-1}, x_t] + b_o \quad (9)$$

The output gate controls which information from the cell state will be provided as output:

$$h_t = o_t * \tanh(C_t) \quad (10)$$

Here, h_t is found by multiplying o_t, the output of the output gate, with the value obtained from applying the hyperbolic tangent function to the cell state C_t. This value represents the current output of the LSTM cell and ranges between (-1) and (1). This multiplication reflects the cell state information in the output, allowing the model to capture long-term dependencies in temporal data for time-series forecasting (Song et al., 2020).

4.6. Hybrid

Research presented in scientific writings suggests that combining multiple models and taking their averages usually improves the overall forecasts made. Hansen et al. (2011) argued that according to the Model Confidence Set Technique, average forecasting values obtained from various models are likely to be more accurate than those of the best-performing model alone. Moreover, it has been shown that even in the case of short-term forecasting, the use of the simple average of the models in the confidence set results in a more accurate forecast. Heretofore, accuracy in forecasting can also be enriched through model dressing hence the combination of models yields different benefits (Garcia et al., 2017).

In this study, the average of the four methods mentioned above was computed, and this approach was named the hybrid model. The hybrid model combines the forecasts from Holt-Winters, Prophet, ARIMA, SARIMA, and LSTM models to get an overall forecast, thereby trying to take advantage of the strengths of each single method. It is based on the idea that combining many models results in more reliable outcomes than relying on a single model, especially in cases where complex patterns occur in data.

4.7. Artificial Neural Networks (ANN)

ANNs are models inspired by the information processing structure of the human brain, capable of extracting meaning from complex and nonlinear data. ANNs consist of artificial neurons and the connections between them, performing operations such as learning, classification, and clustering, based on the structure of nerve cells in the human brain (Zakaria et al., 2014). Each neuron calculates a net input using incoming data and weights. This net input is then processed through a linear or nonlinear activation function to produce an output. The weighting of the inputs determines the level of importance the neuron assigns to the data, while a bias value allows the network to learn even when the data is zero. The most common activation function, the sigmoid, transforms the input into a nonlinear output, enhancing the network's learning capacity (Haykin, 1998). In addition to the sigmoid function, other activation functions, such as linear, step, sine, threshold, and hyperbolic tangent, are also commonly used (Öztemel, 2006, 51). The formulas for net input and the sigmoid function are shown below.

$$NET = \sum_{i}^{n} (X_i W_i) \tag{11}$$

$$F(Net) = \frac{1}{1 + e^{-Net}} \tag{12}$$

The structure of an ANN consists of input, output, and hidden layers. The input layer receives raw data and passes it on to the hidden layer, which processes the data and transmits it to the output layer. In this structure, connections between neurons may be either feedforward or feedback. In feedforward networks, data flows unidirectionally from the input layer to the output layer, while in feedback networks, data can also be transmitted backward between layers. This characteristic makes feedback networks dynamic in nature (Jain et al., 1996).

ANNs can be classified based on their learning structure into supervised, unsupervised, and reinforcement learning models (Krenker et al., 2011). From the perspective of learning time, they are divided into online and offline learning. In online learning, the network continues the learning process during usage, whereas in offline learning, the network becomes ready for use after a training process. When new information is needed, the network must be retrained offline. The training of an ANN begins with determining the weight values, which are updated until the best result is achieved, allowing the network to generalize based on the examples presented to it. Various learning rules, such as Hebb, Hopfield, and Delta, aim to minimize the difference between the network's outputs and the expected outputs (Öztemel, 2003).

4.8. Random Forest (RF)

RF is a supervised learning algorithm based on an ensemble of multiple decision trees. The model constructs several independent decision trees by randomly sampling subsets of the data and features. For regression tasks, the final forecast is obtained by averaging the outputs of all individual trees, while in classification problems, the majority vote determines the final decision. RF is particularly effective in handling high-dimensional and complex datasets, reducing the risk of overfitting by aggregating multiple forecasts. Additionally, it can model nonlinear relationships between variables, making it a robust method for economic and time-series forecasting. The general mathematical formulation of the RF model is as follows (Breiman, 2001):

$$\hat{y} = \frac{1}{T}\sum_{t=1}^{T} f_t(x) \tag{13}$$

In the equation $\hat{y}$ represents the forecasted value, *T* is the total number of decision trees, and $f_t(x)$ denotes the forecast from each individual tree *t*. By leveraging multiple trees, RF improves forecasting accuracy and stability, making it a valuable tool for forecasting inflation.

4.9. Gradient Boosting Machines (GBM)

GBM is a powerful ensemble learning algorithm that builds a sequence of decision trees, where each tree corrects the errors of the previous one. Unlike RF, which constructs trees independently, GBM builds trees sequentially, optimizing for residual errors using gradient descent. This iterative approach enhances predictive accuracy while maintaining flexibility in capturing nonlinear relationships.

GBM is widely used in economic and financial forecasting due to its ability to handle complex data structures and improve forecasting accuracy. By assigning higher weights to misclassified observations, it effectively reduces bias and variance, making it suitable for time-series forecasting and macroeconomic modeling. The general mathematical formulation of the GBM regression model is as follows (Friedman, 2001):

$$\hat{y} = \sum_{t=1}^{T} \lambda f_t(x) \tag{14}$$

In the equation $\hat{y}$ represents the forecasted value, *T* is the total number of decision trees, and $f_t(x)$ denotes the forecast from each individual tree *t*, and λ is the learning rate, which controls the contribution of each tree. By sequentially minimizing forecasting errors, GBM offers superior forecasting accuracy, making it a valuable tool for inflation forecasting.

4.10. Support Vector Regression (SVR)

SVR is an ML algorithm based on SVMs, designed for regression tasks. Unlike traditional regression models, SVR aims to find a function that approximates the data within a given margin of tolerance, rather than minimizing the absolute error. This allows SVR to effectively handle high-dimensional and nonlinear relationships by mapping input data into a higher-dimensional space using kernel functions.

SVR is particularly useful for economic and financial forecasting due to its robustness in dealing with outliers and its ability to generalize well with unseen data. The model is trained by minimizing a loss function that ignores small deviations from the true values while penalizing larger errors. The mathematical formulation of SVR is as follows (Drucker, 1997):

$$\min_{w,b,\xi,\xi^*} \frac{1}{2}\left|\left|w\right|\right|^2 + C\sum_{i=1}^{n}(\xi_i + \xi_i^*) \tag{15}$$

$$\text{Subject to: } y_i - (w \cdot \phi(x_i) + b) \leq \epsilon + \xi_i$$
$$(w \cdot \phi(x_i) + b) - y_i \leq \epsilon + \xi_i^* \tag{16}$$
$$\xi_i, \xi_i^* \geq 0$$

In the equation w is the weight vector, b is the bias term, $\phi(x_i)$ is the kernel function mapping inputs into a higher-dimensional space, ϵ defines the margin of tolerance, ξ_i and ξ_i^* are slack variables allowing some observations to fall outside the margin, and C is a regularization parameter controlling the trade-off between model complexity and tolerance to deviations. By leveraging kernel functions and margin-based optimization, SVR provides accurate and stable forecasts, making it a valuable tool for inflation forecasting.

4.11. Error Indicators

In the study, various error indicators have been used to comparatively measure the accuracy of the forecasts. The equations for these indicators are presented in the table below.

$$MSE = \left(\frac{1}{n}\right) * \Sigma(y_i - \hat{y}_i)^2 \tag{17}$$

$$RMSE = \sqrt{\left[\left(\frac{1}{n}\right) * \Sigma(y_i - \hat{y}_i)^2\right]} \tag{18}$$

$$MAE = \left(\frac{1}{n}\right) * \Sigma|y_i - \hat{y}_i| \tag{19}$$

$$MPE = \left(\frac{1}{n}\right) * \Sigma\left[\frac{(y_i - \hat{y}_i)}{y_i}\right] * 100 \tag{20}$$

$$MAPE = \left(\frac{1}{n}\right) * \Sigma\left|\left[\frac{(y_i - \hat{y}_i)}{y_i}\right] * 100\right| \tag{21}$$

The Mean Squared Error (MSE) measures the average of the squared differences between the forecasted and actual values. This metric penalizes larger errors more significantly, as the differences are squared. A smaller MSE indicates better model accuracy, while a larger MSE suggests substantial forecasting errors. Despite its usefulness, MSE is sensitive to outliers due to the squaring of errors, which can disproportionately influence the overall error measurement.

The Root Mean Squared Error (RMSE) is the square root of the MSE and provides a more interpretable measure of error by returning the value to the same unit as the original data. RMSE gives a clear indication of the magnitude of the errors, making it easier to interpret the model's forecasting performance. Like MSE, RMSE is also sensitive to large errors. However, because the interpretation of the RMSE is in original units, it is more practical for model evaluation.

The Mean Absolute Error (MAE) designates the mean absolute deviation between forecasted and actual values. Unlike MSE, it does not overemphasize large errors but treats all differences equivalently. Hence, MAE is considered a more robust central tendency measure when data may include some outliers or if extreme fluctuations are to be granted less impact on the outcome.

The Mean Percentage Error (MPE) finds the average percentage error between forecasted and actual values. It's especially helpful for comparing model performance across datasets of varying scales. MPE gives a sense of the model's relative accuracy, but it has a drawback. When actual values are near zero, even small differences can cause unusually large percentage errors, which may lead to misleading results.

The Mean Absolute Percentage Error (MAPE) simply gives the average of absolute percentage errors. It's a common metric for evaluating the accuracy of forecasting models. MAPE is especially useful for comparisons across datasets. It standardizes errors, making it easier to compare across different scales. However, like MPE, it can be distorted by small actual values, leading to unusually high percentage errors.

5. Results

The work was carried out in four major stages. Each of the stages was carefully organized so that it would divide the research into smaller convenient sections. This allowed for a thorough investigation at every stage and deliberation and analysis of every component that was worth including in the end output. Dividing the study into stages is also aimed at enhancing clarity and coherence, supporting the transparency and reproducibility of the methodology. The process began with the first stage, focusing on forecasting the independent variables.

5.1. First Stage: Forecasting the Independent Variables

To achieve the primary objective of this study, producing the most accurate and realistic inflation forecasts using an ANN, it was first necessary to forecast the independent variables for the target period. In budget planning, forecasters forecast inflation before forecasting budget items for the upcoming year. However, since the inflation figure used in budget calculations is itself a forecast, there is inherent uncertainty in the process. To simulate this uncertainty and replicate the real-world approach of budget forecasters, this study first generated forecasts for key macroeconomic indicators using multiple methods. Specifically, four forecasting techniques, along with a hybrid model, were applied to forecast independent variables from October 2023 to December 2024. The accuracy of these forecasts was then assessed by comparing them with actual values, and the MAPE was reported in the Table 2. The most accurate forecasts, as determined by this evaluation, were subsequently used as inputs for the ANN, RF, SVR, and GBM models to forecast inflation over the same period. Detailed forecasts for all independent variables can be found in Appendix A (A1–A11), while the Table 2 presents a summary of their forecasting performance.

Table 2. Forecasting Results for Independent Variables (MAPEs)

Variable	Method					
	Holt-Winters	**LSTM**	**Prophet**	**ARIMA***	**SARIMA***	**Hybrid**
BSK	3,3629	49,6784	21,4465	**2,3292**	*	7,4363
UNP	8,9241	19,3377	33,0774	*	**5,5779**	15,5206
EXP	4,5372	6,3505	4,3334	*	**4,0806**	4,1576
IMP	**5,3338**	25,2906	6,3197	*	6,1771	6,9652
EXT	10,7095	11,9165	48,3201	*	**10,5830**	19,1495
REV	19,7634	22,8691	42,7335	*	**12,8751**	14,5103
INT	**4,5518**	65,4885	63,7742	*	8,1831	34,8151
IPI	4,0219	**1,9769**	8,1346	*	2,0298	3,3276
MSP	10,1985	6,7530	7,7572	7,3089	*	**2,0854**
GPI	4,9450	4,9190	10,7046	3,4645	*	**2,4949**
WGH	16,1155	17,6804	46,1207	**12,9457**	*	22,6539

Note: Bold values indicate the best MAPEs for each independent variable.
*The SARIMA model was used for seasonal, and the ARIMA model was used for non-seasonal data.

The outcomes shown in Table 2 prove to be insightful in assessing the independent variable capability for forecasting by different models. From the models critiqued, SARIMA came out best, as shown by the lowest MAPE values recorded on UNP, EXP, EXT, and REV, which suggests a superior ability to learn the latent trend alongside capturing short-term fluctuations of those significant macroeconomic indicators. Therefore, it can be said that SARIMA is indeed a very trustworthy forecasting tool based economic variables that follow the patterns of seasonality and cyclical behaviors of inflation modeling as well.

For this research, SARIMA's improved performance is particularly critical as the reliability of inflation forecasts largely depends on forecasting the independent variables with precision. Because UNP, EXP, EXT, and REV are among the determinants of inflation dynamics, accurate forecasts of these variables enhance the general efficiency of the process of forecasting inflation. By delivering improved input data, SARIMA indirectly helps ANN perform better by ensuring inflation forecasting is done based on more accurate macroeconomic forecasting, thus strengthening the validity of this research study.

In comparison, Prophet performs worst among the models in question, and it does not produce the best forecast for any of the variables. Prophet is highly flexible and can handle non-standard time series. et, its relatively larger error rates point to a lack of suitability in identifying the structural patterns of macroeconomic variables, which tend to be erratic due to policy interventions and external shocks. This result indicates that Prophet may not be appropriate for forecasting extremely volatile and policy-sensitive indicators.

Further, this result serves to highlight a key methodological point: despite the flexibility afforded by more recent ML methods like LSTM and Prophet, older statistical models like SARIMA may prove superior in particular macroeconomic contexts. That SARIMA performs so well in this analysis serves to illustrate the value of choosing the most suitable methodology based on the particular features of the data available as opposed to preferring newer or more complex methods. By doing so, this emphasizes the value of a hybrid approach, where classical econometric models can complement ML algorithms in achieving optimum forecasting performance.

Among the variables, IPI and MSP are forecast with the least errors. This implies that these variables have relatively stable and consistent patterns that can be easily modeled using statistical techniques. IPI is driven to a great extent by manufacturing cycles and economic activity, which have recognizable trends, and MSP is influenced by monetary policy decisions, which follow a systematic framework, thus being predictable.

Conversely, EXT, REV, and WGH are associated with the largest forecasting errors. The finding reflects the inherent uncertainty and complexity of fiscal policy and labor market variables which are subject to discretionary policy changes, political shocks, and political influences. Unlike monetary variables, which tend to follow a more structured adjustment process, government budget items and the labor market can experience sudden shifts due to policy interventions, collective bargaining agreements, or unexpected fiscal adjustments. These factors make them more challenging to forecast accurately, highlighting the need for specialized modeling approaches when dealing with such volatile economic indicators.

5.2. Second Stage: Forecasting Inflation

In this foundational stage of the study, which reflects the primary objective, monthly inflation forecasts were generated using the most accurate independent variable forecasts identified in Table 2. Specifically, the models that produced the lowest MAPE for each independent variable were selected, and their forecasts were used as inputs for the ANN model.

This study employs normalized values for all input variables, as required by the ANN model to ensure optimal performance and numerical stability. Given that ANN operates more effectively when input data are scaled within a consistent range, normalization was applied to prevent any variable from disproportionately influencing the forecasting process. To maintain comparability and consistency across models, the same normalization procedure was extended to the SVR, GBM, and RF models, ensuring that differences in forecasting accuracy stem from the models' inherent predictive capabilities rather than disparities in data scaling. Additionally, all error metrics presented in Table 3 were computed using normalized values to preserve the validity and integrity of model comparisons.

Based on both actual (January 2005 – September 2023) and forecasted independent variables (October 2023 – December 2024), the ANN model produced inflation forecasts for October 2023 – December 2024. The resulting inflation forecasts, along with some key error statistics, are presented in the Table 3.

Table 3. Forecasting Results for Inflation

Period	ANN	RF	GBM	SVR	Actual
October 2023	4,16	3,93	2,42	5,10	3,43
November 2023	3,94	3,99	2,47	5,20	3,28
December 2023	3,73	4,26	2,42	4,68	2,93
January 2024	3,31	4,30	2,44	4,71	6,70
February 2024	3,17	4,05	2,23	4,23	4,53
March 2024	3,30	5,30	4,15	4,01	3,16
April 2024	3,07	5,17	2,47	3,83	3,18
May 2024	2,73	5,31	2,48	4,11	3,37
June 2024	2,83	5,29	2,47	3,46	1,64
July 2024	2,84	4,40	2,48	3,77	3,23
August 2024	2,52	3,99	2,48	3,58	2,47
September 2024	2,48	4,08	2,48	3,31	2,97
October 2024	2,34	3,97	2,49	3,19	2,88
November 2024	2,67	3,91	2,49	3,17	2,24
December 2024	2,68	3,75	2,14	3,04	1,03
MSE	0,39	0,95	0,58	0,48	-
MAE	4,46	8,68	5,43	6,01	-
MAPE	12,74	27,2	14,61	18,47	-
RMSE	6,21	9,77	7,61	6,91	-
MPE	-1,44	-23,2	6,34	-15,31	-

Table 3 presents a comparative analysis that indicates that ANN possesses the lowest error rates in all the most important performance metrics, demonstrating its superior ability to forecast inflation with greater accuracy. As a model that can learn complex and nonlinear relationships, ANN significantly outperforms traditional ML methods in generating accurate monthly inflation forecasts. With a MAPE of 12.74%, ANN makes the most precise forecasts, significantly reducing forecasting errors that have a tendency to hinder budget planning. This improved performance is

due to ANN's ability to accurately represent complicated interdependencies between macroeconomic variables, allowing it to react to variations in economic conditions more effectively compared to conventional statistical techniques.

The high variation between ANN and other models is an indicator of its reliability in capturing inflationary dynamics with the least errors in forecasting. The short-term horizon of monthly inflation forecasting renders traditional models inadequate in responding to rapid movements caused by exchange rate fluctuations, changes in fiscal policy, or price shocks from individual industries. ANN's much lower rates of error indicate that it accurately integrates these volatile variables into its predictive model, making forecasts that more accurately depict actual inflation trends. The results in Table 3 suggest that ANN not only excels in overall precision but also is more stable over different time periods, minimizing extreme outliers present in other models. This stability is particularly valuable to budget forecasters, as even tiny variations in monthly inflation forecasts can compound over time to create astronomical fiscal mistakes.

The significantly higher error rates in the remaining models are an indication that the traditional ML methods have minimal efficacy when applied to inflation forecasting. On a notable note, the highest error rates are obtained from the RF model, with the highest MAPE and MSE of 27.2% and 0.95, respectively, which are extreme deviations from the truth. Likewise, SVR and GBM models are indicative of greater error compared to ANN, a pointer to the susceptibility of orthodox models to movements in multiple macroeconomic dimensions. These findings make the argument even stronger than traditional statistical as well as ML models in their failure to incorporate inflation determinant complexity as the explanation for their weaker forecasts.

On determinants of the inflation gap, the published error margins in Table 3 indicate that precision in forecasting inflation is highly sensitive to a combination of macroeconomic variables. Among the most prominent drivers of differences between forecasted and realized inflation are exchange rate volatility, public expenditure volatility, wage growth trends, and external trade deficits. In import-dependent economies, such as Türkiye, exchange rate volatility has a direct impact on inflation via import prices, widening the inflation gap. Similarly, surprise fiscal expansions or revenue shortfalls can exert upward pressure on inflation, reducing the forecasting accuracy of models.

Labor market conditions, namely employment and wage dynamics, also have a strong impact on the inflation gap. Growth in wages not accompanied by productivity growth can fuel cost-push inflation, generating forecast errors. ANN's lower rates of error mean that it is better able to capture the nonlinear relationship between these economic variables and hence it is a more reliable instrument for budget forecasters requiring accurate inflation forecasting.

Last, the findings in Table 3 highlight ANN's superior performance in forecasting inflation and its ability to more accurately model the determinants of the inflation gap. Accurate inflation forecasts are particularly crucial for budget forecasters, as inflation errors can undermine the credibility of public expenditure and revenue forecasts. The significantly lower error rates achieved by ANN suggest that its use in budget planning can lead to more informed and efficient fiscal decision-making.

5.3. Third Stage: Comparison of Forecasts

To measure how close the forecasts are, these must be compared to what is forecasted by the government and other institutions, typically on a year-to-year basis. For such a significant comparison, monthly forecasts from January to December 2024 obtained with the assistance of ANN added up to an annual forecast of inflation (39,75), thereby making them comparable to official statistics. This forecast was then compared to Türkiye's central government budget, Medium-Term Plan (MTP), Central Bank target, Central Bank Market Participant's Survey (MPS), IMF World Economic Outlook (WEO), OECD Economic Outlook (EO), and EU Economic Forecasts (EF).

Table 4. Comparison of Inflation Forecasts

Source	Forecast	Source	Forecast
2024 Budget	33	MTP 2023	13,8
Central Bank's Target	5	MPS September 2023	38,59
IMF WEO October 2023	62,50	OECD EO September 2023	39,20
EU EF November 2023	53,60	ANN Forecast	39,75
RF Forecast	68,79	GBM Forecast	35,49
SVR Forecast	54,61	Actual	44,38

Annual inflation forecasts in Table 4 are derived from the cumulative monthly forecasts of each model rather than simply adding the twelve monthly values. Using a cumulative method means that the annual forecast reflects the compounding aspect of inflation over time and provides a more accurate approximation of year-end inflation rates. By incorporating the interplay between adjacent months, such a method follows standard inflation forecasting practices used by financial institutions and policymakers. The forecasted inflation rates for the yearly periods hence offer a better benchmark against institutional and official forecasts.

A comparison of forecasts shows the ANN providing a 2024 inflation forecast of 39.75%, nearest to the OECD EO (39.20%) and the MPS (38.59%), although much higher than the government budget (33%) and the MTP (13.8%) forecast. The Central Bank target inflation (5%), as a longer-run policy objective than forecast over the near term, stands significantly lower than all other forecasts, indicating a divergence between policy goals and market forecasts.

Among the ML models, the ANN forecast is far closer to institutional forecasts compared to RF, GBM, and SVR. The RF model anticipates a 68.79% per annum inflation rate, which severely over-forecast actual inflationary trends, indicating its tendency to overfit short-term volatility. The GBM model (35.49%), on the other hand, under-forecast inflation compared to ANN but is still closer to market-based forecasts compared to RF. The SVR model (54.61%), while smaller than RF, still suggests a considerable deviation from actual inflation dynamics, demonstrating its limited potential in following long-run inflationary trends. Such divergences emphasize the superiority of ANN in making inflation forecasts that not only achieve greater accuracy but also follow more closely expert forecasts used in policy and budget planning.

The actual inflation rate of 44.38% for 2024 also confirms ANN's satisfactory performance because it remains within a correct margin of error from its forecast. Over-forecasting of RF's and SVR's and under-forecasting of GBM contrast with the issue of gaining sensitivity to economic shocks at the cost of long-run trend stability. ANN's ability to mimic inflation patterns

with minimal errors relative to real inflation reasserts its reliability as a forecasting instrument, particularly for budget forecasters who require forecasts grounded on macroeconomic reality rather than statistical or policy assumptions.

5.4. Fourth Stage: Forecasting 2025

The study was not solely designed for retrospective analysis but also to serve as a foundation for future academic research. To facilitate long-term comparisons and enable forecasting beyond realized data, forecasts for 2025 were generated. Once actual data becomes available, these forecasts can be evaluated for accuracy, providing a valuable reference for subsequent studies. As in the previous period, both independent variable and inflation forecasts were produced. The forecasts for independent variables are presented in Appendix B, while the primary focus, inflation forecasts, is detailed in the Table 5.

Table 5. 2025 Inflation Forecasts

Period	ANN Forecast	Period	ANN Forecast
January 2025	2,39	July 2025	4,04
February 2025	1,89	August 2025	1,47
March 2025	3,66	September 2025	1,77
April 2025	2,44	October 2025	1,83
May 2025	4,96	November 2025	1,36
June 2025	1,21	December 2025	0,87
2025 Cumulative Annual ANN Forecast		31,63	

Based on the ANN model, monthly inflation in 2025 was forecasted to fluctuate between 0,87 and 4,04 percent, with an annual rate of 19,74 percent. This forecast aligns with expectations, particularly considering the tight policy measures currently in place in Türkiye, which may lead to such an outcome in 2025. The differing inflation forecasts for 2025, recently mentioned by the Ministry of Treasury and Finance, the Central Bank Governor, and the President, highlight the prevailing uncertainty surrounding economic conditions. In this context, the approach may be somewhat challenging. However, while the primary aim is to provide a realistic inflation forecast for 2024, the 2025 forecast serves as a reference point for future studies. By analyzing potential deviations, researchers can further explore factors contributing to forecast errors and enhance the budget forecasting process for policymakers in Türkiye.

6. Discussion

This study was motivated by a practical need; providing a workable inflation forecast to budget forecasters. Unlike micro-economists who may pursue highly technical inflation forecasts, the objective was to equip fiscal planners with a realistic inflation forecast that aligns with the budget preparation period. Thus, the approach was tailored not for theoretical accuracy but for applicability within the constraints faced by budget planners.

The empirical findings of this study align with prior research that identifies ANNs as a highly effective model for inflation forecasting, particularly in capturing complex, nonlinear relationships and adapting to macroeconomic volatility better than traditional econometric

approaches (Choudhary and Haider, 2012; Haider and Hanif, 2008; Nakamura, 2005; Moshiri and Cameron, 2000; Barkan et al., 2023). ANN's ability to learn from data patterns without requiring strong parametric assumptions has been found to be one of its greatest strengths, enabling it to outperform conventional statistical models in the majority of economic applications. The improved forecasting ability of ANN in this study confirms these findings, particularly in the case of Türkiye, where inflation is highly sensitive to currency fluctuations, fiscal policy changes, and global economic conditions. By using these variables in its predictive model, ANN has proven to be a viable option as a more precise tool for inflation forecasting than other ML methods.

However, not all studies have named ANN the most precise forecasting method, as its performance could vary with the economic environment, data structure, and forecasting horizon. Sometimes econometric models have performed better with traditional econometric models that accurately captured time-dependent inflationary patterns, while others have worked better than ANN in terms of accuracy and stability (He et al., 2012; Almosova and Andresen, 2023; Araujo and Gaglianone, 2023; Ülke et al., 2018). These findings show that while ANN can offer considerable gains, its superior predictive abilities are not absolute, and its utilization needs to be properly assessed in light of some macroeconomic parameters as well as structures of data.

This study is superior to that in the literature which made fairly accurate forecasts using actual, observable independent variables. The technique used to construct the inflation forecast was grounded in all of the forecasted values of these independent variables. Thus, creating data that would realistically be available to those engaged in budgetary planning. This guarantees that the results are useful and designed for a particular purpose, which is budgetary planning, rather than achieving a perfect backward simulation based on past records. In developing a forecast based on expected values rather than measured outcomes, the study sought to replicate the inherent level of uncertainty that in reality, is always experienced by fiscal analysts.

In addition, the forecasts for 2025 were made by forecasting the independent variables as of that year and then forecasting inflation based on those variables. The purpose of this is that in the course of time, the model shall be evaluated using the forecast as well as its assessed performance as the basis of comparison and such advances will in turn help in improving the art of forecasting.

In the context of the wider literature, the findings contribute to the ongoing discussion on the efficacy of various forecasting methods for inflation and their subsequent impact on fiscal planning accuracy. While other studies have achieved high levels of accuracy through advanced ML techniques, their results often rely on realized data that would not yet be available during the budget preparation period. By contrast, this study’s approach, based on anticipated independent variables, highlights the trade-offs between forecasting accuracy and applicability, particularly in the context of the unpredictable economic climate in Türkiye.

The dataset and staged methodology further reinforce the study’s pragmatic design. By focusing on essential macroeconomic indicators, including the exchange rates, unemployment, exports, imports, expenditure, revenue, interest rate, wage growth, and production indexes, the study intentionally targeted variables that consistently appear in the preparation documents used by budget analysts in Türkiye. Each stage of the methodology was crafted to align with the real-world forecasting challenges faced by budget offices, bridging the gap between theoretical accuracy and practical utility. The comparative analysis revealed that the ANN model outperformed the government forecasts. The model produced results that are very close to real-

world inflation values. This outcome confirms the ANN model’s utility for budget planning under realistic data limitations.

Even though the findings of this study reconfirm the greater predictive ability of ANN, there is a need to acknowledge its strengths and weaknesses. The most important strength of ANN lies in its ability to capture complex, nonlinear relationships unhindered by pre-economic assumptions. This flexibility makes it possible for it to track inflationary patterns that would otherwise not be captured by traditional statistical models, and thus it proves to be particularly useful for economies that undergo frequent structural changes. Additionally, ANN is demonstrating greater flexibility to short-term economic shifts, allowing for more precise monthly inflation forecasts, which are critical for budget planning. Compared to the other ML models examined, ANN is more robust across different time horizons, with reduced susceptibility to extreme forecast errors.

That being noted, ANN also has its weaknesses. One of these is the fact that ANN is dependent upon large datasets and high computation, something that can be a burden for policymakers with limited access to high-frequency macroeconomic datasets. Another possible downpoint is ANN's low interpretability; while it performs well in making short-term foresight, it cannot be easily reverse-engineered or interpreted since every tweak in the weights and secret layers can turn out to be inscrutable. In contrast, traditional econometric models, while less accurate, are clearer and more theoretically coherent, and this might be desirable in certain policy contexts. Future research would need to explore the merging of ANN with hybrid approaches, accessing its predictive power while improving its explainability for practical policymaking applications.

7. Policy Recommendations

The research reveals the profound challenges the increasing inflation in Türkiye poses to fiscal planning as it derails revenue, tax, and expenditure forecasts among others. In the view of Kara (2024a), compounding the inflationary forecast errors in Türkiye, inflation affects the quality of budget forecasts. Empirical findings such as this demonstrate the necessity for the enhancements of inflation forecasting techniques as a safeguard for the viability of the budgetary process. To mitigate such challenges, it becomes imperative to identify and evaluate policy options that would improve forecasting and provide a buffer for fiscal planning against inflation risks. This part discusses risks posed by an inflationary environment on the fiscal planning process and suggests possible improvements in the forecasting processes to reduce such risks.

Practical Inflation Forecasts to Improve Budget Forecasting Precision: In forecasting inflation, the most important aspect is the forecasts that fund managers can realistically utilize within their budgeting timelines. Straightforward but credible forecasts of future inflation trends, such as the one generated by the ANN model, should take precedence over complex but sophisticated techniques. In this way, by constricting inflation forecasts to the relevant budget execution periods for budget analysts, fiscal institutions enhance the planning of revenue and expenditure.

Integrate Predictive Methods into Budget Forecasts to Reflect Real-World Constraints: Given that budget officers typically work with macro-level data rather than detailed microdata and often face a lag in the release of updated economic indicators, the use of forecasted values

for inflation determinants should be institutionalized. This approach provides budget analysts with a model of inflation that aligns more closely with the aggregated data available during the preparation process. Implementing such practices will promote forecasts that not only meet academic standards but also address the practical needs of policy formulation.

Regularly Update and Improve the Core Data Set for Inflation Forecasting: To enhance the robustness of inflation forecasts, policymakers should prioritize the consistent collection of macroeconomic data that most influence inflation, such as exchange rates, unemployment, exports, imports, expenditure, revenue, interest rate, wage growth, production indexes. Ensuring that this core data set remains up-to-date and accessible is essential for effective inflation forecasting.

Emphasizing Mid-Term Forecasting Accuracy for Greater Budget Credibility: Mid-term forecasts are very important for economic stability and fiscal planning. Therefore, budget institutions should prioritize models like ANN, which evidenced greater accuracy throughout multiple forecasting periods. Greater mid-term forecasting accuracy will ensure that the general public and investors will show confidence in fiscal policies, especially in tumultuous economic conditions.

Encourage the Use of Real-Time Data to Enhance the Development and Training of the Forecasting Models: To complement the intrinsic uncertainties in budget planning, fiscal authorities should accept models with effective results over forecasted values rather than relying on actual data only. This adaptation would result in forecasts reflecting real-time uncertainties; hence, more practicable in budget planning under changed economic conditions.

Encourage the Union of Economists with Budgetary Policy Analysts for New Methodology Development: Policymakers should facilitate partnerships between economists specializing in advanced forecasting techniques and budget analysts. This collaboration can give rise to innovation in developing inflation forecasts specifically for fiscal planning. The emergence of hybrid models which would be a balance between practical application and methodological rigor could also emanate from such partnerships.

Establish Criteria for Fiscal Forecasting Models: With the introduction of an evaluation criterion that evaluates forecasting methods in relation to their usefulness in the process of budget development, and the degree of the current country's uncertainties, the fiscal policymakers will be able to appreciate the merits and demerits of any given model. This will also help the policymakers with added refinements in making their forecasts, resulting in better fiscal policies and cushioning budgets against shocks.

Improvement in the Integration of Multinational and Market-Based Inflation Forecasts into Budgetary Processes: Given the accuracy that has so far been established in inflation forecasts provided by multinational organizations like the OECD and those market-based, such as MPS, enhancing their integration into budgetary processes could raise the standard of inflation forecasts within fiscal policy. External forecasts often use more complex econometric techniques and the most detailed real-time data available and, in many cases, may provide better information than internal forecasts. By using these reliable external forecasts as benchmarks or supplements, budget analysts can leverage their predictive accuracy and achieve a more neutral view when budgetary assumptions are developed. With such high-caliber forecasts of inflation embedded consistently, budget offices should be able to enhance their forecasting frameworks and thus have

more accurate budgetary anticipations, de facto tracking global economic patterns and market influences.

Embrace Uncertainty Projection for Budgetary Policy: Given the study's focus on the significance of forecasting with the pregnancy of some degree of uncertainty about the future, it is apparent that the intention is to act as a proxy of a real-life fiscal problem. In this context, fiscal institutions are suggested to incorporate predictive uncertainty as a form of strategy, and as a way to test the robustness of their budgets as well as prepare for any eventual fiscal slippage.

The recommendations hereinafter are aimed at helping fiscal policymakers and budget analysts to produce inflation forecasts that meet both the technical requirements and those specific demands imposed by the very process of practical budget preparation. In closer associating inflation forecasting methods with the needs of budget preparation, Türkiye can further enhance its fiscal frameworks and increase coherence in economic policy.

8. Conclusion

The critical role of inflation forecasting accuracy in attaining realistic budget revenue and expenditure forecasts was emphasized in this study. Government budgets play an indispensable role in ensuring economic stability and the sustainability of public spending, together with fiscal balance. Errors in inflation forecasts can undermine these objectives directly. A mis-forecasting of inflation certainly results in less reliable budget forecasts, which affect the efficiency of public expenditure, the accuracy of revenue forecasts, and the attainment of fiscal targets. In other words, proper inflation forecasting is of the essence in the budgetary planning process of the public sector.

In this context, an ANN model has been developed with the purpose of obtaining more realistic inflation forecasts. To begin with, eleven independent variables that underpin the inflation forecasts were forecasted. This was followed by the forecasting of inflation itself with the ANN, SVR, GBM, and RF models based on those variables. The forecasts are then compared with the forecasts made by the government and international organizations. Results showed that the ANN model's forecasts were better than the other forecasts.

These results are very useful to guide public institutions and budget preparers. They assist those seeking more realistic inflation forecasts in budget forecasting. The proposed methodology offers an alternative to improve forecast accuracy. It also serves as a useful reference for academic studies examining inflation's impact on public budgets. In high-inflation contexts like Türkiye, this approach could help achieve more reliable forecasts.

In conclusion, this study highlights the central role of inflation in budget forecasting. It demonstrates that ANN can achieve greater forecasting accuracy than traditional methods. This approach could help develop more realistic inflation forecasts. Such improvements would benefit both public budget planning and academic research.

Despite the strong empirical findings, this study has certain limitations that should be acknowledged. Initially, while the ANN model reveals better forecasting performance, its effectiveness relies on input data availability and quality. Errors or biases in the forecasted independent variables have the potential of spilling over into the terminal inflation forecasts with the possibility of affecting reliability. Second, even while the study has a severe approach, reliance

upon historical macro relationships is grounded upon the hypothesis of continuity in existing trends, and this may not always be present in the context of unanticipated economic crises or structural adjustments. Third, the black-box nature of ANN models represents a limitation on interpretation and, therefore, limits their immediate direct applicability for policy arguments, compared to classical econometric ones that give a clearer theoretical conceptualization.

Future research needs to explore hybrid approaches that blend ANN with more explainable models for the purpose of enhancing transparency and usability in policymaking environments. Furthermore, the incorporation of real-time macroeconomic and high-frequency financial data could make forecasting more effective by enabling models to better adapt to shifting economic patterns in real-time. Broadening the analysis to various countries with disparate inflation patterns would also provide significant insights into how ANN's forecast capability can be applied.

Declaration of Research and Publication Ethics
This study which does not require ethics committee approval and/or legal/specific permission complies with the research and publication ethics.

Researcher's Contribution Rate Statement
The authors declare that they have contributed equally to the article.

Declaration of Researcher's Conflict of Interest
There are no potential conflicts of interest in this study.

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Appendix A: October 2023 – December 2024 Forecasts for Independent Variables

Table A.1. Forecasts for Unemployment

	Holt-Winters	LSTM	Prophet	SARIMA	Hybrid	Actual
October 2023	9,1	9,3	11,3	8,9	9,6	8,2
November 2023	9,1	9,6	11,9	8,9	9,9	8,8
December 2023	9,7	9,9	12,8	9,4	10,4	8,9
January 2024	10,4	10,1	12,6	9,9	10,8	9
February 2024	10,6	10,3	12,0	9,9	10,7	8,7
March 2024	10,0	10,4	11,2	9,3	10,2	8,6
April 2024	9,3	10,5	10,4	8,8	9,7	8,6
May 2024	8,6	10,5	10,5	8,1	9,4	8,5
June 2024	8,6	10,5	11,2	8,0	9,6	9,2
July 2024	9,5	10,6	11,0	9,0	10,0	8,8
August 2024	9,0	10,6	11,2	8,5	9,8	8,6
September 2024	9,0	10,7	11,3	8,3	9,8	8,6
October 2024	9,1	10,8	11,3	8,3	9,9	8,7
November 2024	9,1	10,9	12,0	8,3	10,0	8,6
December 2024	9,7	10,9	12,8	8,8	10,6	8,5

Table A.2. Forecasts for Exchange Rate Basket

	Holt-Winters	LSTM	Prophet	ARIMA	Hybrid	Actual
October 2023	28,71	35,24	22,63	28,42	28,75	28,62
November 2023	29,50	37,14	23,77	29,08	29,87	29,76
December 2023	30,28	39,32	24,67	29,72	31,00	30,39
January 2024	31,06	41,66	25,21	30,36	32,07	31,45
February 2024	31,85	44,07	24,80	31,00	32,93	32,00
March 2024	32,63	46,49	25,02	31,64	33,95	33,41
April 2024	33,41	48,87	25,28	32,29	34,96	33,52
May 2024	34,20	51,16	26,13	32,93	36,10	33,54
June 2024	34,98	53,31	26,95	33,57	37,20	33,80
July 2024	35,76	55,29	27,42	34,21	38,17	34,27
August 2024	36,55	57,10	27,74	34,86	39,06	35,27
September 2024	37,33	58,71	27,06	35,50	39,65	35,87
October 2024	38,11	60,14	27,64	36,14	40,51	35,79
November 2024	38,90	61,39	28,43	36,78	41,38	35,50
December 2024	39,68	62,48	29,04	37,43	42,16	35,77

Table A.3. Forecasts for Export

	Holt-Winters	LSTM	Prophet	SARIMA	Hybrid	Actual
October 2023	21986	21813	22246	22073	22029	22367
November 2023	21882	22498	22146	22135	22165	22437
December 2023	21833	23505	22162	22366	22466	22614
January 2024	19656	20932	20493	20250	20333	20001
February 2024	20539	20673	21212	20747	20793	21091
March 2024	22498	24565	22966	23003	23258	22651
April 2024	21012	21217	21779	21340	21337	19295
May 2024	21030	22984	21932	21587	21883	24173
June 2024	21652	22229	22873	21777	22133	19016
July 2024	21110	21637	22183	21231	21540	22479
August 2024	21389	23246	21914	21499	22012	22007
September 2024	22479	23826	23089	22521	22979	21974
October 2024	22742	23962	23408	22982	23273	23485
November 2024	22638	24833	23583	22992	23511	22289
December 2024	22589	25918	23785	23097	23847	23463

Table A.4. Forecasts for Import

	Holt-Winters	LSTM	Prophet	SARIMA	Hybrid	Actual
October 2023	26320	24168	28307	26014	26202	27292
November 2023	27660	23341	28630	26185	26454	26849
December 2023	28897	22381	30104	27799	27295	27260
January 2024	26762	21531	28082	26414	25697	26187
February 2024	25699	20851	27873	25782	25051	27857
March 2024	27859	20440	30501	27638	26609	29952
April 2024	26269	20294	29426	26117	25527	29185
May 2024	28196	20247	30280	27951	26668	30649
June 2024	27359	20336	30973	26166	26209	24905
July 2024	29160	20354	30661	27787	26991	29783
August 2024	28622	20465	30377	26811	26568	27007
September 2024	29078	20453	30955	26487	26743	27116
October 2024	28443	20417	30386	26298	26386	29410
November 2024	29783	20389	31215	26800	27047	29748
December 2024	31020	20333	32499	28133	27996	32287

Table A.5. Forecasts for Government Budget Expenditure

	Holt-Winters	LSTM	Prophet	ARIMA	Hybrid	Actual
Oct. 2023	534435100	570482438	64749301	580072200	437434760	569210857
Nov. 2023	561878400	599218084	477133412	596213000	558610724	671182985
Dec. 2023	838667000	626707811	563404490	653732300	670627900	1392476506
Jan. 2024	648463100	663708335	617969071	632991400	640782977	767968295
Feb. 2024	711633700	684223762	355219372	699671100	612686983	689904673
Mar. 2024	722908300	712641677	394781158	693861800	631048234	692807231
Apr. 2024	757312800	733913904	416844138	747737900	663952186	773642510
May 2024	742003600	763071641	470540833	749309400	681231368	787727639
June 2024	759930900	785513766	407512613	808779500	690434195	866498264
July 2024	886065600	806153865	663823811	807877000	790980069	827705758
Aug. 2024	893324000	822347206	653074403	871478700	810056077	820314488
Sep. 2024	936636400	843946003	254487394	874076800	727286649	932067951
Oct. 2024	867425300	855964029	227838976	938301000	722382326	955478385
Nov. 2024	894687400	879433158	572928043	944659800	822927100	956105370
Dec. 2024	1312056000	901274246	542843451	1011528000	941925424	1706788225

Table A.6. Forecasts for Government Budget Revenue

	Holt-Winters	LSTM	Prophet	ARIMA	Hybrid	Actual
Oct. 2023	430261215	450089931	301063800	557930486	434836358	473750122
Nov. 2023	588076812	459091729	339884200	624104913	502789414	746809887
Dec. 2023	576142358	468273564	245357700	560344524	462529537	549944707
Jan. 2024	546288126	477639035	352157000	633809184	502473336	617249000
Feb. 2024	612941091	487191816	359189000	625179246	521125288	536107000
Mar. 2024	621409688	496935652	333700400	637573722	522404865	483842000
Apr. 2024	696980716	506874365	328230100	649321381	545351641	595813000
May 2024	883136833	517011853	576645400	823383160	700044311	1007136000
June 2024	777925665	527352090	348008400	675429806	582178990	591218000
July 2024	797975080	537899132	490253900	804554408	657670630	730930000
Aug. 2024	1113640519	548657114	634712500	901351261	799590349	690720000
Sep. 2024	799036092	559630256	450536900	806450065	653913328	831603497
Oct. 2024	868545629	570822862	378897200	877472089	673934445	769207199
Nov. 2024	1187119654	582239319	419241300	961009752	787402506	939459855
Dec. 2024	1163028201	593884105	298970400	917385410	743317029	877577463

Table A.7. Forecasts for Overnight Interest Rate

	Holt-Winters	LSTM	Prophet	SARIMA	Hybrid	Actual
October 2023	35,3	20,5	16,8	34,3	26,7	36,5
November 2023	38,8	22,1	16,3	37,1	28,6	41,5
December 2023	41,7	22,4	18	39,4	30,4	44
January 2024	44,1	22	17,5	41,5	31,3	46,5
February 2024	45,8	21,2	17,2	42,9	31,8	46,5
March 2024	47,2	20	17,9	44,3	32,4	53
April 2024	48,3	18,5	17,2	45,4	32,3	53
May 2024	49,2	17	16,3	46,3	32,2	53
June 2024	50,8	15,5	18,4	48,4	33,3	53
July 2024	51,6	14	18,4	49,3	33,3	53
August 2024	52,4	12,7	18,3	50,6	33,5	53
September 2024	53,1	11,5	18,4	51,8	33,7	53
October 2024	53,3	10,7	18,5	52,1	33,6	53
November 2024	53,6	10	18,9	52,7	33,8	53
December 2024	53,8	9,4	17,8	53,3	33,6	49

Table A.8. Forecasts for Industrial Production Index

	Holt-Winters	LSTM	Prophet	SARIMA	Hybrid	Actual
October 2023	108,11	105,44	112,81	107,30	108,41	106,90
November 2023	108,74	105,71	114,25	106,68	108,84	105,07
December 2023	109,28	105,94	113,64	106,68	108,88	107,28
January 2024	109,45	106,06	109,66	107,13	108,07	107,82
February 2024	109,72	106,07	111,56	105,96	108,33	110,45
March 2024	110,06	106,37	115,39	106,78	109,65	110,10
April 2024	108,47	106,34	114,79	106,60	109,05	104,63
May 2024	109,82	106,30	114,17	106,55	109,21	106,78
June 2024	111,09	106,20	115,16	106,22	109,67	104,28
July 2024	111,04	106,01	115,88	107,42	110,09	104,75
August 2024	112,36	105,86	116,24	106,66	110,28	103,11
September 2024	112,40	105,76	117,50	107,10	110,69	104,83
October 2024	112,93	105,68	118,45	106,52	110,89	103,98
November 2024	113,60	105,69	119,42	106,58	111,32	106,98
December 2024	114,15	105,68	119,38	106,36	111,39	112,34

Table A.9. Forecasts for Money Supply

	Holt-Winters	LSTM	Prophet	ARIMA	Hybrid	Actual
Oct. 2023	13187068605	12660259840	11315669401	13150388790	12578346659	13097974238
Nov. 2023	13733000074	13093295104	11752794069	13658437178	13059381606	13388504649
Dec. 2023	14302542507	13485339648	12532681133	14185019335	13626395656	14032110771
Jan. 2024	14896759050	13862022144	12807871693	14730769333	14074355555	14170572337
Feb. 2024	15516762547	14206865408	13319003640	15296341404	14584743250	14588406812
Mar. 2024	16163717947	14545294336	13721976445	15882410529	15078349814	14983979333
Apr. 2024	16838844827	14867467264	14260292507	16489673047	15614069411	15258074085
May 2024	17543420052	15149976576	14803532627	17118847268	16153944131	15763121325
June 2024	18278780552	15395716096	15335644304	17770674117	16695203767	16325989816
July 2024	19046326257	15667662848	15839022591	18445917779	17249732369	16989587529
Aug. 2024	19847523165	15799282688	16230129872	19145366374	17755575525	17675451244
Sep. 2024	20683906572	15895826432	16786991028	19869832642	18309139168	18037952952
Oct. 2024	21557084464	15980609536	17463790136	20620154649	18905409696	18490024940
Nov. 2024	22468741079	16324576256	17935801533	21397196508	19531578844	18871576626
Dec. 2024	23420640653	16643947520	19105243273	22201849123	20342920142	19499570053

Table A.10. Forecasts for General Price Index

	Holt-Winters	LSTM	Prophet	ARIMA	Hybrid	Actual
Oct. 2023	806680606	799744495	694266928	804296275	776247076	796787500
Nov. 2023	842670963	831018342	719826072	838382514	807974473	820206931
Dec. 2023	878661321	863515146	745456284	872468754	840025376	839128458
Jan. 2024	914651678	897282731	772899942	906554993	872847336	878460269
Feb. 2024	950642036	932370790	801353927	940641233	906251996	919256515
Mar. 2024	986632393	968830961	828919755	974727472	939777646	953993097
Apr. 2024	1022622751	1006716899	859436086	1008813712	974397362	1000407747
May 2024	1058613108	1046084360	890037269	1042899951	1009408672	1026356315
June 2024	1094603466	1086991277	922803615	1076986191	1045346137	1065901125
July 2024	1130593823	1129497851	955661070	1111072430	1081706294	1076998143
Aug. 2024	1166584181	1173666635	990843328	1145158670	1119063204	1087528686
Sep. 2024	1202574539	1219562631	1027320806	1179244910	1157175721	1138266482
Oct. 2024	1238564896	1267253381	1063899713	1213331149	1195762285	1139987269
Nov. 2024	1274555254	1316809068	1103066731	1247417389	1235462110	1170582455
Dec. 2024	1310545611	1368302620	1142342656	1281503628	1275673629	1180170768

Table A.11. Forecasts for Wage Growth

	Holt-Winters	LSTM	Prophet	ARIMA	Hybrid	Actual
October 2023	12016	10997,77	7452,96	11429,12	10473,96	11402,32
November 2023	12016	10997,77	7452,96	11429,12	10473,96	11402,32
December 2023	12016	10997,77	7452,96	11429,12	10473,96	11402,32
January 2024	13805,91	13395,36	8672,48	14260,80	12533,64	17002,12
February 2024	13805,91	13395,36	8672,48	14260,80	12533,64	17002,12
March 2024	13805,91	13395,36	8672,48	14260,80	12533,64	17002,12
April 2024	13805,91	13395,36	8672,48	14260,80	12533,64	17002,12
May 2024	13805,91	13395,36	8672,48	14260,80	12533,64	17002,12
June 2024	13805,91	13395,36	8672,48	14260,80	12533,64	17002,12
July 2024	13805,91	13395,36	8672,48	14260,80	12533,64	17002,12
August 2024	13805,91	13395,36	8672,48	14260,80	12533,64	17002,12
September 2024	13805,91	13395,36	8672,48	14260,80	12533,64	17002,12
October 2024	13805,91	13395,36	8672,48	14260,80	12533,64	17002,12
November 2024	13805,91	13395,36	8672,48	14260,80	12533,64	17002,12
December 2024	13805,91	13395,36	8672,48	14260,80	12533,64	17002,12

Appendix B: 2025 Forecasts for Independent Variables

Table B1. 2025 Forecasts for Independent Variables

	UNP	BSK	INT	GPI	IPI	WGH
Jan.	9,3	38,27	51,92	1190841385	103,24	21513,4
Feb.	9,4	38,90	51,33	1215440467	102,94	21513,4
Mar.	8,9	39,53	51,21	1244128209	102,60	21513,4
Apr.	8,4	40,15	50,70	1270991487	102,30	21513,4
May	8,0	40,78	50,26	1296710793	102,11	21513,4
June	8,1	41,41	50,66	1322696126	101,88	21513,4
July	8,5	42,04	50,53	1350042999	101,69	21513,4
Aug.	8,4	42,67	50,46	1376146855	101,49	21513,4
Sep.	8,2	43,30	50,44	1404879998	101,32	21513,4
Oct.	7,8	43,93	50,08	1428539693	101,11	21513,4
Nov.	8,1	44,56	49,89	1455637937	100,93	21513,4
Dec.	8,5	45,19	49,57	1483565084	100,75	21513,4
	EXP	**IMP**		**EXT**	**REV**	**M3**
Jan.	22049	27793		1162263618	868378087	20410235000
Feb.	23194	27121		1199726070	758235606	21131872500
Mar.	23772	29006		1235464261	923917646	21662997500
Apr.	21866	27438		1270269315	786268879	22499997500
May	23049	29171		1304517737	945020033	23311782500
June	21808	27549		1338463127	829378090	24240452500
July	23683	30275		1372242096	979055404	25127970000
Aug.	22298	29293		1405927471	854813494	26028495000
Sep.	24057	29483		1439560873	1015620656	26975942500
Oct.	25951	29554		1473165468	890088679	28108967500
Nov.	25447	30524		1506754023	1044503636	29173515000
Dec.	25030	31754		1540333657	923743754	30407545000

Ekonomi, Politika & Finans Araştırmaları Dergisi, 2025, 10(1): 92-106
Journal of Research in Economics, Politics & Finance, 2025, 10(1): 92-106
Araştırma Makalesi / Research Article, https://doi.org/10.30784/epfad.1588558

THE IMPACT OF CLIMATE CHANGE ON FINANCIAL PERFORMANCE OF THE ELECTRICITY INDUSTRY: THE CASE OF TÜRKİYE

İklim Değişikliğinin Elektrik Sektörünün Finansal Performansı Üzerindeki Etkileri: Türkiye Örneği

Çağdaş GÜNDÜZ*

Keywords:
Securities Markets, Financial Ratios, Climate Change, Electricity Industry

JEL Codes:
G10, G32, Q54, L94

Abstract

The world is encountering increasingly frequent and intense extreme weather events, driven by climate change. There is a strong scientific consensus that warns of an existential threat if greenhouse gas (GHG) emissions are not dramatically reduced and global temperatures kept under control soon. In this context, alternative energy technologies have become essential, as they can generate energy without adding to GHG emissions. Türkiye's electricity energy industry, as a core component of the country's economic stability and energy security, plays a major role in adapting to climate change. This study specifically focuses on listed electricity energy firms in Türkiye over the period from 2008 to 2022, investigating how climate change impacts their financial performance using panel data methodology. The empirical findings show that climate change has a significant and positive influence on financial outcomes, suggesting that adapting to climate pressures can benefit the industry financially. As a result, it is essential for the electricity power industry to incorporate climate-related strategies into their corporate agendas. However, technological innovations will mean little without large-scale public action, where local and national governments work together with international organizations and nations.

Anahtar Kelimeler:
Menkul Kıymetler Piyasaları, Finansal Oranlar, İklim Değişikliği, Elektrik Endüstrisi

JEL Kodları:
G10, G32, Q54, L94

Öz

Dünya, iklim değişikliğinin etkisiyle giderek daha sık ve şiddetli ekstrem hava olaylarıyla karşı karşıya kalmaktadır. Sera gazı emisyonlarının ciddi şekilde azaltılmaması ve küresel sıcaklıkların yakında kontrol altına alınmaması durumunda varoluşsal bir tehdit oluşturacağı konusunda güçlü bir bilimsel fikir birliği vardır. Bu bağlamda, sera gazı emisyonlarına yol açmadan enerji üretebilen alternatif enerji teknolojileri hayati önem kazanmıştır. Türkiye'nin ekonomik istikrarı ve enerji güvenliğinin temel bir unsuru olan elektrik enerjisi sektörü, iklim değişikliğine uyum sağlamada büyük bir rol oynamaktadır. Bu çalışma, 2008-2022 döneminde Türkiye'deki halka açık elektrik enerjisi firmalarına odaklanarak iklim değişikliğinin bu firmaların finansal performansını nasıl etkilediğini panel veri metodolojisi ile incelemektedir. Ampirik bulgular, iklim değişikliğinin finansal sonuçlar üzerinde anlamlı ve olumlu bir etkiye sahip olduğunu, iklim baskılarına uyum sağlamanın sektör için finansal olarak fayda sağlayabileceğini göstermektedir. Sonuç olarak, elektrik enerjisi sektörünün iklimle ilgili stratejileri kurumsal gündemlerine dahil etmesi gereklidir. Ancak, teknolojik yenilikler geniş çaplı bir kamu eylemi olmadan yeterli olmayacaktır; bu noktada yerel ve ulusal hükümetlerin uluslararası kuruluşlar ve diğer ülkelerle iş birliği içinde çalışması önemlidir.

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Received Date (Makale Geliş Tarihi): 20.11.2024 Accepted Date (Makale Kabul Tarihi): 16.01.2025

1. Introduction

Many industries, such as energy, logistics, and aviation, operate under dynamic conditions largely shaped by external developments and stakeholder expectations, both physical and social. Consequently, the business world views climate change as a phenomenon with substantial financial and strategic impacts on its activities.

The Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2023) states that approximately 3.5 billion people reside in areas that are particularly vulnerable to the impacts of climate change. Climate change leads to massively negative impacts and associated losses for both nature and humans, with these effects being unevenly distributed across various systems, regions, and industries. Economic harm from climate change has been observed specifically in industries vulnerable to climate shifts, such as agriculture, forestry, fishing, energy, and tourism which seriously affects productive activities. Furthermore, the effects of extreme climate risks may consume available economic resources to mitigate it. Looking at the statistics of the last research by the World Economic Forum (WEF, 2024), climate change topics (extreme weather events, natural resource shortages) are selected as the top global risks over a 10-year period. Adaptation efforts stand behind at the intensity of climate change-related events while countries are grappling with the impacts of record-breaking climate change-related issues. If the global community does not commit to more proactive climate change control measures and provide support to poorer nations in managing its effects, world GDP will decrease by 4% in 2050 (S&P Global, 2022).

Every year, 1.3 billion tons of food waste, 300 million tons of plastic waste and 50 million tons of electronic waste are among the main factors causing climate change. Also, this causes a rise in GHG emissions. 60 billion tons of resources transferred to the economy become waste and trigger the climate crisis (DCube Döngüsel Ekonomi Kooperatifi, 2020). On the other hand, the dependence on a constant flow of resources exposes national economies to fluctuating commodity prices and economic shock waves. High volatility in resource price levels increases uncertainty, discourages firms from investing, and increases the cost of protecting against resource-related risks (Ellen MacArthur Foundation, 2016). All of these factors will negatively impact economic growth, leading to economic losses that could reach nearly $8 trillion by 2050 (Qing et al., 2024).

The global electricity power system is influenced too much by climate change because it is highly sensitive and vulnerable to climate change effects (Vafadarnikjoo et al., 2022). The design, generation, demand, and allocation of electricity energy supply become more crucial due to climate change influences on this system (Perera et al., 2020). Some key climate change events impact various parts of the world. Extreme weather events such as Hurricane Katrina in the U.S. and Typhoon Haiyan in the Philippines, extreme heat in big cities like New Delhi and Paris, droughts in regions like sub-Saharan Africa, California, wildfires in places like Australia and the Amazon rainforest, climate-induced migration in places like Bangladesh and parts of Africa will also change conditions of demand, generation, and allocation of energy assets.

In terms of Türkiye, extreme climate change events are putting raising pressure on her infrastructure, ecosystems, and economy. For instance, coastal cities like Istanbul, Izmir, and Antalya are at risk of flooding due to rising sea levels. More frequent and severe heatwaves in Istanbul, Ankara, and İzmir lead to energy demands for cooling. Çukurova, Konya, and Söke plains, Southeastern Anatolia, and other agricultural parts of Türkiye have been facing prolonged droughts impacting agricultural productivity. In recent years, forest fires that occurred in regions

in the southern and western parts of the country have been causing economic and environmental damage. All of these events have been putting strain on energy production and significant disruptions in the power system. According to the World Bank (2022) geographical, climatic, and socioeconomic conditions in Türkiye make the country highly vulnerable to the effects of climate change hazards. They highlight the need for enhanced resilience and reliability in Türkiye's power system, indicating that the adaptation of the energy market to climate change still requires large public and private investments.

Besides, apart from physical risks including heatwaves, droughts, forest fires, and floods, there are also transitional climate change risks. Transitional risks can affect the market. The electricity power industry has significant potential for reducing emissions and is one of the key points for struggling against climate change. According to the Republic of Türkiye Ministry of Energy and Natural Resources (2024) data, nearly 60% of Türkiye's electricity generation will be obtained from renewable energy sources in 2023. The promotion of low-carbon policies has been causing the growth of renewable energy generation. Moreover, these policies will drive up production costs in carbon-intensive industries, then temporarily lower the market competitiveness of these firms. When looking at statistics, emissions related to the energy industry have the largest share with 72% among other industries according to the Turkish Statistical Institute (2024) in 2022. To survive into the green transition, non-renewable industries must boost technological innovation investment and enhance the efficiency of energy system (Sun et al., 2023).

Climate change and reducing its effects are on the agenda of many countries. Obviously, in order to solve this problem, it is necessary to invest in clean and renewable energy sources (Gençyürek and Ekinci, 2021). When the cost of such an investment is considered, unfortunately, it leaves a question mark in minds about how eager developed countries are to make these investments in struggling against climate change or how sincere they are in reducing the use of coal and fossil fuels.

Previous research (Durmuşkaya, 2016; Heyes et al., 2016; Pagnottoni et al., 2022; Dang et al., 2023) about the effects of climate change performance on financial performance has massively focused on the macro level, such as examining the physical impacts of hotter temperatures, air pollution, and natural disasters. Studies (Huang and Song, 2006; Dhaliwal et al., 2011) about the financial performance of the electricity industry have primarily concentrated on factors like corporate capital management, capital structure, and social responsibility. However, as an external factor, climate change performance role has received less attention. In this context, this paper centers on publicly listed electricity firms in Türkiye from 2008 to 2022, exploring the impact of climate change performance on their financial performance through panel data analysis. Accordingly, the potential contributions of this paper encompass three key aspects. Firstly, the paper examines how climate change performance affects the publicly listed electricity power firms' financial performance in Türkiye's securities market. Secondly, this study systematically analyzes the positive and negative impacts of climate change performance on corporate financial performance using both firm-level and country-level data. Finally, it develops a methodology including a range of climate performance data, containing GHG emissions, renewable energy, energy use and climate policy, to analyze their composed impacts on electricity power firms' operations.

The introduction part of the paper is followed by a review of the relevant literature. Third section clarifies the data and the methodology. Section four presents the empirical findings and discussions; and the final section is the conclusion part including policy recommendations.

2. Literature Review

Many studies in the field of finance show that climate change can directly and indirectly affect the financial health of both climate-sensitive industries, like energy, agriculture mining, forestry, fishing, and non-climate-sensitive industries (for instance; service and insurance) (Liu et al., 2020). These effects can cause various changes. Studies have shown that exposure to climate change risks leads to serious economic, social, and physical losses (Campiglio et al., 2018; Pagnottoni et al., 2022).

Climate change impacts on specific industries, such as the energy industry, have garnered widespread attention. Electricity generation is widely recognized as sensitive to climate change risks due to its reliance on temperature variations and weather conditions. (Sun et al., 2023). These kinds of events can disrupt the operations of electric power firms by damaging infrastructure, reducing efficiency, and increasing operational expenses resulting in potential revenue losses. Consequently, climate change events are expected to negatively affect the financial performance of electricity power firms. Some scholars have searched the link between climate change events and the financial performance of electricity energy firms in terms of multiple perspectives, including corporate social responsibility, environmental regulation, corporate capital structure, capital management, electricity supply, and demand. Few studies have been focused on financial performance. Heyes et al. (2016), compared daily data from the S&P 500 with air quality readings from U.S. Environmental Protection Agency (EPA) sensors near Wall Street. They found a correlation between high air pollution and lower stock values, with each standard deviation decrease in air quality leading to a 12% drop in stock returns. In other words, over 100 trading days, S&P 500 performance was 15% worse on the 25th most polluted day compared to the 75th cleanest day. They also observed this effect when analyzing data from the New York Stock Exchange and Nasdaq. Fan et al. (2019), examined the sensitivity of electricity demand to climate change events by panel data method for 22 years. The paper finds that climate change conditions positively impact per capita electricity demand. As climate change intensifies in the future, electricity demand is expected to rise, particularly to accommodate the increasing need for cooling. Without the implementation of effective climate policies, more energy will be consumed to manage this growing cooling demand. To Van Ruijven et al. (2019), future energy demand is projected to rise due to climate change, with the increase ranging from 11% to 58% by 2050, depending on the severity of warming and socioeconomic scenarios. The greatest increases in energy demand are expected in tropical regions and parts of the USA, Europe, and China, while socioeconomic factors will strongly influence the extent of this impact, particularly for low-income populations. Li et al. (2016), focus on electric power generation expansion planning while considering the uncertainties of climate change. They develop a preliminary model using data from various sources and define discrete climate scenarios to optimize planning decisions under uncertainty. Two optimization models, one minimizing total expected cost and the other minimizing maximum regret, are proposed to find robust solutions that work across all climate scenarios, helping policymakers avoid the risks of relying on a single forecast. Yu et al. (2020), examine optimal investment strategies for Chinese power enterprises in light of the nationwide

carbon emissions trading market. Their study suggests that, while short-term investments in clean technology should be prioritized over large-scale green energy installations to improve profits and manage carbon emissions, long-term investments in green energy will help mitigate the rising costs of carbon trading.

In this study, climate change impacts on the electricity energy industry are mostly from both macro and corporate levels to explore the effect of changes in macro and corporate policies on the operation of electricity energy firms. A study exploring the impact of air pollution on stock returns at Borsa İstanbul (BIST) during the period from February 1, 2007 to July 20, 2016 shows that air pollution significantly and negatively affects BIST Services Index returns, while it has a delayed effect on the returns of BIST-100, BIST Industrial, and BIST Financial Indices (Eyüboğlu and Eyüboğlu, 2018). Güngör and Küçün (2019), discuss the trading volume and trading size in BIST 100 Index and weather conditions between February 2011 and September 2015. The findings show that there is a significant difference between the averages of trading volume and trading size in terms of weather conditions in the classification as sunny, cloudy, rainy and snowy.

Hong et al. (2019), explore climate change impacts, particularly rising global temperatures and increasing drought risks, on food stock prices. Researchers analyzed publicly traded food companies' data from 31 countries. Then, they ranked data based on long-term drought trends via the Palmer Drought Severity Index. They explored that countries with worsening drought trends tend to experience lower growth in profit and poorer stock returns. This suggests that stock prices are not fully accounting for the risks posed by climate change, leading to predictable underperformance in countries more vulnerable to drought. The mining industry is highly exposed to climate change risks, which impact corporate financial performance both directly and indirectly. An analysis of China's 75 listed mining firms from 1995 to 2017 shows that climate risks affect financial outcomes, with varying sensitivity based on resource types. To mitigate these risks, mining firms should adopt low-carbon strategies, and increase transparency in emissions reporting to strengthen brand value and long-term competitiveness (Sun et al., 2020). Another study analyzes the impact of temperature changes on Chinese-listed manufacturing companies, finding that higher temperatures decrease financial performance importantly, while other seasons have no notable effect. Extreme temperatures, both below -12°C and above 27°C, negatively affect corporate financial outcomes, primarily by reducing labor productivity and increasing adaptation costs (He et al., 2021). Pagnottoni et al. (2022) conducted a statistical analysis of how natural disasters and global climate change affect international stock markets. Using an event study methodology, the study examines the impact of various disasters (meteorological, biological, geophysical, climatological, hydrological) in 104 countries on 27 stock market indexes between 2001 and 2019. The results reveal that stock market reactions vary by disaster type and location, with climatological and biological events causing the most significant market responses, particularly in Europe. The study also develops a hedging strategy to explore investment opportunities related to natural disaster risk mitigation. Sun et al. (2023) searched climate change risk impact on the financial performance of Chinese electricity energy firms and find a significant and positive correlation. While rainfall and drought indices improve financial performance, cryogenic freezing disasters negatively affect it by causing regional power system breakdowns. To them, in order to enhance adaptability, power firms should integrate climate risks into their management frameworks, and optimize energy sources, and governments should support this transition with green financial tools.

3. Research Methodology

3.1. Variable Selection

Evaluating the performance of firms correctly is crucial when making investment decisions in the financial world. There are many indicators used for evaluation. To show climate change performance impacts on financial health, this paper consults the existing literature to select Tobin's Q (Lo and Sheu, 2007; Ziegler, 2012), earnings per share (EPS) (Sun et al., 2023), and return on assets (ROA) (Vena et al., 2020; Sun et al., 2020) as corporate financial performance indicators. These indicators play a guiding role to evaluate the financial health of firms in the literature. Among these, EPS and ROA are solely derived from the firm's financial data and may not completely capture the long-term performance.

While both EPS and ROA are important financial metrics that help an investor to understand the firm's overall financial health, Tobin's Q reflects the market value of a firm (Lindenberg and Ross, 1981; Chung and Pruitt, 1994; He et al., 2021). The market value of a firm is actually influenced by its current financial position, which aligns with the information reflected in metrics like EPS and ROA (Sami and Zhou, 2004). Moreover, the market value of a firm signifies the present value of its anticipated future profits, reflecting not only its future profitability but also adjustments for risk (Brealey et al., 2007; Rabier, 2017). Since it can provide more comprehensive information about financial condition, this paper chooses Tobin's Q as another measure of corporate financial performance.

To test the impacts of climate change performance on the financial performance of Türkiye's listed electric power firms, Climate Change Performance (CCP) is selected as the independent variable. Considering that climatic factors are linked to climate change and play a significant role in influencing the output of firms, the study combines these factors such as renewable energy, GHG emissions, climate policy, and energy use under a single heading as CCP in the research model.

The financial health of firms may also be affected by other different indicators. According to existing research, the study uses two kinds of control variables. The first kind of control variable is the micro-level corporate financial indicators. The second one is macro-level control variables. Therefore, the study refers to He et al. (2021) and Sun et al. (2023) for controlling the micro-level variables such as firm size (SIZE), internal rate of return (IRR), asset-liability ratio (LEV), fixed asset ratio (FIX), and macro-level variables such as per capita GDP (LnPGDP), foreign investments (INV) in the research model.

3.2. Data Source

The study focuses on publicly listed electricity power firms from the "Electricity, Gas and Water" industry on the BIST stock market between 2008 and 2022 as the research subjects. Financial data at the firm level is sourced from their financial statements, while macroeconomic data is obtained from the International Monetary Fund (2023) database.

The data on climate change performance in the paper is from the annual Climate Change Performance Index (Burck et al., 2022). Index data covers four categories defining the overall score, which collects GHG emissions, renewable energy, energy use, and climate policy data.

This study gathers financial data of firms from their financials. After removing missing data and outliers, the final dataset consists of 31 firms and 465 observations. To remove the impact of outliers for the firm-level data, the paper eliminates samples that have a large number of missing observations. A description of all variables is shown in Table 1 below.

Table 1. Definitions of Variables

Type	Name	Code	Description
Dependent Variables	Earnings Per Share	EPS	Net Profit/Capitalization
	Return on Assets	ROA	Net Profit/Average Total Assets
	Tobin's Q	Tobin's Q	(Total Debts+Market Value)/Total Assets
Independent Variable	Climate Change Performance	CCP	The yearly indices of four climatic factors which are weighted average
Micro-Level Control Variables	Firm Size	SIZE	Asset growth rate
	Internal Rate of Return	IRR	Growth in operating income
	Asset-liability Ratio	LEV	Liabilities/Total Assets
	Fixed Asset Ratio	FIX	Fixed Assets/Total Assets
Macro-Level Control Variables	Per Capita GDP	Ln PGDP	Logarithm of (GDP/Population)
	Foreign Investments	INV	Percent of GDP

3.3. Model Setting

In this study, CCP is used as the independent variable, while financial performance, measured by EPS, ROA, and Tobin's Q, serves as the dependent variable for analyzing the correlation between climate change performance and financial performance by establishing a panel data model. Since the analysis involved time series (T) data for a large number of firms, panel data analysis, which combines cross-sectional (N) and time series analyses, was chosen as the econometric method in the study. In this method, it is generally observed that the number of cross-sectional units exceeds the number of time periods, leading to a situation where N>T (Tatoğlu, 2016). The study constructs the following models by referring to Chen and Yang (2019):

$$EPS_{it} = \alpha_0 + \alpha_1 CCP_{it} + \alpha_2 Control_{it} + u_i + \vartheta_i + \varepsilon_{it} \quad (1)$$

$$ROA_{it} = \beta_0 + \beta_1 CCP_{it} + \beta_2 Control_{it} + u_i + \vartheta_i + \varepsilon_{it} \quad (2)$$

$$TobinQ_{it} = \gamma_0 + \gamma_1 CCP_{it} + \gamma_2 Control_{it} + u_i + \vartheta_i + \varepsilon_{it} \quad (3)$$

where EPS_{it}, ROA_{it} and $TobinQ_{it}$ represent the corporate financial performance of firm *i* in year *t*. $Control_{it}$ denotes the control variable for firm *i* in year *t*, encompassing micro-level characteristics and macro-level factors. To avoid excluding non-time-varying unobservable factors and to avoid biased estimates resulting from time trends, the study controls the time-invariant firm fixed effects (u_i) and the year fixed effects (ϑ_i). ε_{it} is an error term. Additionally, to address issues of heteroscedasticity and autocorrelation, the study employs firm-level clustered robust standard errors.

At the start of the analyses, this study applies the F-test and the Hausman test to choose between the classical, fixed-effects, and random-effects models. Then, a series of specification tests are conducted to examine the potential presence of issues frequently encountered in panel regression models, such as heteroskedasticity, autocorrelation, and cross-sectional dependency. The paper executes Breusch-Pagan (1980) / Cook-Weisberg (1983), Levene (1960), Brown and Forsythe (1974) tests for heteroskedasticity in the estimated models, then it applies the Durbin Watson (DW) test of Bhargava et al. (1982), the Locally Best Invariant (LBI) test of Baltagi-Wu

(1999) and Wooldridge (2002) tests for autocorrelation. However, since the dataset used in the paper is unbalanced, cross-sectional dependency tests could not be conducted. The results of the heteroskedasticity and autocorrelation tests are presented in Table 2. The study used Stata 14 in order to estimate the panel data model.

4. Empirical Findings and Discussion

In panel data models, the validity of the classical model, in other words, the presence of unit and/or time effects, can be determined using the F-test. It is generally examined whether the data varies across units in this test. If the data does not differ across units, the classical model is deemed appropriate. In the F-test, the hypothesis ($H_0: \mu_i = 0$) that all unit effects are equal to zero is tested. Therefore, F-test was first conducted to make a choice between the classical model and the fixed-effects/random-effects model in the study. Then the Hausman test was used to make a decision between the fixed-effects model and the random-effects model. Table 2 reports the regression results.

Table 2. Regression Results of Climate Change Performance on EPS, ROA and Tobin's Q

		EPS (1)	ROA (2)	Tobin's Q (3)
F-test	Prob > F	0.0035	0.5141/0.2939	0.0000
LM Test	Prob>chi2	0.0028	-	-
Hausman Test	Prob>chi2	0.7867	-	0.0216
Heteroskedasticity	W0	0.0000	-	0.0000
	W50	0.0445	-	0.0000
	W10	0.000	-	0.0000
	Breusch-Pagan / Cook-Weisberg	-	0.0001	-
Autocorrelation Tests	DW	1.3555	-	1.0387
	LBI	1.9943	-	1.6461
	Wooldridge	-	0.0005	-

Note: Significance at the 5% confidence level.

Based on the results presented in Table 2, the null hypothesis (H_0) that all unit effects are equal to zero is rejected for models (1) and (3), indicating the presence of unit effects. Therefore, the classical model is not suitable for these models. For model (2), however, the null hypothesis (H_0) that unit and time effects are equal to zero cannot be rejected, indicating that these effects are insignificant. F-test statistics are calculated at 0.5141 for unit effects and 0.2939 for time effects which means the classical estimator is appropriate for only this model. Breusch-Pagan (1980), developed the Lagrange Multiplier (LM) test, based on the residuals of the classical model, to test the suitability of the classical model against the random effects model (Tatoğlu, 2016). In this test, the hypothesis ($H_0: \sigma_\mu^2 = 0$) that the variance of the random unit effects is zero is tested. In this test statistic, if the null hypothesis (H_0) is rejected, it is concluded that the classical model is not suitable. Baltagi and Li (1990) extended the Breusch-Pagan test for unbalanced panels. Based on all the test results, the null hypothesis (H_0) is rejected. The variance of the unit effects is different from zero, meaning the presence of unit effects is accepted. Therefore, it is concluded that the classical estimator is not convenient for model (1). In other words, the baseline regression utilizes the random-effects model.

As a result of the tests, if unit and/or time effects are found to be present, it is necessary to determine whether these effects are fixed or random. In the study, the Hausman test was used to decide between these estimators. The Hausman test, used to test the null hypothesis "the random effects model is appropriate" against the fixed effects model, provides the following values based on the results 0.7867 for model (1) and 0.0216 for model (3). As a result of the tests, for model 1, since the null hypothesis was accepted, it is concluded that the random effects estimator is valid. For model 3, since the null hypothesis was rejected, it is concluded that the fixed effects estimator is valid. Thus, the first model was estimated using the random effects estimator, while the third model was estimated using the fixed effects estimator.

To test for heteroskedasticity, this study applied the Levene (1960) and Brown and Forsythe (1974) tests (W0, W50, and W10) for models (1) and (3), Breusch-Pagan (1980) / Cook-Weisberg (1983) tests for model (2). The null hypothesis (H0), which states "the variances of the units are equal" is rejected for the research models, indicating that there is heteroskedasticity in these models.

According to the findings in Table 2, since the LBI and DW test statistics are less than 2, it can be understood that there is autocorrelation in the models (1) and (3). For model (2), the paper applied Wooldridge (2002) test and decided that there is autocorrelation.

Multicollinearity refers to the situation where two or more predictor variables exhibit a high degree of linear relationship with each other. Even if no pair of variables has an exceptionally high correlation, it is still possible for a linear relationship to exist among three or more variables. This phenomenon is called multicollinearity. It occurs when the explanatory variables influence not only the dependent variable but also each other. The degree of this effect can reduce the predictive power of the explanatory variables in the model. A better way to assess multicollinearity is by calculating the variance inflation factor (VIF). In practice, there is typically a small degree of linearity among the predictors. As a general rule, while VIF value above 5 suggests problematic multicollinearity, above 10 suggests highly problematic multicollinearity (Roso et al., 2005; James et al., 2013). To test for multicollinearity in the paper, VIF values are calculated and presented in Table 3.

Table 3. VIF Values

Variable	EPS (1)	ROA (2)	Tobin's Q (3)
CCP	1.88	1.81	1.81
SIZE	1.33	1.31	1.30
IRR	1.14	1.10	1.10
LEV	1.25	1.21	1.19
FIX	1.18	1.12	1.10
LnPGDP	3.64	2.92	2.97
INV	4.19	3.22	3.28

As can be seen from Table 3, VIF values are within acceptable limits. Therefore, it is decided that there is no multicollinearity in the models. Since autocorrelation and heteroskedasticity were detected in the research models, they were re-estimated using the robust Huber (1967), Eicker (1967), and White (1980) estimator.

To determine whether climate change performance is important for the financial performance of listed electricity energy firms, the models in Equations (1), (2), and (3) were re-estimated using robust estimators. The estimation results are presented in Table 4.

Table 4. Robustness Regression Results

Variable	EPS (1)	ROA (2)	Tobin's Q (3)
CCP	0.1446008**	0.4242471**	0.1502995***
SIZE	0.0125847**	0.0292484**	0.0029345
IRR	-0.0001309	0.0017238***	-0.0000384
LEV	-0.0483871**	-0.2615851***	0.0331027*
FIX	-0.0343392*	-0.227367***	-0.0108851
LnPGDP	5.500521***	20.95785**	3.702598***
INV	-0.0637677	-0.6244762*	0.0557311

Note: *, **, *** represent significant at 10%, 5%, 1% confidence level.

Table 4 summarizes the regression results of CCP on EPS, ROA, and Tobin's Q of listed firms in the electricity market in Türkiye's securities market. The impact of CCP on the financial performance of listed electricity energy firms is significantly positively correlated. In other words, CCP has positive impacts on the financial performance of listed firms this study is searching for. These impacts can be argued in some ways. Initially, climate change risk encourages electric power firms to invest in restructuring energy efficiency and renewable energy thereby gaining long-term competitive advantage and reducing cost. Secondly, most electric power firms are actively trying to improve their environmental brand image. They are adapting to take steps towards environmental sustainability policies. At the same time, information is being received from corporate ads, news, and media indicating that the government supports firms in managing the negative impacts of climate change on stakeholders. Thirdly, firms can face with new business opportunities by managing rightly their climate change policies. Today, people are talking too much about sustainability, carbon trading, green finance, and renewable energy. These projects can create financial opportunities for firms to strengthen their long-term financial performance. Of course, there are also some negative climate change impacts on financial performance. For instance, natural disasters brought on by climate change (floods, droughts, storms, etc.) can damage firms' physical assets, production processes, and supply chains. This means that production losses and unexpected costs in terms of firms. Also, adapting to sustainability issues like climate change policies requires significant capital expenditures. Firms have to invest in high amounts to reduce carbon emissions and switch to climate-friendly technologies. This also points out financial burdens in the short term especially. Considered together, the results indicate that the advantages outweigh the drawbacks, although natural disasters and financial challenges arising from climate change events could have some negative impact on the electricity energy industry.

SIZE is positively correlated with EPS and ROA. It is known that adapting to climate change-related issues is costly. The larger a firm's asset, the more budget it can allocate to such issues. When they expand their assets, they will focus not only on short-term survival or profit but also on pursuing sustainable growth, thereby enhancing their profitability. Another positive correlation is observed between the IRR and ROA of listed firms. Typically, the growth rate of operating income indicates the extent of business expansion and the pace of development acceleration. Thus, the larger this indicator, the greater the rise in profitability. LEV is negatively

correlated with EPS and ROA and positively correlated with Tobin's Q. If a firm's debt levels increase relative to its assets, its profitability tends to decrease. The increase in this ratio means the firm is relying on more debts to finance its operations, this can limit liquidity and put pressure on operational efficiency. Since, with a higher LEV, more of the firm's earnings will be directed to the payment of interest. Thus, the firm cannot invest in new projects. These issues can lead to decrease in profitability, result in lower EPS and ROA. On the other hand, it is seen that LEV is positively correlated with Tobin's Q. As it is told before, Tobin's Q reflects both market value and long-term performance. If a firm prefers debt to fund expansion or invest in new opportunities and investors believe that these investments will have positive sights on future profit, then Tobin's Q drives up. Since interest payments are tax-deductible, the firm get a chance to enhance tax efficiency which can drive up its market value. It is seen from Table 4 that FIX is negatively correlated with EPS and ROA. Results show that when a firm holds more of long-term investments, its profitability tends to decrease. Fixed assets such as property, plant, and equipment have lower liquidity and cannot generate cash immediately. While most of the firm's assets are tied up in long-term investments this may reduce overall asset efficiency. ROA measures how effectively a company utilizes its assets to generate profit so lower efficiency in assets may negatively impact ROA. Also, fixed assets are subject to depreciation. The more fixed assets a firm owns, the higher depreciation expenses rise, net income falls. Thus, it is directly reducing overall profitability and the income available to shareholders which directly impacts EPS. The results state that the effect of macroeconomic conditions (LnPGDP and INV) on firm performance is mixed. According to the empirical findings, while LnPGDP is positively correlated with firm performance at all confidence levels, INV is negatively correlated with firm performance at a 10% confidence level.

5. Conclusion and Policy Implications

This paper confirms the correlation between climate change performance and the listed electricity firm's performance on BIST by setting a panel data model for empirical analysis. The study covers the years between 2008 and 2022. The findings of this paper are consistent with recent studies such as Sun et al. (2023), Hong et al. (2019) and Heyes et al. (2016) highlighting these matters. For example, Sun et al. (2023), investigate the impact of climate change risks on the financial performance of Chinese electricity energy firms and report a significant positive correlation. Moreover, Hong et al. (2019), discover that countries facing worsening climate change events often experience slower profit growth and weaker stock returns. Heyes et al. (2016), found a correlation between extreme climate change events and financial performance too. Clearly, findings show that firms need to fully account for the risks posed by climate change and reflect them in financial conditions.

The empirical findings based on panel data model show that CCP positively impacts the firm performance which is measured by EPS, ROA and Tobin's Q of electricity power firms. The positive sign of the coefficient indicates that higher (lower) CCP in a firm's activities improves (worsens) performance. As firms invest more in CCP issues, they get better financial results, which positively affects their performance. Therefore, electric power industry must take into account the effects of climate change risks and set varied strategic responses for such kind of risks. The findings of this paper offer policy recommendations for a large number of stakeholders such as the environment, investors, regulatory institutions, governments, and others.

Firstly, electricity energy firms should consider climate change investments together with their own resources. This means that using a single energy production source can create inefficiency due to the negative effects of climate change. Therefore, existing facilities should be optimized according to the conditions that climate change risks may create. So, when a firm decides to make an infrastructure investment and design future production activities, it should notice to the trend of climate change risks.

Second, firms should optimize their production processes according to climate change conditions in their local areas. These crucial efforts help firms adapt to changing climate patterns. By analyzing climate change performance, firms can improve their clean energy projects. Additionally, they can set up relevant departments related to climate change-related issues and then integrate these departments into their risk management system. Moreover, these departments should issue various green instruments to get cheap funds from investors, to build a good reputation and brand value in the market.

Third, listed firms should actively complete low-carbon emission and energy use responsibilities, shifting to renewable energy responsibilities in order to avoid high fines from the legal authorities. These authorities should encourage the development of GHG emissions, renewable energy, energy use and climate policy for firms to obtain financial support.

Fourth, the more investors are enthusiastic about green instruments, the more firms consider climate change. For this reason, governments, and legal institutions should encourage market-driven reforms in the industry and improve electric power firm's ability to adapt to climate change. Hence, these initiatives will accelerate industry firms to take advantage of supportive policies and spend more on clean energy investments.

Finally, when awareness of climate change is embraced by all segments of society, it will also have positive effects on the environment. Reduced fossil fuel consumption, and investing more in green strategies will lead to less environmental pollution and a healthier life.

Industries, from industrial facilities to our homes, from transportation to healthcare directly depends on energy. A reliable and sustainable energy supply is a milestone of modern life. As in almost all emerging markets, electric power firms in Türkiye are one of the most important institutions to reduce energy dependency. Energy independence reduces a country's vulnerability to energy shocks. It supports economic development and social well-being. Therefore, a healthy structure of the industry is of great importance for the welfare of the economy. As a result, it can be said that governments and electric power firms in Türkiye should take into account climate change-related issues and the impact of these issues on overall performance. Since the majority of electric power firms in Türkiye are not publicly listed, the sample size in this paper is limited and need to be expanded. Future research can focus on addressing this limitation.

Declaration of Research and Publication Ethics
This study which does not require ethics committee approval and/or legal/specific permission complies with the research and publication ethics.

Researcher's Contribution Rate Statement
I am a single author of this paper. My contribution is 100%.

Declaration of Researcher's Conflict of Interest
There is no potential conflict of interest in this study.

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Ekonomi, Politika & Finans Araştırmaları Dergisi, 2025, 10(1): 107-126
Journal of Research in Economics, Politics & Finance, 2025, 10(1): 107-126
Araştırma Makalesi / Research Article, https://doi.org/10.30784/epfad.1595915

PREDICTING FINANCIAL FAILURE: EMPIRICAL EVIDENCE FROM PUBLICLY – QUOTED FIRMS IN DEVELOPED AND DEVELOPING COUNTRIES*

Finansal Başarısızlığın Tahmini: Gelişmiş ve Gelişmekte Olan Ülkelerdeki Halka Açık Şirketlerden Ampirik Kanıtlar

Yavuz GÜL** & **Serpil ALTINIRMAK*****

Keywords:
Financial Failure, Logistic Regression, Artificial Neural Networks, Decision Trees

JEL Codes:
C13, C15, C38, G33

Abstract

This paper analyzes the data of 570 firms from developed and developing countries between 2010 and 2019 in an attempt to create high–accuracy financial failure prediction models. In this sense, we utilize three different methods, namely logistic regression (LR), artificial neural networks (ANN), and decision trees (DT), and compare the classification accuracy performances of these techniques. Using 16 financial ratios as independent variables, ANN is able to generate the most accurate prediction and outperforms the other methods in predicting failure. Otherwise said, ANN yields a correct classification accuracy of 98.1% one year prior to failure while LR and DT achieve accuracy rates of 94.7% and 96.1%, respectively. Furthermore, the empirical results demonstrate that the classification accuracy rate reaches 92.5% by ANN, 91.1% by DT, and 84.4% by logistic regression two years in advance. The findings of current research provide valuable insights into financial failure prediction and may entice practical implications for stakeholders, especially investors and regulatory bodies, by indicating that the use of the ANN approach may be more effective.

Anahtar Kelimeler:
Finansal Başarısızlık, Lojistik Regresyon, Yapay Sinir Ağları, Karar Ağaçları

JEL Kodları:
C13, C15, C38, G33

Öz

Çalışmada yüksek doğruluğa sahip finansal başarısızlık tahmin modelleri oluşturmak üzere gelişmiş ve gelişen ülkelerden 570 şirket 2010 – 2019 dönemi için analiz edilmektedir. Bu çerçevede, lojistik regresyon (LR), yapay sinir ağları (YSA) ve karar ağaçları (KA) uygulanmış ve bahsedilen yöntemlerin sınıflandırma doğrulukları karşılaştırılmıştır. 16 finansal oran bağımsız değişken olarak kullanılmış ve YSA en doğru tahmin sonuçlarını üreterek başarısızlık tahmininde diğer yöntemlere üstünlük sağlamıştır. Diğer bir ifadeyle, YSA başarısızlıktan bir yıl öncesi için %98,1 sınıflama doğruluğu üretirken, LR ve KA sırasıyla %94,7 ve %96,1 doğruluk oranlarına ulaşmışlardır. Buna ek olarak, ampirik sonuçlara göre başarısızlıktan iki yıl öncesi için ANN %92,5, KA %91,1 ve LR %84,4 sınıflama doğruluğu sağlamışlardır. Mevcut çalışmanın bulguları finansal başarısızlık tahminine yönelik ışık tutmaktadır ve YSA yönteminin kullanılmasının daha efektif olabileceğini işaret ederek, özellikle yatırımcılar ve düzenleyici otoriteler gibi paydaşlar açısından pratik sonuçlar ortaya koymaktadır.

* This article has been produced from the PhD thesis entitled "Predicting the Financial Failures of Firms Traded on the Stock Markets of Developed and Developing Countries" which was carried out under the supervision of Prof. Dr. Serpil Altınırmak.

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Received Date (Makale Geliş Tarihi): 03.12.2024 Accepted Date (Makale Kabul Tarihi): 01.02.2025

1. Introduction

Predicting the financial failure of a firm is one of the subjects that has been intensively studied for many years. In these researches, we can see the different definitions of financial failure (Beaver, 1966; Altman, 1968; Deakin, 1972; Blum, 1974). Today, firms operating in intense competition conditions must efficiently utilize their resources in order to gain an advantage against their competitors. If firms fail to allocate scarce resources efficiently or cannot keep up with the latest technological advancements, they may enter the bankruptcy process. Financial failures have the potential to affect not only firms but also could cause massive economic damage. Firms that experience financial difficulties due to internal and/or external factors may take several precautions to overcome this condition with the least damage as long as they use financial failure prediction models and forecast the failure before it takes root. Creditors and investors, on the other side, will be able to make better decisions in matters such as loan options and investment choices according to the current and future state of the firm. Also, the government will have a chance to revise the policies in a timely manner.

Each model developed to predict failure has its own set of advantages and disadvantages. For instance, some models can be easy and simple to use while some of them are more complicated but they may produce more accurate results. Despite the developments in forecasting methods over the years, the fact that a "perfect" model still does not exist is the most important reason why research on financial failure continues today. This paper aims to guide stakeholders by creating models that can predict financial failure one year and two years in advance with high accuracy and hence help avoid possible business failure. We include firms that have different characteristics and operate in different countries and/or under various economic conditions to add depth and richness to the study. We, in this vein, focus on the firms listed in the benchmark stock market indices in G – 20 countries over the period from 2010 to 2019. Results show that ANN is the most efficient in predicting financial failure and profit margins are crucial for financial success. The main contributions of the paper are the following: (1) It builds models to predict the probability of a financial failure by including firms listed on different stock exchanges (2) It provides evidence on which model yields a higher prediction rate and which financial ratios play a role in the prediction of financial failure (3) It draws attention to the importance of early detection of financial failure, thus increases the interest in this field and enriches the literature.

With the first section being an introduction, the rest of the paper is structured as follows: Section 2 provides the theoretical background of the dimensions and concept of financial failure. Section 3 reviews the relevant literature. Section 4 presents the methodology and dataset while Section 5 outlines the empirical findings. Finally, section 6 concludes the paper.

2. Theoretical Background

Firms may face significant financial challenges due to various factors such as inadequate cash flow management, market conditions, and risks. The term financial failure can be defined in several ways based on the different perspectives and refers, in its broadest sense, to the inability of a firm to meet its financial obligations or to have difficulty fulfilling them (İçerli and Akkaya, 2006: 413). Altman (1968) uses the word "bankruptcy" and considers the legal filing for bankruptcy and the appointment of a trustee or the granting of the right to reorganize under the "National Bankruptcy Act" as a financial failure while Beaver (1966) defines financial failure as

the inability to pay its financial obligations as they came due. According to Deakin (1972), financial failure means being insolvent, bankrupt, or liquidated. Blum (1974) argues that financial failure is when a firm is unable to pay its debts when due, applying for bankruptcy, or signing an agreement with creditors to waive their receivables.

Financial failure comes in four forms: business failure, technical failure, having a negative net worth, and bankruptcy. These are essentially the types of financial failure and bring to mind the final stages of the failure path. It is generally claimed that firms encounter problems in the initial stage, followed by technical failure, namely liquidity issues and then having a negative net worth and bankruptcy. Although financial failure and bankruptcy are terms often used interchangeably, bankruptcy is a situation where the liabilities exceed the assets by virtue of financial failure and emerges as a special case of failure. In some cases, asserting that firms experiencing financial failure will go bankrupt may not be correct, however. Firms can get out of bankruptcy and continue their operations healthily again by making arrangements.

In the common literature, financial and non–financial indicators are adopted to measure financial stress and these criteria can be bifurcated into two subsections: numerical and non–numerical. Numerical indicators are expressed through financial statements and fall into two main groups: indicators based on market value and indicators based on book value (Özdemir, 2011: 52-53). Contrarily, no specific reference point is mentioned for financial failure in non–numerical indicators, e.g., delisting of shares, transferring the shares in the watchlist market, filing for bankruptcy, stopping or slowing down production, and layoffs.

There are many reasons why a firm falter financially. Financial failures can occur due to internal issues caused by poor management, excessive borrowing, insufficient cash flow, inadequate working capital management, lack of effective budgetary control system, and absence of a cost management system (Mills and Robertson, 1991; Cemalcılar et al., 1985 as cited in Karacan and Savcı, 2011), as well as external factors such as economic climate, politics, market structure – related conditions, technological changes, legal conditions and environmental issues.

The major objectives of the analyses conducted and the steps taken are to ensure the survival of the failed firm. At this point, precautionary actions that turned out successful may not yield the same results when applied to other firms in similar circumstances, since firms may experience failure due to different reasons and the degree of the failure may vary significantly. The high number of business failures may have a negative impact on the country's economy. Financial failures also constitute an obstacle to the efficient use of resources and lead to an increase in unemployment rates. Investors and creditors can avoid or reduce investment losses, thanks to failure prediction models. Prediction of financial failures is of vital importance due to the spillover effects of such events. Researchers have devoted a great deal of time since the 1960s, e.g., Altman (1968), to predict financial failures and to develop early warning systems. Considering the growing attention towards the financial services industry, distress prediction models are gaining momentum in parallel. The current study contributes to the existing literature by developing prediction models.

3. Literature Review

In the early days of studies on financial failure prediction, we see that the methods such as linear regression and linear discriminant analysis were widely used but the idea of determining a

financial failure using a single variable began to be deemed risky in subsequent years. Thus, methods such as multiple regression, multiple discriminant analysis, logistic regression, and probit regression, which allow to include of more than one explanatory variable, have come to the fore. The study conducted by Altman (1968), using multiple discriminant analysis, is one of the pioneering studies in the financial failure literature. He examined 33 bankrupt and 33 non–bankrupt firms over the period 1946 – 1965 and accurately classified 95% of the firms one year in advance and 72% of them two years in advance. Meyer and Pifer (1970) compared 39 pairs of failed and sound banks from 1948 to 1965 through a multiple regression analysis and achieved classification accuracy of 80% for one or two years before the failure occurred. In another research, Edmister (1972) applied a multiple discriminant analysis on the data of 32 failed and 562 successful firms in the USA during the period 1954 – 1969 to classify failed and non–failed firms with an accuracy of 90%. In the following years, Ohlson's (1980) pioneering work introduced logistic regression into financial failure prediction. The author created three different models and reported that these models yield an overall correct classification accuracy of 96.12%, 95.55%, and 92.84%, respectively. He also stated that the firm size, liquidity, capital structure, and profitability statistically significantly affect the likelihood of failure. Among the studies aiming to predict financial failure using the probit model, the research conducted by Zmijewski (1984) stands out. Zmijewski (1984) examined 81 unsuccessful and 1600 successful firms in the USA and correctly predicted the failure for 62.5% of failed firms and 99.5% of successful firms. Canbaz (1998), using a sample of 60 firms operating in Türkiye, applied a multiple discriminant analysis to predict financial failure and obtained an accuracy of 95.7%. In a similar research, Ünsal (2001) employed data from 16 failed and 55 successful firms from Türkiye and achieved a classification accuracy of 95.77%. While Aktaş et al. (2003), utilized discriminant analysis, multiple regression, and ANN along with logistic regression and emphasized that ANN is the most successful in predicting financial failure, Altaş and Giray (2005) included 33 textile firms and built a model by logistic regression and factor analysis. They were able to achieve an overall classification accuracy of 74.2%. Doğanay et al. (2006) analyzed a unique set of 19 failed and 23 non–failed banks for the period 1997–2002 and reached, one year prior to failure, the accuracy rate of 78.9% by probit regression, 89.5% by multiple regression and 84.2% by discriminant analysis for failed banks. A study conducted by Chung et al. (2008) focused on 10 unsuccessful and 35 successful firms in New Zealand and correctly predicted the failure for 62% of firms using multiple discriminant analysis. Authors also claimed that failed firms are less profitable and have lower liquidity. Gepp and Kumar (2008) used Cox SA, discriminant analysis, and logistic regression to predict the likelihood of financial failure of 117 successful and 72 unsuccessful firms over 1974 – 1991 and found that all three methods attained 96% accuracy one year in advance. Lin (2009) used 20 financial ratios to analyze 96 unsuccessful and 158 successful firms in Taiwan employing probit regression, logistic regression, multiple discriminant analysis, and ANN. They provided evidence that the probit regression method was the most successful and stable model. Using multiple discriminant analysis, Yap et al. (2010) examined the dataset of 32 successful and 32 unsuccessful firms in Malaysia over the period 1996 – 2005 and stated that classification accuracy ranged from 88% to 94% five years prior to failure. Lastly, Büyükarıkan and Büyükarıkan (2018) attempted to forecast the probability of failure and suggested that the classification accuracy reached 87.27% with probit regression, 89.1% with logistic regression, 88.2% with multiple discriminant analysis 86.36% with multiple regression.

Technological advancements have altered life around the world and resulted in increasing use of techniques such as DT, random forest (RF), ANN, support vector machines (SVM), and deep learning, which can effectively handle massive datasets, in financial studies. For instance, Odom and Sharda (1990) developed a model using ANN and compared the predictive power of this model with the prediction ability of discriminant analysis. The authors examined a total of 129 firms, 65 of which filed for bankruptcy and 64 of which did not go bankrupt, for the period 1975 – 1982 and stated that ANN was more successful in the prediction. In a related research, Atiya (2001) built a model to predict financial failure three years in advance using ANN and reported a classification accuracy ranging from 81.46% to 89.41%. Similarly, Yıldız (2001) analyzed 53 successful and 53 unsuccessful firms listed on the stock exchange and/or subject to Capital Markets Board of Türkiye (CMB) regulations by ANN and produced a classification accuracy of 94.4% while Ravi and Pramodh (2008) examined 66 Spanish and 40 Turkish banks using combined ANN and principal component analysis to reveal that the models achieved an accuracy rate of 97.5% for Spain and 100% for Türkiye. Likewise, Wu et al. (2008) utilized ANN in a dataset of 48 firms operating in the Chinese manufacturing sector and obtained an 87.5% accuracy one year in advance and 81.3% accuracy three years in advance. Çelik (2010) examined 36 private banks with 36 financial ratios and delivered, using ANN, 100% classification accuracy one year prior to failure and 89.4% classification accuracy two years prior to failure. Gregova et al. (2020) compared the performances of RF, logistic regression, and ANN in failure prediction and discovered that ANN had the highest accuracy. Hui and Sun (2006) employed support vector machines, ANN, and logistic regression in their research conducted in China. According to the authors, support vector machines were more stable compared to the other methods. In a similar vein, Vieira et al. (2009) analyzed the data of 600 successful and 600 unsuccessful French firms for the period 2002 – 2007 applying logistic regression, ANN, and support vector machines, and stated that support vector machines were the most accurate in predicting the financial failure. Bae (2012) achieved the same results. The author used the data from 1888 firms in South Korea and concluded that support vector machines performed better than the other methods. Supporting these results, Altınırmak and Karamaşa (2016), analyzing 17 unsuccessful and 13 successful banks over the period 1996 – 2000, found that support vector machines outperform ANN by providing better prediction accuracy. These results are in line with Mselmi et al. (2017), who emphasized that support vector machines achieved a classification accuracy of 88.57% and emerged as the most efficient technique. In another study, Aksoy and Boztosun (2021) included 86 firms traded in Borsa Istanbul (BIST) and documented that SVM was the most effective in predicting failure with an accuracy of 92.31%. Based on a sample of 1443 banks from 2007 to 2013, Gogas et al. (2018) suggested that support vector machines reached a classification accuracy of 99.22%. Le and Viviani (2018) applied support vector machines, ANN, k – nearest neighbor algorithm (KNN), logistic regression, and discriminant analysis on the data of 1438 failed and 1562 non-failed banks and noted that support vector machines had an accuracy score of 71.6%. The study of Aktan (2011) focused on 180 firms publicly traded in BIST and applied classification–regression trees, ANN, and support vector machines to affirm that classification and regression trees yielded more accurate results. Yakut and Elmas (2013) analyzed 140 publicly listed firms from 2005 to 2008 and claimed that DT lead to rather accurate classification results. Çöllü et al. (2020), using the data of 20 firms traded in BIST from 2016 to 2018, determined that the CART method provided the most efficient classification with 95 percent accuracy. A study conducted in Taiwan for the period 2010 – 2016 reported that the XGBoost algorithm showed the highest accuracy among the four models (Huang and Yen, 2019). More recently, Malakauskas

and Lakstutiene (2021) analyzed a dataset of 12000 firms from Estonia, Latvia, and Lithuania to predict financial failure using RF, ANN, and logistic regression. They stated that RF demonstrated the best performance. Similar results were obtained by Petropoulos et al. (2020). Researchers tried to predict bank failures in the USA by RF, discriminant analysis, logistic regression, support vector machines, and ANN and uncovered that RF yielded more successful results than all other methods. Noviantoro and Huang (2021) and Yousaf et al. (2022) also confirmed that RF was the top performer in terms of prediction accuracy.

Based upon the findings of our literature review, we infer that machine-learning techniques have been used extensively in recent years. In addition, most empirical studies have concentrated on firms in a single country (Jo et al., 1997; Aktaş et al., 2003; Benli, 2005; Doğanay et al., 2006; İçerli and Akkaya, 2006; İşseveroğlu and Gücenmez, 2007; Chung et al., 2008; Wu et al., 2008; Lin, 2009; Çelik, 2010; Bae, 2012; Altunöz, 2013; Cengiz et al., 2015; Kulalı, 2016; Gogas et al., 2018; Le and Viviani, 2018; Huang and Yen, 2019; Gregova et al., 2020; Tang et al., 2020; Aksoy and Boztosun, 2021; Halim et al., 2021; Jan, 2021; Noviantoro and Huang, 2021; Oribel and Hanggraeni, 2021; Qian et al., 2022; Yousaf et al., 2022). In the current study, to mitigate the limitations of this, we create failure prediction models by including firms both from developed and developing countries, thus adding dimension to the present body of literature.

4. Data and Methodology

We include the firms traded on the stock markets of G – 20 members and use the financials of the firms (that is, balance sheet and income statement) as a starting point. The fact that publicly traded firms are required to present and disclose financial reports, special circumstances, and material events in a timely and transparent manner in accordance with the disclosure principles is the reason why we prefer firms listed in capital markets. We remove firms operating in the financial sector or carrying little or no inventory due to the nature of their activities (such as waste management, information technology, and asset management firms) from the sample. Additionally, we exclude firms from the analyses if they have missing data and then divide the sample into two types of countries based on IMF (International Monetary Fund) classification: developed and developing. Table 1 presents the stock market indexes adopted in the study.

Table 1. Stock Market Indices

Country	Index	Country	Index
Germany	DAX40	India	BSE30
USA	DOW30	UK	FTSE100
Argentina	S&P MERVAL	Italy	FTSE MIB
Australia	ASX50	Japan	TOPIX100
Brazil	BOVESPA	Canada	TSX60
China	SSE50	Mexico	S&P BMV IPC
Indonesia	LQ45	Russia	RTS
France	CAC40	Saudi Arabia	MSCI TADAWUL30
South Africa	JSE TOP40	Türkiye	BIST50
South Korea	KOSPI50		

Our entire period spans from January 1, 2010 to December 31, 2019. The 2008 Global Financial Crisis and the COVID–19 outbreak, which started in early 2020, have had severe

consequences and implications on economies and firms, we therefore start the study period on January 1, 2010 and end on December 31, 2019. We collect data from Thomson Reuters, various databases and corporate websites of firms.

We classify firms with two or more successive losses as having been unsuccessful and the others as successful. We then create a dependent variable to represent their successful (1) or unsuccessful (0) status and consider financial ratios as independent variables. We identify the financial ratios by conducting an in-depth systematic review of literature (Jo et al., 1997; Atiya, 2001; Aktaş et al., 2003; Altaş and Giray, 2005; Torun, 2007; Chung et al., 2008; Vuran, 2009; Aktan, 2011; Terzi, 2011; Yakut and Elmas, 2013; Cengiz et al., 2015; Selimoğlu and Orhan, 2015; Ural et al., 2015; Huang and Yen, 2019; Gogas et al., 2018; Gregova et al., 2020; Aksoy and Boztosun, 2021; Jan, 2021) and hence include 16 financial ratios in the study (Table 2).

Table 2. Financial Ratios

Liquidity Ratios	Efficiency Ratios	Profitability Ratios	Leverage Financial Ratios	Growth Ratios
X1 Current ratio	X3 Receivables turnover ratio	X5 Gross profit margin	X11 Debt to equity	X13 Sales growth rate
X2 Quick ratio	X4 Inventory turnover ratio	X6 Net profit margin	X12 Interest coverage ratio	X14 Gross profit growth rate
		X7 Return on equity (ROE)		X15 EBITDA growth rate
		X8 Return on assets (ROA)		X16 Net profit growth rate
		X9 Operating profit margin		
		X10 Earnings per share (EPS)		

5. Experimental Results

The data set consists of a total of 91200 points (570 firms, 10 years, 16 ratios). We perform logistic regression (LR), ANN, and DT analysis to predict financial failure.

5.1. Logistic Regression

The outputs of our first model are summarized in Table 3. The Nagelkerke R^2 value shows that 82.4% of the change in the dependent variable is explained by the model. According to the results, net profit margin, ROE, ROA, operating profit margin, and interest coverage ratio have statistically significant effect on financial failure. Thus, equation (1) can be written as follows:

$$Z1 = 0.553 + 42.698X6 + 7.198X7 - 32.842X8 + 12.000X9 + 0.196X12 \quad (1)$$

Table 3. LR Classification Results 1-Year Prior to Failure (Overall)

Variable	Ratios	B	S.E.	Wald	df	Sig.
X6	Net profit margin	42.698	11.863	12.954	1	0.000
X7	ROE	7.198	1.887	14.547	1	0.000
X8	ROA	-32.842	16.340	4.039	1	0.044
X9	Operating profit margin	12.000	4.678	6.580	1	0.010
X12	Interest coverage ratio	0.196	0.070	7.792	1	0.005

	Observed		Predicted		
			0.00	1.00	Percentage Correct
Step 1	Success (1) – Failure (0)	0.00	78	6	92.9
		1.00	24	462	95.1
	Overall Percentage				94.7

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	118.309	0.467	0.824

Our model correctly classifies the failed firms by 92.9% and non–failed firms by 95.1% for one year before failure. The overall correct classification rate of the firms is 94.7%.

The findings of the model estimated for developed–country firms are reported in Table 4. As shown in the table below, the net profit margin reaches statistical significance at a 1 percent level ($p<0.01$). Along with this, ROA and interest coverage ratio are statistically significant at the level of 0.05. These variables contribute significantly to the predictive power of the model and equation (2) is written as follows:

$$Z2 = -0.387 + 70.225X6 - 68.026X8 + 0.234X12 \quad (2)$$

Table 4. LR Classification Results 1-Year Prior to Failure (Developed-Country Firms)

Variable	Ratios	B	S.E.	Wald	df	Sig.
X6	Net profit margin	70.225	26.215	7.176	1	0.007
X8	ROA	-68.026	34.224	3.951	1	0.047
X12	Interest coverage ratio	0.234	0.114	4.208	1	0.040

	Observed		Predicted		
			0.00	1.00	Percentage Correct
Step 1	Success (1) – Failure (0)	0.00	33	3	91.7
		1.00	15	267	94.7
	Overall Percentage				94.3

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	57.444	0.409	0.807

In Table 4, the model is able to accurately classify 33 of the 36 failed firms, leading to correct classification in the case of 91.7% of failed firms. The model, on the other hand, has a classification percentage of 94.7% of non–filed firms and percent 5.3 indicates the type II error. For this model, the overall percentage of correctly classified firms is 94.3%.

The summary of the model developed using data from 252 firms listed on developing country stock markets is given in Table 5. Net profit margin has a statistically significant influence on financial failure at the 1% level ($p<0.01$). In the meantime, the interest coverage ratio acquires a significance level of 0.014 smaller than the 0.05 significance level. Equation (3) is specified as follows:

$$Z3 = -4.277 + 83.485X6 + 0.783X12 \quad (3)$$

Table 5. LR Classification Results 1-Year Prior to Failure (Developing-Country Firms)

Variable	Ratios	B	S.E.	Wald	df	Sig.
X6	Net profit margin	83.485	30.821	7.337	1	0.007
X12	Interest coverage ratio	0.783	0.320	5.977	1	0.014

	Observed		Predicted		
			0.00	1.00	Percentage Correct
Step 1	Success (1) – Failure (0)	0.00	47	1	97.9
		1.00	6	198	97.1
	Overall Percentage				97.2

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	29.698	0.575	0.924

The model correctly classified 97.9 percent of failed firms and 97.1 percent of non–filed firms. For Type I errors, the probability of classifying a failed firm as non–filed is 2.1 percent while for Type II errors, the probability of classifying a non–filed as failed is 2.9 percent. The model yields an overall correct classification accuracy of 97.2% one year prior to failure.

The outputs of the model built to predict the probability of financial failure two years in advance are illustrated in Table 6. Cox Snell and Nagelkerke R^2 suggest that the variation in the probability of financial failure explained by the financial ratios ranges between 25.7% and 45.3%. ROA is statistically significant at the 1% level ($p<0.01$) and gross profit margin exhibits a statistical significance at the 5% level ($p<0.05$). Equation (4) can be expressed as follows:

$$Z4 = -0.045 + 2.248X5 + 28.845X8 \quad (4)$$

Table 6. LR and Classification Results 2-Years Prior to Failure (Overall)

Variable	Ratios	B	S.E.	Wald	df	Sig.
X5	Gross profit margin	2.248	1.113	4.076	1	0.043
X8	ROA	28.845	7.271	15.737	1	0.000

	Observed		Predicted		
			0.00	1.00	Percentage Correct
Step 1	Success (1) – Failure (0)	0.00	62	22	73.8
		1.00	67	419	86.2
	Overall Percentage				84.4

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	307.707	0.257	0.453

According to Table 6, our model attains 73.8% accuracy in the classification of failed firms while the classification accuracy rate for non–failed firms is 86.2%. The model yields an overall correct classification accordance of 84.4% two years prior to failure.

We then create a model to predict the failure of publicly listed firms in developed–country markets two years prior to distress and find that only ROA is statistically significant at the level of significance of 1% (Table 7). All other variables in the model seem to be statistically insignificant. Equation (5) is shown below:

$$Z5 = -1.051 + 35.472X8 \quad (5)$$

Table 7. LR Classification Results 2-Years Prior to Failure (Developed-Country Firms)

Variable	Ratios	B	S.E.	Wald	df	Sig.
X8	ROA	35.472	12.791	7.690	1	0.006
	Observed		**Predicted**			
			0.00	**1.00**	**Percentage Correct**	
Step 1	Success (1) – Failure (0)	0.00	25	11	69.4	
		1.00	23	259	91.8	
	Overall Percentage				89.3	
Step	**-2 Log likelihood**		**Cox & Snell R Square**		**Nagelkerke R Square**	
1	147.505		0.215		0.425	

Table 7 shows that two years before failure, the correct classification rate of failed firms was 69.4%. According to the percentage of the correctly classified non–failed firms' cases, the model achieves 91.8% accuracy and results in a total correct classification rate of 89.3%.

The model designed to predict the financial failure of developing-country firms two years ahead of failure is presented in Table 8. The table indicates that ROA is statistically significant at the 0.05 significance level ($p<0.05$). Accordingly, Equation (6) is written as follows:

$$Z6 = -0.501 + 22.639X8 \quad (6)$$

Table 8. LR Classification Results 2-Years Prior to Failure (Developing-Country Firms)

Variable	Ratios	B	S.E.	Wald	Df	Sig.
X8	ROA	22.639	10.601	4.561	1	0.033
	Observed		**Predicted**			
			0.00	**1.00**	**Percentage Correct**	
Step 1	Success (1) – Failure (0)	0.00	38	10	79.2	
		1.00	39	165	80.9	
	Overall Percentage				80.6	
Step	**-2 Log likelihood**		**Cox & Snell R Square**		**Nagelkerke R Square**	
1	133.996		0.357		0.574	

According to Table 8, the model correctly predicts 79.2 percent of the failed firms and is 80.9% accurate in predicting the likelihood of financial failure of non-failed firms. Our model produces an overall correct classification rate of 80.6%.

5.2. Artificial Neural Network (ANN)

The results obtained with the ANN approach to forecast financial failure one year and two years before it occurs are given in Table 9. Results suggest that the classification accuracy of non-failed firms is 100% and the correct classification rate of failed firms is 91.3%. The model yields an overall classification accuracy of 98.1%. This implies that the model achieves good prediction performance. The classification accuracy of successfully developed-country firms is 87.5% while ANN correctly classifies 100 percent of 486 non–failed firms. The overall classification performance percentage is 98.6%. Further, in the case of developing-country firms, ANN correctly predicts the failure for 85.7% of failed firms and 100% of successful firms, making an overall wrong estimate is occurred only for 2.1%.

Table 9. Classification Results of ANN

	N	One Year Prior to Failure	Two Years Prior to Failure
Entire sample	570	98.1%	92.5%
Failed	84	91.3%	57.9%
Non – failed	486	100.0%	99.0%
Developed – country firms	318	98.6%	96.6%
Failed	36	87.5%	75.0%
Non – failed	282	100.0%	98.2%
Developing – country firms	252	97.9%	94.4%
Failed	48	85.7%	75.0%
Non – failed	204	100.0%	97.8%

Table 9 indicates that the percentage of correct classification of failed firms two years before the failure is 57.9%. The model correctly classifies 99.0% of successful firms and yields an overall correct classification accuracy of 92.5% two years prior to failure. The accuracy of our model for correctly predicted failed developed-country firms is 75.0%, and 98.2% for appropriately assigned non-failed developed-country firms. The overall prediction accuracy is 96.6%. Our model, additionally, is able to classify correctly the failed firms 75.0% and successful firms 97.8% accurately. Overall, the model properly classifies 94.4% of the developing-country firms.

The ranked importance of each dependent variable, that is, financial ratios, is shown in Table 10. Net profit margin is the most important in determining the success or failure of the firm one year in advance. ROA seems to be another significant variable for predicting financial failure. Contrarily, the inventory turnover ratio is the least important one among financial ratios.

Table 10. Ranked Variable Importance

Financial ratios	One year prior to failure			Two years prior to failure		
	Entire Sample	Developed-Country Firms	Developing-Country Firms	Entire Sample	Developed-Country Firms	Developing-Country Firms
Current ratio	11	16	16	10	**3**	8
Quick ratio	13	14	15	13	10	10
Receivables turnover ratio	6	11	10	16	15	9
Inventory turnover ratio	15	15	14	14	16	16
Net profit margin	**1**	**1**	**1**	4	8	**2**
Gross profit margin	10	6	12	7	13	12
Operating profit margin	9	13	9	5	9	6
ROE	**2**	9	**2**	8	14	5
ROA	5	**2**	6	**1**	**2**	**1**
Earnings per share	7	7	8	**2**	6	11
Debt to equity	8	10	11	15	7	**3**
Interest coverage ratio	14	12	13	9	4	13
Sales growth rate	12	**3**	**3**	11	11	14
Gross profit growth rate	16	5	7	6	**1**	4
EBITDA growth rate	4	4	4	12	12	7
Net profit growth rate	**3**	8	5	**3**	5	15

According to the failure prediction models developed using ANN to predict financial failure two years in advance, the most critical factor affecting financial success is ROA. This factor is followed by the gross profit growth rate. The top three financial ratios to predict the financial failure of developed-country firms one year in advance are net profit margin, ROA, and sales growth rate, while only ROA is replaced by ROE for developing-country firms. Besides, gross profit growth rate, ROA, and current ratio seem to be the most important ratios for predicting the failure of developed-country firms two years in advance, while ROA, net profit margin, and debt to equity emerge as the significant variables with regard to developing-country firms.

5.3. Decision Trees (DT)

The classification accuracies of the models derived using the CHAID algorithm are presented in Table 11. The model correctly predicts 94 percent of failed firms and 96.5 percent of non-failed firms. The overall predictive accuracy (one year before the failure) is 96.1%. Furthermore, the second model is able to accurately classify 97.2% of failed developed-country firms and 95.7% of non-failed developed-country firms. For this model, the overall percentage of correctly classified firms is 95.9%. Our third model attains 87.5% accuracy in the classification of failed firms, while the classification accuracy rate for non-failed firms is 96.1%. The model produces an overall correct classification accordance of 94.4% one year prior to failure.

Table 11. Classification Results of CART

	N	One Year Prior to Failure	Two Years Prior to Failure
Entire sample	570	96.1%	91.1%
Failed	84	94.0%	53.6%
Non – failed	486	96.5%	97.5%
Developed – country firms	318	95.9%	92.1%
Failed	36	97.2%	58.3%
Non – failed	282	95.7%	96.5%
Developing – country firms	252	94.4%	91.3%
Failed	48	87.5%	68.8%
Non – failed	204	96.1%	96.6%

In Table 11, our model accurately discriminates 97.5 percent of the non-failed firms but is only 53.6 percent accurate at predicting the financial failure of unsuccessful firms two years in advance. The overall predictive accuracy of the model is 91.1%. In addition, the fifth model manages to correctly classify non-failed developed-country firms by 96.5% and failed ones by 58.3%. The model achieves an overall correct classification accuracy of 92.1%. The last model, in the case of developing-country firms, accurately predicts 96.6 percent of the non-failed firms and 68.8 percent of the failed firms and thus results in a total correct classification rate of 91.3%.

The model created to predict financial failure one year in advance using DT is given in Table 12. Accordingly, the decision tree starts with a root node which is the net profit margin. This means that the most important variable influencing the financial success of the firms is the net profit margin (p=0.000). Firms with a net profit margin of less than -4.95% are split into subgroups based on their interest coverage ratio with a 1% level of significance (p=0.000). Another ratio affecting the likelihood of financial failure is the earnings per share, which is also

a key metric of a firm's profitability (p<0.01). EBITDA growth rate seems to be another critical parameter that demonstrates the overall financial performance of firms (p=0.000).

Table 12. DT Based Failure Prediction Model 1-Year Prior to Failure (Overall)

Profile	Node	Net Profit Margin	Interest Coverage Ratio	Earnings Per Share	EBITDA Growth Rate
1	1	≤ -0.049			
2	2	-0.049 – 0.011			
3	3	> 0.011			
4	4	≤ -0.049	≤ 3.730		
5	5	≤ -0.049	> 3.730		
6	6	-0.049 – 0.011		≤ 0.000	
7	7	-0.049 – 0.011		> 0.000	
8	8	> 0.011			≤ -0.278
9	9	> 0.011			> -0.278

The tree generated, using the data of 318 developed-country firms, by the CHAID algorithm is presented in Table 13. According to the table, the net profit margin is at the root of the model and is statistically significant (p = 0.000). Firms with a net profit margin between -1% and 2.34% and with a net profit margin higher than 2.34% are divided into two subgroups based on their earnings per share (p<0.01) and operating profit margin (p<0.01), respectively.

Table 13. DT Based Failure Prediction Model 1-Year Prior to Failure (Developed-Country Firms)

Profile	Node	Net Profit Margin	Earnings Per Share	Operating Profit Margin
1	1	≤ -0.010		
2	2	-0.010 – 0.023		
3	3	> 0.023		
4	4	-0.010 – 0.023	≤ 0.280	
5	5	-0.010 – 0.023	> 0.280	
6	6	> 0.023		≤ 0.052
7	7	> 0.023		> 0.052

From Table 14, we can infer that the model obtained using data from 252 developing–country firms emphasizes the importance of three financial ratios, namely net profit margin, gross profit margin, and earnings per share. The net profit margin forms the root as in the previous models (p = 0.000). Firms with a net profit margin of less than -1.76% and with a net profit margin between -1.76% and 2.2% are further classified into two sub-categories according to their gross profit margin (p<0.01) and earnings per share (p<0.05), respectively.

Table 14. DT Based Failure Prediction Model 1-Year Prior to Failure (Developing-Country Firms)

Profile	Node	Net Profit Margin	Gross Profit Margin	Earnings Per Share
1	1	≤ -0.017		
2	2	-0.017 – 0.022		
3	3	> 0.022		
4	4	≤ -0.017	≤ 0.2954	
5	5	≤ -0.017	> 0.2954	
6	6	-0.017 – 0.022		≤ 0.000
7	7	-0.017 – 0.022		> 0.000

Results of the failure prediction model which tries to forecast the financial failure two years in advance are shown in Table 15. The most important variable and also the root node is ROA (p=0.000), followed by interest coverage ratio (p<0.05). Firms with ROA between 2.0% and 6.7% are split into two subgroups according to their interest coverage ratio. One can, therefore, claim that the interest coverage ratio appears as the second most important variable. Further, firms with ROA between 2.0% and 6.7% and having an interest coverage ratio higher than 2.96 are classified based on the gross profit growth rate (p<0.01). Lastly, firms with ROA higher than 6.7% are divided into two subgroups according to, once again, their gross profit growth rate (p<0.01).

Table 15. DT Based Failure Prediction Model 2-Years Prior to Failure (Overall)

Profile	Node	ROA	Interest Coverage Ratio	Gross Profit Growth Rate
1	1	≤ 0.006		
2	2	0.006 – 0.020		
3	3	0.020 – 0.067		
4	4	> 0.067		
5	5	0.020 – 0.067	≤ 2.960	
6	6	0.020 – 0.067	> 2.960	
7	9	0.020 – 0.067	> 2.960	≤ 0.090
8	10	0.020 – 0.067	> 2.960	> 0.090
9	7	> 0.067		≤ 0.158
10	8	> 0.067		> 0.158

Table 16 provides an illustration of the model built for predicting the failure of developed-country firms two years in advance. ROA shows up as the most important variable (p=0.000). We see that, in general, the probability of failure decreases as the return on assets increases. Firms that generate ROA both between 0.7% - 4.07% and higher than 4.07% are divided into subgroups according to their EBITDA growth rate, meaning that the second most important variable is the EBITDA growth rate. Besides, firms that have ROA between 0.7% and 4.07% and also have EBITDA growth rates larger than -22.2% are reclassified according to the gross profit growth rate (p<0,01). While ROA is between 0.7% and 4.07%, firms having an EBITDA growth rate higher than -22.2% and a gross profit growth rate higher than 6.7% are divided into two sub-categories based on the debt-to-equity ratio (p<0.05). So, another crucial variable seems to be debt to equity in predicting financial failure.

Table 16. DT Based Failure Prediction Model 2-Years Prior to Failure (Developed-Country Firms)

Profile	Node	ROA	EBITDA Growth Rate	Gross Profit Growth Rate	Debt to Equity
1	1	≤ 0.007			
2	2	0.007 – 0.040			
3	3	> 0.040			
4	4	0.007 – 0.040	≤ -0.2220		
5	5	0.007 – 0.040	> -0.2220		
6	8	0.007 – 0.040	> -0.2220	≤ -0.1863	
7	9	0.007 – 0.040	> -0.2220	-0.1863 – 0.067	
8	10	0.007 – 0.040	> -0.2220	> 0.067	
9	11	0.007 – 0.040	> -0.2220	> 0.067	≤ 0.6994
10	12	0.007 – 0.040	> -0.2220	> 0.067	> 0.6994
11	6	> 0.040	≤ 0.3108		
12	7	> 0.040	> 0.3108		

Table 17 demonstrates the decision tree model which is created to predict the likelihood of financial failure of developing-country firms two years before the failure occurs. The root node of the constructed tree is ROE (p=0.000). Firms having a ROE between -1.4% - 8.15% and greater than 8.15% are both divided into sub-categories according to their net profit growth rate. Firms with ROE higher than 8.15% and net profit growth rate between 10.29% - 131.34% are split into two subgroups based on operating profit margin ($p<0.05$).

Table 17. DT Based Failure Prediction Model 2-Years Prior to Failure (Developing-Country Firms)

Profile	Node	ROE	Net Profit Growth Rate	Operating Profit Margin
1	1	≤ -0.014		
2	2	-0.014 – 0.081		
3	3	> 0.081		
4	4	-0.014 – 0.081	≤ 0.2313	
5	5	-0.014 – 0.081	> 0.2313	
6	6	> 0.081	≤ -0.3541	
7	7	> 0.081	-0.3541 – 0.1029	
8	8	> 0.081	0.1029 – 1.3134	
9	9	> 0.081	> 1.3134	
10	10	> 0.081	0.1029 – 1.3134	≤ 0.0991
11	11	> 0.081	0.1029 – 1.3134	> 0.0991

When we consider all the models, we observe that the profitability ratios, growth ratios, and leverage financial ratios come to the fore. Although both profit margins and growth are important and necessary for a firm to be successful and remain in business, they may not be sufficient for business continuity. Firms must provide a balance between financial structure (financial statements are all linked and dependent on each other) and continuing operations. On the flip side of the coin, suggesting that every firm that makes a loss will eventually go bankrupt or shut down might not be true or, for example, firms with negative net working capital and/or high debt can continue their operations with no interruption if they can maintain a healthy cash flow. So in short, as much as firms are interested in preserving and improving their profit-making ability, they should also strive to determine the right balance between debt and equity, establish effective cash management and stock control policies, and adopt a good corporate governance structure. In addition, investor relations play a crucial role in providing reliable and transparent information to investors and building loyal relationships with their existing and potential investors, so firms must attach more importance to investor relations practices.

6. Concluding Remarks

Although much research has been carried out in the field of financial failure prediction to date, the fact that a model that can be defined as perfect and can be applied to every firm still has not yet been designed is one of the reasons why studies related to financial failure continue at high speed and our main motivation stems from this point. We analyze the data available from January 1, 2010 to December 31, 2019, and use the financial ratios of 570 firms traded on the stock markets of G – 20 members to create models and predict the probability of financial failure by logistic regression, ANN, and DT. Results show that ANN exhibits better classification performance than the other methods. This is parallel to previous findings by Jo et al. (1997), Aktaş

et al. (2003) and Gregova et al. (2020). In these researches, similar to the current one, the authors concluded that ANN outperforms the other methods. ANN is followed by the DT and logistic regression, respectively. One can argue that machine learning techniques attain superior results compared to traditional methods and ANN is useful for predicting financial failure. It is worth bearing in mind that advancements in technology and computer science affect financial studies and application of machine learning techniques and algorithms in financial analysis may yield superior results.

The models created show that profitability ratios are some of the most critical financial ratios in achieving and maintaining financial success. It would also be appropriate to claim that growth and leverage financial ratios provide valuable insights into financial stability and a firm's overall health. Achieving more favorable profit margins according to the nature of business, the country in which it operates and sector averages and ensuring profitable growth are the key factors to success. However, it is also crucial that firms should pay special attention not only to their profit margins but also to their operating cash cycle. Thus, they will be able to increase profit margins in the coming years.

As is the case with all studies, we acknowledge some limitations and those should be taken into consideration when generalizing the findings of our study. We exclude financial institutions (banks, insurance firms, brokerage firms, etc.) -because their financial statements differ in structure-, service sector firms, software firms, and waste management firms from the study. Second, the essence of our analyses is based on a set of financial ratios, which are derived from financial statements. Considering the possibility of window dressing of financial statements, the ratios may not reflect the firm's real situation and may show a better position than the actual. Since information asymmetry arises among managers and market participants, it is of vital importance to carefully evaluate the results of the current research. The value of the study, on the other hand, lies in two aspects: (1) Our study period coincides with the globally stable period (2) The models we develop are universal since we include firms from different countries and do not focus on the effect of firm size.

The methods do not seem to be equally accurate for predicting failed and non – failed firms because successful firms are classified more accurately. Investors, therefore, cannot completely avoid investing in firms likely to fail. As a consequence of the classification of a failing firm as successful, corrective actions may not be taken by the firm or it may already be too late. Future studies should focus on techniques that will reduce the risk of making a Type II error. In addition, researchers may succeed in improving classification accuracy by utilizing different financial ratios and including various macroeconomic indicators and non–financial variables such as firm size, age, ownership structure, and number of employees. It is also possible to collect data over a longer period of time and to use support vector machines, RF, or deep learning.

Declaration of Research and Publication Ethics
This study does not require ethics committee approval and/or legal/specific permission complies with the research and publication ethics.

Researcher's Contribution Rate Statement
The authors declare that the first author contributes 60% while the second author contributes 40%.

Declaration of Researcher's Conflict of Interest
There is no potential conflicts of interest in this study.

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Journal of Research in Economics, Politics & Finance, 2025, 10(1): 127-139
Araştırma Makalesi / Research Article, https://doi.org/10.30784/epfad.1599083

DYNAMICS OF CAUSALITY BETWEEN REAL ESTATE AND STOCK PRICES: EVIDENCE FROM TÜRKİYE

Gayrimenkul ve Hisse Senedi Fiyatları Arasındaki Nedenselliğin Dinamikleri: Türkiye'den Kanıtlar

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Keywords:
Real Estate Prices, Stock Prices, Asymmetric Relationship, Nonlinear ARDL Models

JEL Codes:
C22, G11, R31

Abstract

This paper aims to examine the causal relationship between real estate and stock prices in Türkiye over the 2010-2023 period and uncover whether the wealth effect or the credit price effect has been dominant. This study investigates the association between real estate prices and stock prices in Türkiye using both linear and non-linear ARDL cointegration models. A recently developed non-linear ARDL technique by Shin, Yu, and Greenwood-Nimmo (2014) is employed to investigate possible asymmetric relationships between real estate and stock prices. Linear ARDL bounds test results indicate strong evidence of wealth effect for Türkiye. The findings of the non-linear ARDL technique reveal that there is a strong asymmetric association between real estate and stock prices in Türkiye and there is evidence of the existence of both wealth and credit price effects. The asymmetric association is more dominant in the credit price effect model. The findings of the study will help both investors and policymakers to establish effective policies for developing portfolios considering the asymmetric associations and provide a better understanding of the driving forces behind real estate prices.

Anahtar Kelimeler:
Gayrimenkul Fiyatları, Hisse Senedi Fiyatları, Asimetrik İlişki, Doğrusal Olmayan ARDL Modelleri

JEL Kodları:
C22, G11, R31

Öz

Bu makale, 2010-2023 döneminde Türkiye'deki gayrimenkul ve hisse senedi fiyatları arasındaki nedensellik ilişkisini incelemeyi ve servet etkisinin mi yoksa kredi fiyatı etkisinin mi baskın olduğunu ortaya çıkarmayı amaçlamaktadır. Çalışmada Türkiye'de gayrimenkul ve hisse senedi fiyatları arasındaki ilişki doğrusal ve doğrusal olmayan ARDL eş bütünleşme modelleri kullanılarak incelenmektedir. Bu çalışmada, gayrimenkul ve hisse senedi fiyatları arasındaki olası asimetrik ilişkileri araştırmak için Shin, Yu ve Greenwood-Nimmo (2014) tarafından yakın zamanda geliştirilen doğrusal olmayan bir ARDL tekniği kullanılmaktadır. Doğrusal ARLD sınır testi sonuçları Türkiye için servet etkisine dair güçlü kanıtlar sunmaktadır. Çalışmanın bulguları, Türkiye'de gayrimenkul ve hisse senedi fiyatları arasında güçlü asimetrik bir ilişki olduğunu ve hem servet hem de kredi fiyatı etkilerinin varlığını ortaya koymaktadır. Asimetrik ilişki kredi fiyatı modelinde daha baskındır. Çalışmanın bulguları hem yatırımcıların hem de politika yapıcıların asimetrik ilişkileri göz önünde bulundurarak portföy geliştirmeye yönelik etkili politikalar oluşturmasına ve gayrimenkul fiyatlarının arkasındaki itici güçlerin daha iyi anlaşılmasına yardımcı olacaktır.

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Received Date (Makale Geliş Tarihi): 10.12.2024 Accepted Date (Makale Kabul Tarihi): 25.03.2025

1. Introduction

The vast growth of interest in financial markets has also brought about the importance of portfolio diversification possibilities. Besides the alternative financial instruments, investors have started to add real estate assets to their portfolios to improve the risk-returns performance. Investors increase their demand for assets in the stock market during the boom periods and balance their portfolios through investing in other assets, particularly real estate (Markowitz,1952). Traditionally, real estate assets, stocks, bonds, and similar instruments have been assumed to have low correlations (Kakes and Van Den End, 2004; Chan et al., 2011). Hence, these assets could be used together for portfolio diversification. However, recent experiences particularly during the COVID-19 pandemic period, indicate strong linkages between the real estate and stock markets (Al Refai et al., 2021; Chaudhry et al., 2021; Büyükkara et al., 2023; Kartal et al., 2023). Hence, clarifying the linkage between these markets, namely whether stock market performance leads the real estate market or real estate market performance leads the stock market provides crucial information.

In this study, we focus on Türkiye, an economy in which real estate has been a traditional investment instrument. There has been a rapid increase in the demand for housing in Türkiye particularly in the last decade. One of the reasons for this increase in demand is the aim of protecting the purchasing power of investors' savings in the face of high inflation. The rapid monetary expansion in the aftermath of the 2008 global financial crisis led to the rapid growth of the construction sector in Türkiye. Expansionary monetary policy over the 2018-2022 period eased the access to financial resources. This fostered an increase in commercial and residential projects. The increase in the number of immigrants, the increasing housing demand of foreigners due to the depreciation of the TL, and the granting of citizenship to foreigners also triggered the increase in housing demand. As of 2023, the homeownership ratio in Türkiye is 56.2 percent (TURKSTAT, 2024). The housing price index in Türkiye has increased from 154.90 in 2020 to 1273.30 in 2024 from 2020 to 2024 (CBRT, 2024). Preceding the global financial expansion after the 2008 crisis and expansionary monetary policy rules in Türkiye after 2018, interest in the Turkish stock market has also increased. As of mid of 2023, the demand for housing started to decline and this was also reflected in the lower real price index of housing in July 2023 for the first time after May 2020 (BETAM, 2023). In parallel, the Turkish economy has witnessed a 2.78 percent growth in stock market return in 2018 and this has reached 33.24 percent in 2021. In the meantime, despite the COVID-19 pandemic, Türkiye's economy grew by 1.9 percent in 2020 and achieved 11.4 percent growth in 2021, and 5.5 percent in 2022 (World Bank, 2024). In summary, the Turkish economy has experienced a period of dynamic and complex interactions among the real estate and financial sectors over the last decade. Hence, executing the link among them will provide valuable information for the policymakers and the investors.

There are two prominent approaches explaining the relationship between real estate and stock markets in the existing literature. The first is the "wealth effect" which reveals that households and investors tend to invest more in real estate due to the increase in their welfare caused by unexpected gains in the stock market. Second is the "credit-price effect". Credit-constrained firms use real estate as collateral. Hence, increases in real estate prices translate into lower costs of borrowing for credit-constrained firms and reduce their borrowing costs. This cost reduction will positively affect the profitability of the companies and consequently increase the stock prices of these companies.

The aim of this study is to examine the causal relationship between real estate and stock markets in Türkiye over the 2010-2023 period and uncover whether the wealth effect or the credit price effect has been dominant. The period of the study also includes the Covid-19 pandemic. Hence the findings will provide information about the dynamics of the relationship between real estate and stock markets in the shade of an unexperienced era. The study contributes to the literature in several ways. The majority of the previous papers on the relation between real estate and stock prices employ linear symmetric models, however, the direction and magnitude of the changes in real estate and stock prices may exhibit asymmetric patterns when the interaction among them is considered. For instance, increases and decreases in stock prices may not lead to equal and opposite effects on real estate prices. Few empirical studies applied the nonlinear autoregressive distributed lag (NARDL) model, considering this possible asymmetric relationship. To the authors' best knowledge this is the first study comprising the Turkish economy that uses the NARDL model developed by Shin et al. (2014) to analyze the dynamics among the real estate and stock prices. In that way, we aim to explore the possible asymmetric impact of positive and negative shocks on the series and their asymmetric adjustment patterns.

The remainder of the article is organized as follows. The literature is reviewed in Section 2. Section 3 describes the data and the estimation methodology. Estimation results are presented in Section 4. Section 5 concludes with the main findings and some concluding remarks.

2. Literature Review

The importance of the relationship between stock markets and real estate markets has gradually increased in the literature due to rapidly growing financial markets and volatility in real estate prices. However, the findings of these studies differ according to the countries and time periods examined and do not show a consensus. While the earliest of these studies find evidence of the wealth effect (E.g. Kapopoulos and Siokis, 2005; Kakes and Van Den End, 2004) more recent efforts based on a larger number of countries have not reached a concurrence. For example, in a study of 7 European countries, Irandoust (2021) found a wealth effect for the 1975-2017 period. However, Ali and Zaman (2017) found mixed effects for 22 European countries for the 1975-2017 period. Using panel cointegration and panel causality methods, this study found stock-led house prices in the short run and joint inter-dependence in the long run which confirms the feedback hypothesis for the stock and house prices. On the other hand, Gökmenoğlu and Hesami (2019) investigated the real estate and stock markets in Germany and found unidirectional causality from the real estate market to the stock market, which indicates the existence of a credit-price effect. In another study, Gil-Alana et al. (2020) analyzed the stock and real estate markets of BRICS countries by using daily values of real estate and stock indices. The findings of this study revealed a positive relationship between real estate and stock market indices for India and Russia, indicating a credit-price effect for these two countries. The study also discovered a two-way causal relationship between stock and real estate indices in South Africa.

Cultural factors are highly influential on individuals' investment decisions. Citizens of the Far East and Asian countries have more traditional investment behaviors like in Türkiye. In these countries, house ownership is very important and housing is seen as the main investment tool. In their study of Korea, where real estate is traditionally seen as an important investment tool, Sim and Chang (2006) examined different regional housing and land markets. The findings of the study revealed that stock prices in both national and regional markets are more strongly affected

by the prices of industrial land, while the effects of commercial and residential land prices are more limited. A strong causal relation from the real estate markets to the stock market was found indicating a credit-price effect. Another country where home ownership is important is Hong Kong. In a study conducted for this country, Hui and Ng (2012) examined the relationship between property prices and stock index for three sub-periods and revealed that the credit-price effect was valid in the first two sub-periods. In the third sub-period, it was observed that capital gains in the stock market increased the investments in this market and the capital gains in the real estate market increased the investments in this market, creating a snowball effect within each market. In another study in Hong Kong, Lee (2017) examined the causality relationship between residential property prices and stock prices. The findings show that in the long run, changes in stock prices affect residential property prices; in other words, the wealth effect is valid in Hong Kong.

With the fast development of financial markets in the last decade the number of studies examining the relationship between real estate prices and stock prices in Türkiye increased. In one of these studies, Yüksel (2016) analyzed the relationship between real estate and house prices in Türkiye and investigated how the 2007 global economic crisis affected this relationship. The study's findings showed that in the pre-crisis period, both credit-price and wealth effects existed in Türkiye however, for the crisis period evidence was found only for the credit-price effect. In a similar study, Afşar and Karpuz (2019) examined the same relationship by using time series estimation methods but could not find a significant relationship between the two markets for the 2000-2017 period. More recently, Torun and Demireli (2022) analyzed the dynamic causality relationship between housing and stock markets for the 2010-2021 period for Türkiye. They concluded that the interaction between the two markets changes over time and both wealth and credit-price effects are observed periodically.

In addition to the above-mentioned studies using the time series and cointegration methods, studies considering the asymmetric relationships between the real estate and stock markets have recently begun to appear in the literature. These studies use the NARDL method which allows researchers to account for asymmetries in responses to positive and negative shocks. One of the first studies that used this method on the subject was Okunev et al. (2000). They employed both linear and nonlinear causality tests to analyze the relationship between stock and housing markets in the US. Their findings indicate that stock prices significantly lead to house prices, demonstrating a wealth effect for the US. Al Refai et al. (2021) also used the NARDL method to analyze the relationship between real estate and stock markets in Qatar and found support for the wealth effect both in the short run and long run. Similarly, Mahmoudinia and Mostolizadeh's (2023) findings using the NARDL method support the wealth effect for Iran.

The NARDL method has been used only for a limited number of countries and Türkiye is not among these countries. To the best of the authors' knowledge, this is the first study to examine the relationship between real estate and stock prices for Türkiye using the NARDL method, and it is expected to contribute to the literature in this respect.

3. Data and Methodology

We address the linkages between real estate and stock markets using the following data. We employ the Borsa Istanbul Index (XU100) (*lnBIST*) to establish the stock market data. To

represent the real estate market we employ residential property indices, namely the general index (*lnhouse)*. We also use the three-month deposit rate (*R*). Following Al Refai et al. (2021), we use the return series both for the real estate and stock market variables. All series are taken in monthly frequency for the period January 2010-March 2023.

The descriptive statistics for the real estate and stock market prices are presented in Table 1. We observe that the average monthly change in the stock market has been greater than the real estate market over the sample period. The higher standard deviation of the stock market prices is in conformity with our expectations. This finding may seem to contradict the risk-return relationship, however, it is not surprising when the dynamics of the Turkish economy are considered over the sample period.

Table 1. Descriptive Statistics for Real Estate and Stock Market Data Indicators

Variable	lnBIST	lnhouse	R
Mean	7.186	4.509	12.481
Median	6.965	4.490	10.440
Std Dev	0.713	0.536	4.199
Max	9.076	6.294	23.770
Min	6.303	3.815	7.530

To trace the dynamic relationship between real estate and stock markets and uncover whether the wealth effect or credit-price effect is dominant in the Turkish economy, we use both linear and nonlinear ARDL models. ARDL models are independent of the order of integration of the series perform well in small samples and produce consistent estimates of long-run coefficients. Recently, Shin et al. (2014) have introduced a nonlinear ARDL model, building further the well-known model of Pesaran et al. (2001). The conventional ARDL model assumes a symmetric relationship among the variables. However, the positive and negative changes in the explanatory variables may have an asymmetric impact on the dependent variable. This approach is valuable in the sense that many economic and financial variables respond to positive and negative shocks in different directions and magnitudes.

We will employ the following equations to investigate the wealth effect and credit-price effect:

Wealth effect:

$$\ln(house_t) = \theta_0 + \theta_1 \ln(BIST_t) + \theta_2 R_t + \mu_t \quad (1)$$

Credit-price effect:

$$\ln(BIST_t) = \alpha_0 + \alpha_1 \ln(house_t) + \alpha_2 R_t + \varepsilon_t \quad (2)$$

To estimate short-run coefficients, we estimate the following error correction models, respectively:

$$\begin{aligned}\Delta\ln(house_t) = \gamma_0 &+ \sum_{k=1}^{m} \gamma_{1k} \Delta\ln(house_{t-k}) + \sum_{k=1}^{m} \gamma_{2k} \Delta\ln(BIST_{t-k}) \\ &+ \sum_{k=1}^{m} \gamma_{3k} \Delta(R_{t-k}) + \delta_1 \ln(house_{t-1}) + \delta_2 \ln(BIST_{t-1}) + \delta_3 \mathrm{R}_{t-1} \\ &+ u_t\end{aligned} \quad (3)$$

$$\Delta \ln(BIST_t) = \rho_0 + \sum_{k=1}^{m} \rho_{1k}\, \Delta \ln(BIST_{t-k}) + \sum_{k=1}^{m} \rho_{2k}\, \Delta \ln(house_{t-k}) + \sum_{k=1}^{m} \rho_{3k}\, \Delta(R_{t-k}) + \vartheta_1 \ln(BIST_{t-1}) + \vartheta_2 \ln(house_{t-1}) + \vartheta_3 \mathrm{R}_{t-1} + v_t \quad (4)$$

In equations 3 and 4, short-run coefficients are represented by differenced variables and δ_i's. ϑ_i 's indicate long run coefficients. Equations 1 and 2 provide long-run symmetric parameter estimates. To incorporate possible asymmetric impact among variables, following Shin et al. (2014), we establish the NARDL model. To this end, we decompose changes in *BIST* and *house* as positive and negative changes and develop new variables representing them.

$$\ln(house_t) = \beta_0 + \beta_1 \ln(BIST_t) + \beta_2\, R_t + \beta_3 \ln(BIST_t^+) + \beta_4 \ln(BIST_t^-) + \varphi_t \quad (5)$$

$$\ln(BIST_t) = \pi_0 + \pi_1 \ln(house_t) + \pi_2\, R_t + \pi_3 \ln(house_t^+) + \pi_4 \ln(house_t^-) + \omega_t \quad (6)$$

β_i and $\pi_i$are long-run parameters. The asymmetric effects of stock market and real estate market are incorporated by positive changes $BIST_t^+$, $house_t^+$ and negative changes $BIST_t^-$, $house_t^-$. $BIST_t^+$ and $house_t^+$ are the partial sums of positive changes in stock and real estate market whereas $BIST_t^-$ and $house_t^-$ are the partial sums of negative changes in these variables. These are defined in equations 7-10, below.

$$BIST^+ = \sum_{i=1}^{t} \Delta \ln(BIST_i^+) = \sum_{i=0}^{t} max\,(\Delta \ln BIST_i\ , 0) \quad (7)$$

$$BIST^- = \sum_{i=1}^{t} \Delta \ln(BIST_i^-) = \sum_{i=0}^{t} min\,(\Delta \ln BIST_i\ , 0) \quad (8)$$

$$house^+ = \sum_{i=1}^{t} \Delta \ln(house_i^+) = \sum_{i=0}^{t} max\,(\Delta \ln house_i\ , 0) \quad (9)$$

$$house^- = \sum_{i=1}^{t} \Delta ln(house_i^-) = \sum_{i=0}^{t} min\,(\Delta ln\, house_i\ , 0) \quad (10)$$

We proceed by substituting these new variables into equations 5 and 6 and reach the NARDL models as below:

$$\Delta \ln(house_t) = \gamma_0 + \sum_{k=1}^{m} \gamma_{1k}\, \Delta \ln(house_{t-k}) + \sum_{k=1}^{m} \gamma_{2k} \Delta {BIST^+}_{t-k} + \sum_{k=1}^{m} \gamma_{3k} \Delta {BIST^-}_{t-k} + \sum_{k=1}^{m} \gamma_{4k}\, \Delta(R_{t-k}) + \delta_1 \ln(house_{t-1}) + \delta_2 {BIST^+}_{t-1} + \delta_3 {BIST^-}_{t-1} + \delta_4 \mathrm{R}_{t-1} + u_t \quad (11)$$

$$\Delta \ln(BIST_t) = \rho_0 + \sum_{k=1}^{m} \rho_{1k}\, \Delta \ln(BIST_{t-k}) + \sum_{k=1}^{m} \rho_{2k} \Delta {house^+}_{t-k} + \sum_{k=1}^{m} \rho_{3k} \Delta {house^-}_{t-k} + \sum_{k=1}^{m} \rho_{4k}\, \Delta(R_{t-k}) + \vartheta_1 \ln(BIST_{t-1}) + \vartheta_2 {house^+}_{t-1} + \vartheta_3 {house^-}_{t-1} + \vartheta_4 \mathrm{R}_{t-1} + v_t \quad (12)$$

Shin et al. (2014) revealed that conventional bounds testing approach by Pesaran et al. (2001) is applicable after estimation of equations 11 and 12. If the bounds test statistics indicate cointegration, the next step is to test for short-run and long-run asymmetries. Wald test for asymmetric association rests on the null hypothesis stating size of negative and positive coefficients are the same. Hence rejection of the null hypothesis provides evidence of presence of asymmetries. These hypotheses are described in Table 2.

Table 2. Hypotheses for Asymmetric Impact

Hypothesis	**Wealth Effect**		**Credit-Price Effect**	
	Short-run Asymmetry	**Long-run Asymmetry**	**Short-run Asymmetry**	**Long-run Asymmetry**
H_0	$\gamma_{2k} = \gamma_{3k}$	$\delta_2 = \delta_3$	$\rho_{2k} = \rho_{3k}$	$\vartheta_2 = \vartheta_3$
H_1	$\gamma_{2k} \neq \gamma_{3k}$	$\delta_2 \neq \delta_3$	$\rho_{2k} \neq \rho_{3k}$	$\vartheta_2 \neq \vartheta_3$

4. Empirical Results

We start with examining unit root tests to investigate the integration properties of the series. To this end we both employ Augmented Dickey Fuller (ADF) test and Phillips-Perron (PP) tests. We use both tests to ensure none of the variables are I(2), since the bounds testing methodology fails in that case.

Table 3. Unit Root Tests (ADF and PP)

Variables	**ADF Unit Root Test**				**PP Unit Root Test**			
	c		**c+t**		**c**		**c+t**	
	Level	**First Diff**	**Level**	**First Diff**	**Level**	**First Diff**	**Level**	**First Diff**
	2.058	-11.188*	-0.012	-11.522*	1.995	-11.188*	-0.069	-11.519*
lnBIST	1.866	-4.424*	0.202	-4.181*	4.762	7.462*	2.502	-8.108*
lnhouse	-1.781	-5.756*	-3.629**	-5.742*	-1.669	-5.910*	-2.782	-5.883
R	2.058	-11.188*	-0.012	-11.522*	1.995	-11.188*	-0.069	-11.519*

Note: c and c+t refer to models with drift and with drift and trend, respectively. * and ** denote rejection of unit root at 1 and 5 percent respectively based on MacKinnon (1991).

The results of unit root tests in Table 3 indicate that none of the variables is integrated of order 2, I(2). Hence, we can proceed with the bounds testing approach. Table 4 presents the linear ARDL bounds test results.

Table 4. Linear ARDL Bounds Test Result

	Wealth Effect		**Credit-Price Effect**	
F-stat	6.017		3.846	
Significance	**Lower bound**	**Upper bound**	**Lower bound**	**Upper bound**
10%	2.630	3.350	2.630	3.350
5%	3.100	3.870	3.100	3.870
1%	4.130	5.000	4.130	5.000

Note: F-statistic is based on the bounds test, Pesaran et al. (2001). Lag length is determined by AIC.

Linear ARDL bounds test results indicate strong evidence of wealth effect. This finding is consistent with Ibrahim (2010), Lee (2017), and Irandoust (2021). However, evidence toward the credit-price effect is significant only at the 10% level since the F statistic falls into the

inconclusive region at 5 percent and 1 percent levels. Hence, we proceed with the NARDL bounds testing approach. The results are presented in Table 5. The NARDL bounds test results indicate strong evidence towards the existence of long-run relationships among variables. We find that both wealth and credit-price effects are present in the sample period.

Table 5. NARDL Bounds Test Result

	Wealth Effect		**Credit-Price Effect**	
F-stat	5.820		8.311	
Significance	**Lower bound**	**Upper bound**	**Lower bound**	**Upper bound**
10%	2.370	3.200	2.370	3.200
5%	2.790	3.670	2.790	3.670
1%	3.650	4.660	3.650	4.660

Note: F-statistic is based on the bounds test, Pesaran et al. (2001). Lag length is determined by AIC.

Proceeding with the error correction mechanism (ECM), we search for the short-run adjustment processes. The estimates of ECM of the linear ARDL model are reported in Table 6. The ECM results for linear ARDL models reveal that error correction terms (Cointeq(-1)) are negative and statistically significant. Hence, we can conclude that the speed of adjustment is 1.8 percent per month for the wealth effect model while it is 2.4 percent per month for the credit-price model. In other words, for the wealth effect model, 1.8 percent of the deviations from the long-run equilibrium are corrected within a month.

Table 6. NARDL Bounds Test Result

Wealth Effect ARDL (4,4,4)		**Credit-Price Effect ARDL (1,1,1)**	
Variable	**Coefficient**	**Variable**	**Coefficient**
D(ln(house)-1)	0.655* (0.076)	D(ln(*house*))	-0.345 (0.306)
D(ln(house)-2)	0.018 (0.094)	D(ln(*R*))	-0.219* (0.083)
D(ln(house)-3)	0.300* (0.075)	***Cointeq(-1)***	-0.024* (0.005)
D(ln(BIST))	0.0001 (0.009)		
D(ln(BIST)-1)	0.006 (0.010)		
D(ln(BIST)-2)	-0.020*** (0.010)		
D(ln(BIST)-3)	-0.019 (0.010)		
D(ln(R))	-0.056* (0.013)		
D(ln(R)-1)	0.055* (0.018)		
D(ln(R)-2)	-0.027 (0.018)		
D(ln(R)-3)	-0.029** (0.015)		
Cointeq(-1)	-0.018* (0.003)		

Note: The numbers in parentheses are the standard errors. ARDL models are specified based on AIC. * and ** denote significance at 1 and 5 percent, respectively.

We also provide the ECM results for the NARDL model. The results are presented in Table 7. The ECM results from the NARDL model indicate that the coefficient of the ECM term, *Cointeq(-1)*, is negative and statistically significant. We observe a 2.3 percent correction per month in the wealth effect model while the speed of correction is 6.7 percent in the credit-price model.

Table 7. Estimates of ECM of NARDL Model

Wealth Effect ARDL (4,4,1)		**Credit-Price Effect ARDL (1,0,0)**	
Variable	**Coefficient**	**Variable**	**Coefficient**
D(ln(house)-1)	0.677* (0.075)	*D(ln(house))*	-0.375 (0.329)
D(ln(house)-2)	0.017 (0.092)	*D(ln(R))*	-0.313* (0.096)
D(ln(house)-3)	0.333* (0.073)	*Cointeq(-1)*	-0.067* (0.010)
D(ln(R))	-0.067* (0.013)		
D(ln(R)-1)	0.065* (0.017)		
D(ln(R)-2)	-0.025 (0.018)		
D(ln(R)-3)	-0.029** (0.014)		
$D(ln(BIST))^{+}$	-0.036* (0.014)		
$D(ln(BIST))^{-}$	0.042* (0.018)		
Cointeq(-1)	-0.023* (0.004)		

Note: The numbers in parentheses are the standard errors. ARDL models are specified based on AIC.

We proceed by testing for long-run asymmetric impact based on NARDL models. The results are reported in Table 8. The results in Table 8 provide F-statistics based on the Wald test, assuming a symmetric coefficient. The findings provide evidence of a long-run asymmetric relationship between real estate and stock markets. This evidence is valid in both wealth effect and credit price effect models.

Table 8. Long-run Asymmetry

	Wealth Effect	**Credit-Price Effect**
	F-stat	**F-stat**
Long-run asymmetry	3.605** (0.029) [1,134]	14.443* (0.000) [1,138]

Note: Long run asymmetry test rests on the null hypothesis of symmetric coefficient. * and ** denote rejection of null hypothesis at 1 and 5 percent significantly.

The results in Table 9 indicate that asymmetric impact is present both in wealth-effect and credit-price effect models. In the wealth-effect NARDL model, we find that a percentage increase in the BIST return leads to an increase of 0.549 percent in real estate prices, on average. This finding is in line with the findings of Al Refai et al. (2021), and Mahmoudinia and Mostolizadeh

(2023). However, the fall in BIST return does not have any significant effect on real estate prices. This result represents a departure from Al Refai et al. (2021) but it is meaningful for the Turkish economy over the sample period. In the last decade, the Turkish stock market has attracted many new domestic and foreign investors owing to its high return potential. Particularly, domestic investors who have built up substantial wealth through stock market operations transferred their earnings toward the real estate market. Hence higher demand has resulted in higher prices in the real estate market. However, a decline in the stock market returns does not have a significant impact on the real estate market.

Table 9. Long-run NARDL Coefficient Estimates

Wealth Effect		**Credit-Price Effect**	
Variable	**NARDL Coefficient**	**Variable**	**NARDL Coefficient**
$ln(BIST)^+$	0.549* (0.165)	$ln(house)^+$	1.489* (0.269)
$ln(BIST)^-$	0.369 (0.278)	$ln(house)^-$	-32.187* (12.204)
ln(R)-1	0.284** (0.045)	*ln (R)*	-1.249** (0.492)
c	3.205* (0.291)	*c*	9.198* (1.119)

The credit-price effect NARDL model results are presented in the last column of Table 9. The findings are surprising to the end that the asymmetric impact of real estate prices on the stock market is very strong in case of bad times in the real estate market than the good times. These two markets are strongly interrelated with each other. Moreover, real estate investments and construction have been one of the major sources of economic growth over the last decade. An increase in real estate returns may be transferred to the stock market for financial investment opportunities. However, when the real estate market experiences a negative shock, this may serve as a signal of economic instability. This signal is negative not only for domestic investors but also for foreign investors. Hence a dramatic decline in the demand for the Turkish stock market is experienced as the negative and statistically significant -32.187 coefficient of *ln(house)* indicates.

Overall, our findings comprising the dynamics of real estate and stock markets in Türkiye indicate a clear asymmetric relationship. We find evidence towards the existence of both the wealth effect and credit price effect. The NARDL results have produced valuable information for policymakers and investors. The asymmetric association is clearly more dominant in the credit price effect model. Long-run positive changes in the real estate prices lead to a small positive impact on the Turkish stock market while a negative shock in the real estate sector leads to a dramatic decline in the stock market. The findings of the study provide valuable information for the policymakers in the sense that to promote the stability of the economy they should pay particular attention to fluctuations in the real estate prices and policies towards regulating real estate the market. The investors will also benefit from these findings and should adjust their portfolios considering the possible asymmetric associations.

5. Conclusion

This study investigates the association between the real estate market and the stock market in Türkiye using both linear and non-linear ARDL cointegration models. Consistent with previous studies, the linear ARDL cointegration test finds evidence of wealth effect (Kakes and Van Den End, 2004; Ibrahim, 2010; Lee, 2017; Irandoust, 2021). However, following Shin et al. (2014), we control the possible asymmetric associations among the variables and find evidence towards the existence of both wealth and credit price effects. It is notable to state that the NARDL process through the wealth effect model reveals that an increase in stock prices will lead to an increase in real estate prices. This finding is consistent with the findings of Okunev et al. (2000), Al Refai et al. (2021), and Mahmoudinia and Mostolizadeh (2023). However, the decline in stock prices does not have a significant impact on the real estate market. Interestingly, when we estimate the credit price effect model, we observe that both increases and decreases in real estate prices lead to significant changes in the stock market. However, the increases in real estate prices seem to have a small positive impact on the stock market whereas a decline in real estate prices will lead to a dramatic downturn in the stock market.

Overall, these findings provide important information for investors while setting up their portfolios and the policymakers to ensure economic stability. The strong asymmetric association among the real estate and stock markets is an important signal for investors who plan to include both assets in their portfolios. Strong asymmetric characteristics of this relationship over the downturn periods of the real estate market may discourage investors from including both assets in their portfolios at the same time. Moreover, the findings of the study reveal valuable information for the researchers. Linear ARDL models may provide misleading information about the association among the variables. Investigating the asymmetric nature of the relationship will demonstrate more relevant and precise policy recommendations. The results of the study unveil important information for the policymakers in the sense that to promote the stability of the economy they should pay particular attention to fluctuations in the real estate prices and develop policies towards regulating real estate the market.

Declaration of Research and Publication Ethics
This study which does not require ethics committee approval and/or legal/specific permission complies with the research and publication ethics.

Researcher's Contribution Rate Statement
The authors declare that they have contributed equally to the article.

Declaration of Researcher's Conflict of Interest
There are no potential conflicts of interest in this study.

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Journal of Research in Economics, Politics & Finance, 2025, 10(1): 140-159
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INFLATION SPILLOVERS AND GEOPOLITICAL RISKS: EVIDENCE FROM EURO AREA COUNTRIES USING TVP-VAR AND QUANTILE MODELS

Enflasyon Yayılma Etkileri ve Jeopolitik Riskler: TVP-VAR ve Kantil Modelleri Kullanılarak Euro Bölgesi Ülkelerinden Kanıtlar

Cumali MARANGOZ*

Keywords:
Inflation Transmission, European Union, Geopolitical Risks

JEL Codes:
C32, E31, R11

Abstract

This study examines the inflation transmission mechanism across 14 European Union countries, from May 1963 to November 2023. Contrary to the existing literature, this study employs a two-stage approach to examine the spillover effect of inflation in the European Region. The study identifies the inflation spillover effects by applying a time-varying parameter vector autoregressive (TVP-VAR) model with the joint connectedness framework. Moreover, we analyze the relationship between the Total Connectedness Index (TCI) and geopolitical risks (GPR) using the Quantile-on-Quantile (QoQ) model and explore how geopolitical uncertainties influence inflation transmission dynamics. The analysis provides significant contributions to the literature in terms of both methodology and scope by allowing responses to risk shocks of different magnitudes to be measured at quantile levels. The findings show that as Denmark, Germany, and France are highly interconnected with other countries in the region, they have an essential of spreading inflation. Unlike, the global and the US's risk indices, Russia's and Europe's GPR have a more significant impact on inflation. Finally, the interaction between TCI and GPR differ across quantiles, implying the existence of non-linear and asymmetric impacts of geopolitical events on inflation interconnectedness.

Anahtar Kelimeler:
Enflasyon Yayılımı, Avrupa Birliği, Jeopolitik Riskler

JEL Kodları:
C32, E31, R11

Öz

Bu çalışma, Mayıs 1963 ile Kasım 2023 arasındaki dönemde 14 Avrupa Birliği ülkesinde enflasyon yayılma mekanizmasını incelemektedir. Literatürün aksine, bu çalışmada Avrupa Bölgesi'nde enflasyonun yayılma etkisini incelemek için iki aşamalı bir yaklaşım kullanılmaktadır. Çalışmada, zamanla değişen parametreli vektör otoregresif (TVP-VAR) modeli ve ortak bağlantılılık çerçevesi kullanılarak enflasyonun yayılma etkileri belirlenmiştir. Ayrıca, Toplam Bağlantılılık Endeksi (TCI) ile jeopolitik riskler (GPR) arasındaki ilişki, Kantil-üzerinde-Kantil (QoQ) modeli ile analiz edilmiş ve jeopolitik belirsizliklerin enflasyon yayılma dinamiklerini nasıl etkilediği incelenmiştir. Analiz, farklı büyüklükteki risk şoklarına verilen tepkilerin kantil seviyelerinde ölçülmesine olanak tanıyarak hem metodoloji hem de kapsam açısından literatüre önemli katkılar sağlamaktadır. Bulgular, Danimarka, Almanya ve Fransa'nın bölgedeki diğer ülkelerle yüksek derecede bağlantılı olduğunu ve bu ülkelerin enflasyonun yayılmasında önemli bir role sahip olduğunu göstermektedir. Global ve ABD risk endekslerinin aksine, Rusya ve Avrupa'nın GPR'si enflasyon üzerinde daha önemli bir etkiye sahiptir. Son olarak, TCI ile GPR arasındaki etkileşimlerin farklı kantillerde değişiklik gösterdiği ve jeopolitik olayların enflasyon bağlantılılığı üzerinde doğrusal olmayan ve asimetrik etkiler yarattığı tespit edilmiştir.

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Received Date (Makale Geliş Tarihi): 11.12.2024 *Accepted Date (Makale Kabul Tarihi): 17.02.2025*

1. Introduction

The predictability and stability of inflation are crucial for effective economic planning and decision-making by individuals, firms, and policymakers. Stable inflation rates allow for more accurate forecasting of future costs and revenues, enabling better long-term investment strategies (Mishkin, 2007; Mankiw, 2014). Moreover, predictable inflation helps maintain the purchasing power of money, fostering consumer confidence and promoting overall economic growth (Taylor, 1993; Brown et al., 2023). Due to these advantages, one of the main targets of central banks is to determine the inflation level and it is generally kept in a band between 2-3 percent for developed countries. For instance, the monetary policy of the European Central Bank incorporates a target of 2% inflation for the aggregate of all Eurozone countries (ECB, 2021). Similarly, the Federal Reserve in the United States adheres to a long-term inflation target of 2%, aligning with its dual mandate of promoting maximum employment and price stability. This target is critical for maintaining economic predictability and fostering sustainable growth (Mishkin, 2007; Federal Reserve, 2023).

Notwithstanding, developed countries recognize the importance of maintaining stable inflation levels, inflation, once predominantly associated with developing nations, has become a significant concern in developed economies. Although it was previously believed that developed economies had resolved the issue of inflation through historical processes and that this phenomenon was primarily associated with developing countries, inflation has recently emerged as a significant concern for developed nations. Notably, the European Union, home to several developed nations, has witnessed heightened inflationary pressure in recent years. Geopolitical factors such as ongoing trade tensions between the US and China and the Russia-Ukraine war have exacerbated these pressures, disrupting economic stability and complicating inflation management. In particular, the Russian-Ukraine conflict led to surging energy costs (Gong, 2023; Hu, 2024) and supply chain interruptions (Zimková et al., 2023; Tyagi, 2024), driving inflation rates across European countries, which have faced substantial fluctuations in inflation rates due to these geopolitical disruptions. Due to geopolitical factors, firms in Europe have difficulties in forecasting costs, and consumers have challenges in spending, leading to disruptions in the entire European economy.

Figure 1 displays the inflation rates for specific geopolitical events influencing the European economy. For instance, inflation rates spiked as European countries faced increased energy costs and supply chain disruptions during the Russian-Ukraine war. Still, imported goods' price volatility caused higher production costs leading to higher consumer prices during trade tensions between the US and China.

Thanks to the events mentioned above causing disruptions in the European economy, there is a need to revisit inflation dynamics, particularly paying attention to different geopolitical risks. Conventional approaches to inflation factors deal with classic determinants. Yet, these approaches are incapable of comprehending the current economic conditions. Hence, scholars should apply a more comprehensive framework considering spillover effects on inflation. Especially, rising geopolitical risks, which have direct and indirect effects on the economy via energy prices and input costs, have made it crucial to apply a comprehensive approach to inflation dynamics (Caldara et al., 2019; García et al., 2024). Still, the literature on the spillover effects of inflation is limited. Many studies focus on the relationship between the spillover effect and geopolitical risk mainly use the global geopolitical risk index. Yet, using only the global geopolitical risk

index has limitations. The global geopolitical risk index offers an overall risk level by incorporating many geopolitical events and risks associated with different regions in a single framework. This approach neglects local differences. For instance, geopolitical incidents in the US, Russia, and Europe might have varying effects on energy markets and economic structures. A single global indicator is most likely to ignore these effects and might fail to analyze the spillover impacts of geopolitical risk on inflation accurately (Bouri et al., 2023). Hence, it would be hard to comprehend the regional differences in regional geopolitical risks.

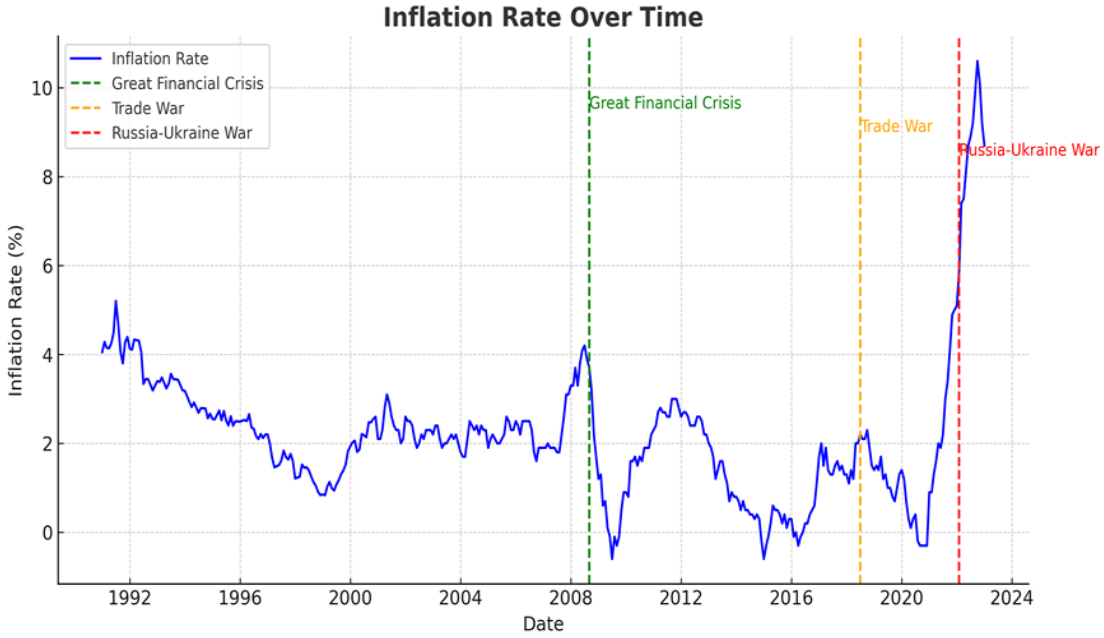

Figure 1. Harmonized Consumer Price Index in Eurozone (1997m12-2024m2)

Contrary to the existing literature, this study employs a two-stage approach to examine the spillover effect of inflation in the European Region. We first obtain the total spillover effect by performing the TVP-VAR model. Second, we incorporate the total spillover effect variable with the Global, European Region, Russia, and the US geopolitical risk indices, and analyze them by employing the QoQ model.

Euro Area forms the core focus of this study as it has a pivotal role in economic and monetary integration in the world. Hence, comprehension of inflation spillover effects and their interaction with geopolitical risks in the region is crucial for taking preemptive actions for possible repercussions.

This analysis method provides significant contributions to the literature in terms of both methodology and scope by allowing responses to risk shocks of different magnitudes to be measured at quantile levels. The findings of the study are crucial regarding policy design and risk management since the paper demonstrates the impact of geopolitical risks on inflation in stationary and dynamic conditions. In addition, employing both the TVP-VAR model and QoQ analysis is one of the paper's originalities enables us to analyze inflation spillover dynamics deeply.

The paper continues as follows. Section 2 provides a comprehensive review of the literature, focusing on inflation spillover dynamics and the role of geopolitical risks. Section 3 describes the data and presents summary statistics, highlighting key variables and their significance. Section 4 elaborates on the methodology, detailing the TVP-VAR and QoQ models employed. Section 5 discusses the empirical results, emphasizing the interconnectedness of inflation spillovers and the impact of geopolitical risks. Finally, Section 6 concludes with policy implications and recommendations for future research.

2. Literature Review

The relationship between inflation and geopolitical risks has been receiving increasing attention from macroeconomic policymakers and academic circles. The effects of geopolitical developments on energy markets, supply chains, and trade flows play a critical role in understanding inflation dynamics. However, studies addressing the regional variations of these effects are limited in the existing literature. Within the scope of the literature review, firstly the general relationship between inflation and geopolitical risks is focused on, then the spillover effects of inflation and the interaction of these effects with geopolitical risks are examined. Finally, studies conducted in the context of the European Region, which is the focus of the study, are evaluated. This comprehensive analysis allows for the identification of gaps in the existing literature and clarifies the contributions of this study.

2.1. Inflation and Geopolitical Risks

The impact of geopolitical threats on inflation has been the subject of conflicting findings in the literature. Some studies suggest that energy price increases (Bouri et al., 2023; Lee et al., 2023; Yang et al., 2023), changes in currency exchange rates (Hui, 2021; Salisu et al., 2022; Hossain et al., 2024), global supply chain disruptions (Ye et al., 2023; Qin et al., 2023), and increased uncertainty (Caldara and Iacoviello, 2022) result in geopolitical risks which lead to higher inflation. Yet some other studies show that geopolitical risk declines investor confidence and thereby reduces demand. Hence, consumers tend to save more than spend in higher geopolitical risk times, which causes a decrease in inflation (Bekaert et al., 2013). Overall, geopolitical risk might increase or decrease inflation and might have inflation-pressure effects in the long or short run.

2.2. Spillover Effect of Inflation and Geopolitical Risk

This study relates spillover effects to geopolitical risk with an extension of macroeconomic dynamics complexity. Many studies suggest that energy costs, trade relations, and regional political uncertainty impact inflation spillover mechanisms. For instance, Caldara and Iacoviello (2022) propose that inflation has a rapid spread in regions with high geopolitical risks, which increases economic uncertainty. The spillover effect is prominent in energy-dependent countries. Forbes et al. (2022) suggest that Germany and France have vital roles in transmitting and receiving inflation spillover effects. The authors also state the economic and trade connections configure the effects. In addition, Köse and Ünal (2025) pinpoint the role of important geopolitical events such as Brexit in cross-country spillover impact.

Policymakers face challenges due to geopolitical uncertainties and financial crises escalating spillover effect. According to García et al. (2024), inflation spillover effects have escalated via financial instability throughout COVID-19. Moreover, Yang et al. (2023) indicate that geopolitical risks have a more substantial impact on industrial demand for oil production than on oil supply disruptions, leading to transient rather than sustained increases in oil prices. In a nutshell, the literature highlights the close interaction among the economy, geopolitical risk, and inflation spillover effects.

2.3. Inflation Spillover Effects and Geopolitical Risks in the Euro Area

Trade bonds, financial integration and regional policies lead to inflation spillover effects in Europe. Table 1 gives a summary of the literature in European countries. The literature performs a diverse set of models to examine the inflation spillover effects in Europe. To illustrate, García et al. (2024) investigate the inflation spillover effects in Europe from 2018 to 2022 by performing structural VAR models. In addition, Bettarelli et al. (2024) how fiscal shocks in a given country affect foreign regions through regional trade linkages with the local projection method and suggest that countries-to-regions fiscal spillovers are positive, statistically significant, persistent, and non-negligible in size. Moreover, Marangoz (2025) finds that oil price shocks with deflationary trends during COVID-19 have inflationary consequences. and the European Central Bank's response to the pandemic-induced economic downturn has affected long-term inflation trends. Similarly, Kang et al. (2019) examine co-influences between inflation cycles of the economies of four Eurozone countries with a wavelet-based measure of synchronization and a directional spillover index approach. Still, Ciccarelli and Mojon (2010) argue that inflation synchronization in core countries was higher than in peripheral countries based on 1985-2009 data.

More recent studies have focused on the effects of geopolitical risks on inflation. Köse and Ünal (2025) emphasized that Brexit and transformed inflation dynamics in Europe and caused the spillover effects to differ. Forbes et al. (2022) showed with network analysis that Germany and France played net spreader roles, while Eastern European countries tended to be more affected. Pham and Sala (2022) found that financial imbalances accelerated the spillover effects after the 2008 global crisis, while Hall et al. (2023) found that inflation effects on peripheral economies intensified in the post-COVID-19 period. Bouri et al. (2023) Using the TVP-VAR connectivity model and QoQ analyses for the period 1963-2022, it was stated that geopolitically induced inflation caused inflation rates to move simultaneously in the North American and European economies, and this situation provided important clues for policymakers. As a result, inflation spillover effects in Europe are not limited to economic dynamics but are also deeply affected by factors such as energy prices and geopolitical risks. Studies in the literature aimed at understanding the complexity of these effects emphasize the need for new approaches in regional policies and the management of global shocks.

Table 1. Key Studies on Inflation Spillover and Geopolitical Risks in the Euro Area

Author (Year)	Data Range	Method	Finding
Ciccarelli and Mojon (2010)	1985–2009	Factor model with inflation synchronization indices	Core EU countries exhibit higher inflation synchronization than peripheral ones.
García et al. (2024)	1999–2013	Structural VAR models	Inflation spillovers are unidirectional from the USA to Europe, especially during crisis.
Kang et al. (2019)	1975–2017	Wavelet-based measure of synchronisation and a directional spillover index approach	Inflation cycles of the largest selected Eurozone economies lead those of the selected non-Eurozone economies
Windberger and Zeileis (2014)	1990 – 2010	Generalized Logistic Model with Structural Break Tests	Structural breaks in inflation dynamics suggest the potential influence of geopolitical or economic factors.
Bettarelli et al. (2018)	1993–2020	Local projection method to a panel of 222 NUTS-2 regions in 20 European countries	Countries-to-regions fiscal spillovers are positive, statistically significant, persistent, and non-negligible in size.
Köse and Ünal (2025)	January 2013–2020 December	Difference-in differences methodology	A nation departing from the EU may have inflationary issues, particularly in the sectors of energy and transportation.
Hall et al. (2023)	2015–2022	VAR and Spatial models	Post-COVID, inflation spillovers intensified, particularly towards peripheral economies.
Bouri et al. (2023)	May 1963 to November 2022	TVP-VAR Connectedness and Quantile on Quantile	Geopolitical-led inflation drives synchronization of inflation rates across North American and European economies.
Yang et al. (2023)	January 2000 to July 2022	Time-Varying Parameter Structural Vector Autoregression (TVP–SV–VAR)	Geopolitical risks have a more substantial impact on industrial demand for oil production than on oil supply disruptions, leading to transient rather than sustained increases in oil prices.
Marangoz (2025)	2010-2023	TVP-VAR model	Oil price and geopolitical shocks with deflationary trends during COVID-19 have inflationary consequences.

As a result, as summarized in Table 1, while there have been significant studies in the literature on the spillover effects of inflation in European economies, the effects of geopolitical risks have not been examined in sufficient detail. Existing studies generally address geopolitical risks at the global level, but do not deeply examine the specific effects of these risks on European economies. For example, Bouri et al. (2023) found that global geopolitical risks increased inflation synchronization in North American and European economies but did not focus on the effects of regional risks.

Euro Area forms the core focus of this study as it has a pivotal role in the economic and monetary integration in the world. Hence, comprehension of inflation spillover effects and their interaction with geopolitical risks in the region is crucial for taking preemptive actions for possible repercussions.

In this study, four different types of geopolitical risks (global, Russian, US, and European-specific risks) were examined and inflation spillover effects in Europe were analyzed. This approach, which specifically addresses the effects of regional risks, fills an important gap in the literature and provides a comprehensive contribution to how the economic dynamics of Europe are shaped by geopolitical factors.

3. Data

This study investigates the inflation transmission mechanism among European Union member countries, including Germany, France, Italy, Spain, the Netherlands, Denmark, Sweden, Poland, Belgium, Austria, Switzerland, Norway, and Finland, covering the period from May 1963 to November 2023, and examines the impact of geopolitical risks on this transmission. The extensive data range covers various economic, political, and geopolitics crises, including the Eurozone crisis, the 2008 global financial crisis, the COVID-19 pandemic, and the Russia-Ukraine war, supporting the accuracy of the analyses conducted in the study. In more detail, we use non-seasonally adjusted consumer price indices (CPI) obtained from the Federal Reserve Economic Database, along with the growth rate from the same period in the previous year, to analyze inflation dynamics. For each country, inflation growth rates from the same period in the previous year are illustrated in Fig.2. As seen in Fig.2, many European countries have been adversely affected in terms of inflation by the oil crisis in the late 1970s, the 2007-2088 global financial crisis, and most recently, the Ukraine-Russia war.

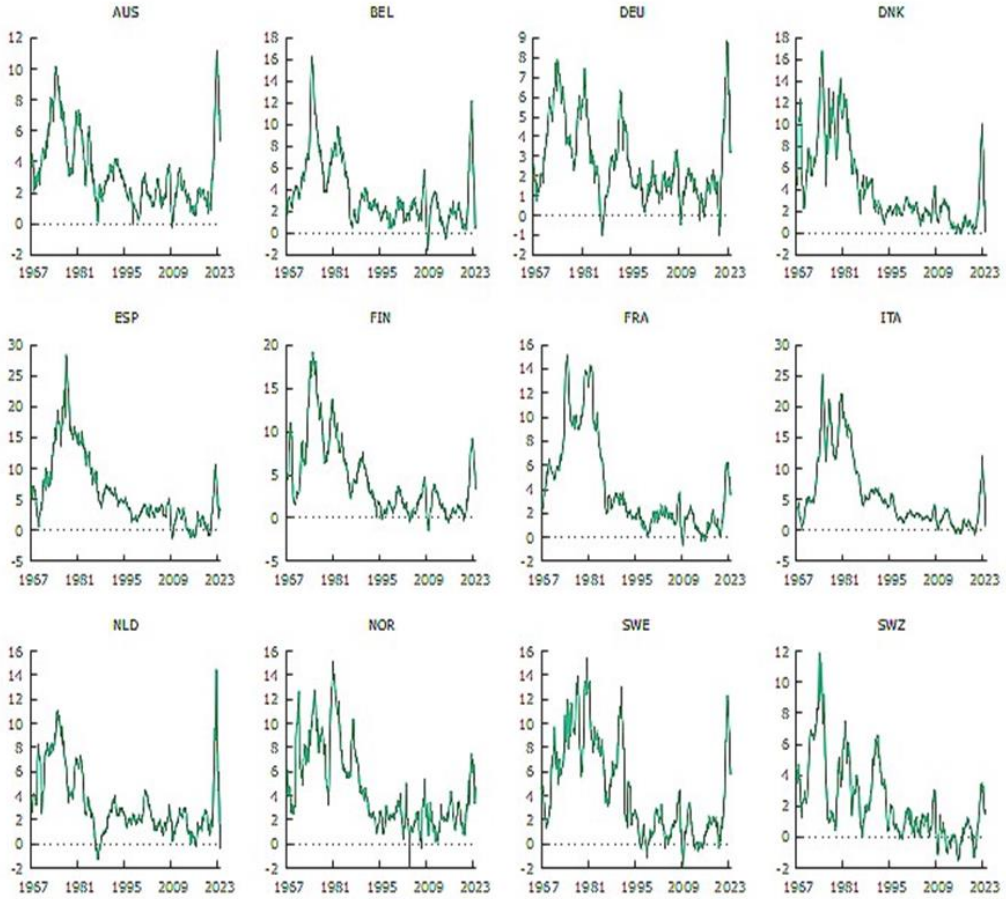

Figure 2. European Countries Inflation Rates (1967-2023)

Table 2 presents summary statistics of inflation rates across various countries. The highest average inflation rates are observed in ITA, followed by ESP, SWE, and FIN, while the lowest average rates are associated with DEU, NLD, and BEL. Regarding inflation rate variability, ITA, ESP, SWE, and FIN exhibit higher variability, whereas DEU, NLD, and BEL show lower variability. Notably, all inflation rates display significant right-skewness and leptokurtosis, except for NLD, which does not exhibit significant leptokurtosis. Moreover, none of the inflation rate series pass the Jarque and Bera (1980) normality test. Autocorrelation and ARCH/GARCH errors are detected in all inflation rates at least at the 1% significance level, with stationarity confirmed at least at the 10% significance level.

Table 2. Descriptive Statistics

Country / **Inflation**	**AUS**	**BEL**	**DNK**	**DEU**	**FRA**	**FIN**
Mean	3.371	3.638	4.377	2.698	4.127	4.55
Variance	5.228	8.901	14.416	4.009	14.766	19.327
Skewness	1.181****	1.531***	1.164***	0.852***	1.204***	1.261***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Ex. Kurtosis	0.888***	2.623***	0.389*	0.004	0.400**	1.054***
	(0.000)	(0.000)	(0.055)	(0.876)	(0.050)	(0.000)
JB	181.076***	462.766***	158.650***	82.678***	169.590***	212.759***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ERS	-2.762***	-3.369***	-2.594***	-2.843***	-1.759*	-2.305**
	(0.006)	(0.001)	(0.010)	(0.005)	(0.079)	(0.021)
Q (10)	3255.904***	3238.912***	3220.448***	3220.249***	3603.276***	3480.516***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Q2(10)	3136.053***	3077.111***	2947.507***	3075.234***	3478.905***	3410.347***
	(0.000)	(0.000)	(0.000)	0.000)	(0.000)	(0.000)
Country / **Inflation**	**ITA**	**NLD**	**NOR**	**ESP**	**SWE**	**SWZ**
Mean	5.88	3.393	4.571	6.303	4.434	2.272
Variance	33.327	7.315	11.22	33.007	15.583	6.255
Skewness	1.328***	1.162***	0.945***	1.268***	0.669***	1.164***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Ex. Kurtosis	0.812***	0.815***	0.034	1.192***	-0.654***	1.024***
	(0.001)	(0.000)	(0.749)	(0.000)	(0.000)	(0.000)
JB	219.529***	172.523***	101.785***	223.356***	63.149***	184.152***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ERS	-2.170***	-2.925***	-2.445***	-1.558***	-2.399**	-1.950*
	(0.000)	(0.004)	(0.015)	(0.000)	(0.017)	(0.052)
Q (10)	3517.756***	3163.942***	3251.585***	3530.342***	3322.996***	3303.482***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Q2(10)	3244.925***	3410.347***	2820.312***	3343.444***	3036.965***	3132.329***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Note: *, **. *** denotes a significance level of 10, 5%, and 1% significance level, respectively. JB: Jarque and Bera (1980) normality test, ERS: Elliott et al. (1996) unit root test, AUS: Austria, BEL: Belgium, DNK: Denmark, DEU: Germany, FIN: Finland, FRA: France, ITA: Italy, NLD: Netherlands, NOR: Norway, ESP: Spain, SWE: Sweden, SWZ: Switzerland

Furthermore, we also utilize the Geopolitical Risk Index (GPR) developed by Caldara and Lacoivello (2022) to examine its impact on inflation. The index is calculated by quantifying the occurrence of adverse geopolitical events within each newspaper monthly, expressed as a proportion of the total number of news articles. This search encompasses eight distinct categories:

War Threats, Peace Threats, Military Buildups, Nuclear Threats, Terror Threats, Beginning of War, Escalation of War, and Terror Acts. We also consider utilizing various geopolitical risk indices, including the GPR indices of Europe, the global domain, Russia, and the United States.

4. Methodology

4.1.TVP-VAR-Based Connectedness Framework

We use the TVP-VAR model. The TVP-Var model enables us to make a dynamic, time-sensitive analysis. Still, we perform the extended joint connectedness methodology proposed by Balcilar et al. (2021). The models of Diebold and Yılmaz (2012; 2014) and Antonakakis et al. (2018) are improved by the joint connectedness model. Thus, our comprehensive approach provides us with a more accurate analysis than static or rolling-window-based methods.

The TVP-VAR (1) model is as follows:

$$y_t = C_t y_t^{-1} + e_t, e_t \sim N(0, H_t), \quad (1)$$

$$vec(C_t) = vec(C_t^{-1}) + w_t, w_t \sim N(0, Q_t). \quad (2)$$

We are able to transform the model into its moving average (TVP-VMA) to grasp the propagation of shocks by using the Wold decomposition theorem:

$$y_t = \sum_{k=0}^{\infty} D_{k,t}\, e_{t-k} \quad (3)$$

We can calculate the Generalized Forecast Error Variance Decomposition (GFEVD) with the formula above (Koop et al., 1996; Pesaran and Shin, 1998). GFEVD quantifies the proportion of variance in one variable that can be attributed to shocks from other variables.

4.2. Extended Joint Connectedness Approach

TVP-VAR connectivity method is able to monitor and reduce spillovers in networks. The model enables policymakers to adjust their economic and political strategies. However, the model has some pitfalls. To overcome these shortcomings, A TVP-VAR approach is proposed by Antonakakis et al. (2018). This model detects the dependency on arbitrary sliding window sizes more accurately and sensitively. In addition, different normalization methods and joint spillover indices have been introduced by Caloia et al. (2019) and Lastrapes and Wiesen (2021). Finally, the extended joint connectivity framework derived from the TVP-VAR connectivity model is suggested by Lastrapes and Wiesen (2021). This model has the capability of computing complicated measures like directional and group-level connectivity indices. Moreover, the model offers a more detailed analysis of the link among variables. The generalized connectedness measure for a specific variable j is defined as:

$$R_j \leftarrow \cdot, t = \frac{(\sum_{k=0}^{P-1} u_j' D_{k,t} \Gamma_t N_j (N_j' \Gamma_t N_j)^{-1} N_j' \Gamma_t D_{k,t}' u_j)}{(\sum_{k=0}^{P-1} u_j' D_{k,t} \Gamma_t D_{k,t}' u_j)} \quad (4)$$

where $D_{k,t}$ is the time-varying impulse response coefficients. $D_{k,t}$ captures the dynamic effects of shocks on the variables over time. Γ_t is the covariance matrix and reflects the variability and interrelations among the shocks at a given time. Lastly, N_j is the contribution of other variables

in the system and helps to measure the influence of each variable on the others. The joint TCI is then calculated as the average contribution of all variables:

$$JTCI_t = \frac{1}{L}\sum_{j=1}^{L} R_{j\leftarrow.,t}^{int,from} \quad (5)$$

This index is between 0 and 1. As the index value comes closer to 1, interconnectedness becomes stronger. In sum, the extended joint connectedness approach, with its ability to capture dynamic relations, is a robust measure for examining inflation spillover effects.

4.3. Quantile on Quantile Regression

The QoQ approach is relatively new and has started to become a prominent model in the literature. The model is able to analyze fluctuating correlations between dependent and independent variables in the entire distribution (Sim and Zhou, 2015). Unlike classical models, the QoQ model examines variables' quantiles by considering distributional dependencies and nonlinear correlations. Thus, the model is likely to detect the effect of extreme values and events. As the effect of geopolitical risks on economic indicators is nonlinear and asymmetric, QoQ model is one of the best fits to examine. Moreover, high geopolitical risks have more impact on inflation than low ones (Ding et. al, 2022; Umar et al., 2022). Our aim is to analyze the diverse effects of GPR on certain levels of the Total Spillover Effect. We include the lagged values of GPR to capture the delayed impact of geopolitical risks on economic dynamics.

This approach allows us to reflect on the temporal dynamics since geopolitical risks propagate through inflationary processes in a timely manner. The QoQ method is as follows:

$$Y_t = Y^{\tau}(X_t) + \mu_t^{\tau} \quad (6)$$

where Y_t is the dependent variable, X_t denotes the independent variables, and τ is the quantile level. μ_t^{τ} is the error term, $Y^{\tau}$is an unknown function capturing the non-linear relationships. The bandwidth value of h = 0.05, following Sim and Zhou (2015). We adapt the general QQ equation to analyze the interactions between TCI and GPRs. We also incorporate the methodology of Bouri et al. (2023) in our analysis. Our model includes lagged GPR indices to evaluate the delayed effects on TCI. The model's equation is as follows:

$$TCI_t = TCI^{\tau}(GPR_{t-h}) + \mu_t^{\tau} \quad (7)$$

where TCI is the dependent variable, denoting the degree of connectedness. The independent variables are the lagged values of geopolitical risk indices (Global, U.S., Russian, and Euro-area geopolitical risks). These lagged values are denoted as GPR_{t-h},. The quantile level, τ, shows heterogeneous impacts. TCI^{τ}, demonstrates the nonlinear and quantile-dependent relationship between the lagged GPR indices and TCI. Finally, μ_t^{τ} is the error term. This specification enables a nuanced understanding of how geopolitical risks interact with economic interconnectedness.

5. Empirical Results

5.1. Total Connectedness

TCI evaluates how one variable influences another, on average. A rise in this index suggests greater interconnections among members (variables) in the network, which increases overall risk since a system shock can readily propagate to others. Conversely, a decline in the index denotes diminished connections between network members, indicating a decreased ability to affect other economies when an inflationary shock hits a specific market.

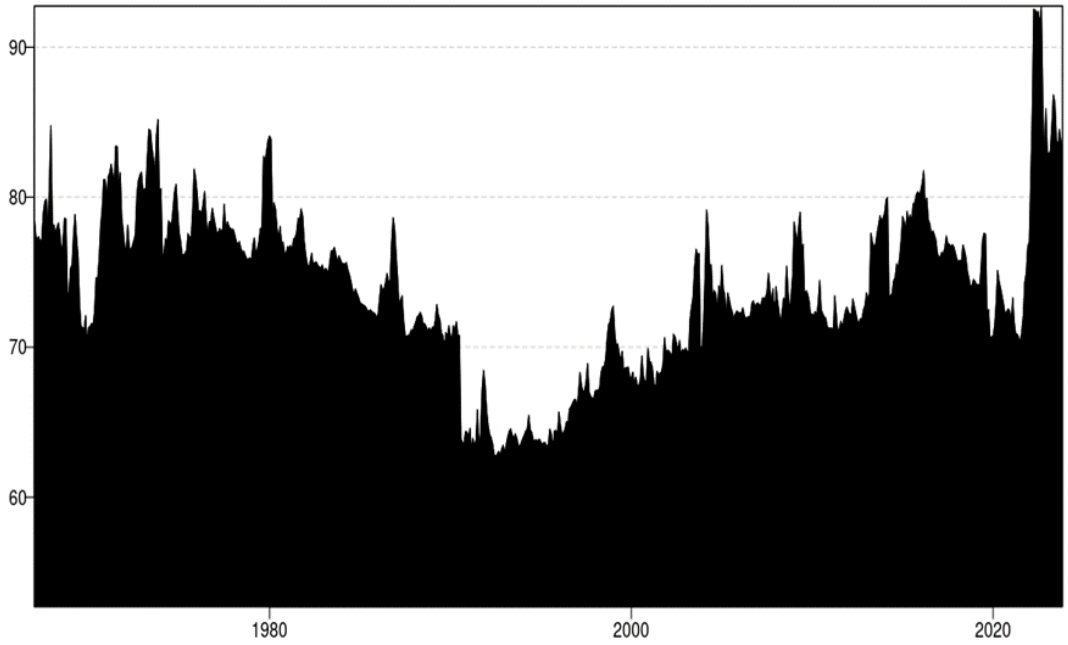

Figure 3. Total Connectedness Index (TCI)

Figure (3) shows the TCI, which measures the spillover effect of inflation among European countries from January 1967 to November 2023. In general, the TCI followed a fluctuating course and experienced significant increases during certain periods. More specifically after the turn of the millennium, as a result of deeper economic connectivity among European nations, inflation shocks have been more strongly transmitted to one another. Processes like the Eurozone's formation and the adoption of a unified currency have strengthened economic ties, leading to this. Major global shocks such as the 2008 Global Financial Crisis intensified this relationship (Barunik and Krehlik, 2018). In addition, the Arab-Israeli wars in the 1970s led to an oil embargo, and caused energy prices to soar, and formed inflationary pressures. Moreover, the peak of TCI in the table shows that the COVID-19 pandemic and the Russia-Ukraine War spread quickly through economic linkages between European countries, suggesting that regional economies are far more vulnerable to macroeconomic shocks. In sum, the figure demonstrates that geopolitical threats have a substantial impact on European countries.

5.2. Averaged Connectedness

Table 3 displays the spillover effect of inflation and the TCI. The TCI indicates the level of economic dependencies among countries and the transmission of inflation shocks to each other. According to Table 3, each country’s own TCI has significant weight in inflation spillover effects. To illustrate, Germany has a 29.95% effect on its own inflation spillover.

The results show that countries' own TCI values have a significant weight in inflation spillover effects. For example, Germany’s share in its own inflation spillover effect is 29.95%. Still, Switzerland’s own share is 36.26%. Besides, France’s effect on Germany’s inflation spillover is 14.89%. Strong economic ties between the two countries increase inflation spillover dynamics.

Table 3 also demonstrates that " the most receiver" country in the table is Austria. Austria has a NET value of -26.31, and it is most likely to be exposed to external shocks in the system with a NET value of -26.31. Likewise, Norway and the Netherlands pose negative NET values and tend to be affected by energy supply volatility. On the contrary, Denmark and Germany are “the most transmitters” of inflation spillover effects with a NET value of +59.18 and 38.79, respectively. That is, Germany has a powerful effect on other countries in the region via energy prices and production costs. These findings are in line with many studies in the literature. To illustrate, Devereux et al. (2023) suggest that Germany has strong fiscal and monetary spillover effects. A fiscal stimulus of 1% of GDP in Germany might result in an average increase of 0.2% of GDP in countries like France, Spain, and the Netherlands.

Moreover, the analysis displays heterogeneous effects. To give an example, Denmark has a negative effect (-12.47) on Sweden, implying that they have disparities in energy supply security and policy preferences. On the other hand, Belgium and the Netherlands have strong ties regarding trade and trade. Our results demonstrate that inflation spillover dynamics are significantly impacted by geopolitical risks, economic connections, and energy dependency. These findings are consistent with studies in the existing literature emphasizing the heterogeneous nature of inflation dynamics (e.g., Diebold and Yılmaz, 2014; Antonakakis et al., 2018).

Table 3. Averaged Connectedness Table

	AUS	BEL	DEU	DNK	ESP	FIN	FRA	ITA	NLD	NOR	SWE	SWZ	From
AUS	21.21 (0.00)	8.55 (2.28)	14.68 (10.54)	6.03 (-0.25)	5.62 (1.71)	8.09 (2.96)	9.65 (6.01)	2.65 (-1.26)	4.31 (-1.09)	4.34 (-2.08)	6.25 (3.02)	8.62 (4.44)	78.79
BEL	6.27 (-2.28)	21.58 (0.00)	10.55 (1.42)	9.58 (4.73)	4.8 (0.65)	6.4 (-0.09)	14.89 (7.10)	2.78 (-2.55)	3.5 (-1.09)	4.14 (0.23)	5.61 (1.43)	9.91 (2.39)	78.42
DEU	4.13 (-10.54)	9.13 (-1.42)	29.95 (0.00)	4.26 (-2.88)	4.31 (-5.83)	6.39 (-5.36)	8.14 (-1.58)	2.88 (-9.22)	3.78 (-7.08)	4.93 (-0.10)	8.81 (0.72)	13.29 (4.53)	70.05
DNK	6.29 (0.25)	4.85 (-4.73)	7.15 (2.88)	35.77 (0.00)	7.08 (-8.11)	3.01 (-13.16)	7.49 (-10.32)	7.29 (-10.78)	5.32 (-1.37)	2.43 (-12.47)	5.4 (-4.06)	7.93 (2.72)	64.23
ESP	3.9 (-1.71)	4.14 (-0.65)	10.14 (5.83)	15.19 (8.11)	20.4 (0.00)	4.02 (-1.18)	8.46 (1.71)	11.23 (4.08)	4.35 (0.70)	3.8 (-0.91)	9.77 (4.12)	4.61 (-0.42)	79.6
FIN	5.12 (-2.96)	6.49 (0.09)	11.76 (5.36)	16.18 (13.16)	5.2 (1.18)	22.65 (0.00)	6.42 (2.14)	4.18 (0.36)	3.15 (-4.61)	3.81 (0.52)	5.17 (0.89)	9.86 (3.35)	77.35
FRA	3.63 (-6.01)	7.79 (-7.10)	9.73 (1.58)	17.82 (10.32)	6.74 (-1.71)	4.28 (-2.14)	19.93 (0.00)	6.67 (-6.91)	5.54 (-2.64)	3.39 (-4.14)	8.89 (1.01)	5.6 (0.42)	80.07
ITA	3.91 (1.26)	5.33 (2.55)	12.1 (9.22)	18.07 (10.78)	7.15 (-4.08)	3.82 (-0.36)	13.58 (6.91)	12.71 (0.00)	3.46 (-0.26)	5.66 (1.00)	9.19 (1.40)	5.02 (1.63)	87.29
NLD	5.4 (1.09)	9.1 (1.09)	10.87 (7.08)	6.7 (1.37)	5.05 (0.70)	7.77 (4.61)	8.19 (2.64)	3.73 (0.26)	26.34 (0.00)	6.16 (1.90)	4.96 (2.31)	5.75 (1.40)	73.66
NOR	6.42 (2.08)	3.91 (-0.23)	5.03 (0.10)	14.91 (12.47)	4.71 (0.91)	3.29 (-0.52)	7.54 (4.14)	4.66 (-1.00)	4.25 (-1.90)	33.28 (0.00)	6.99 (2.09)	5.01 (1.46)	66.72
SWE	3.23 (-3.02)	4.17 (-1.43)	8.09 (-0.72)	9.46 (4.06)	5.64 (-4.12)	6.06 (0.89)	7.88 (-1.01)	7.79 (-1.40)	2.83 (-2.31)	4.9 (-2.09)	33.38 (0.00)	6.55 (-2.45)	66.62
SWZ	4.17 (-4.44)	7.52 (-2.39)	8.75 (-4.53)	5.2 (-2.72)	5.04 (0.42)	6.51 (-3.35)	5.12 (-0.42)	3.39 (-1.63)	2.57 (-3.18)	6.47 (1.46)	9.01 (2.45)	36.26 (0.00)	63.74
TO	52.47	70.97	108.85	123.41	61.33	59.63	97.36	57.23	43.05	50.03	80.05	82.15	886.53
Inc.own	73.69	92.55	138.79	159.18	81.73	82.28	117.28	69.94	69.39	83.31	113.44	118.41	TCI
NET	-26.31	-7.45	38.79	59.18	-18.27	-17.72	17.28	-30.06	-30.61	-16.69	13.44	18.41	73.88
NPT	4	4	9	8	6	3	7	3	2	5	9	8	

In addition, the study also graphically visualizes the Net Pairwise Directional Connectedness between countries. This network graph (Figure 4) reveals the directions of economic connectivity and influences between countries. Blue nodes (e.g., Denmark (DNK), Germany (DEU), Sweden (SWE)) represent the central countries of the network, while yellow nodes (e.g., Italy (ITA), Netherlands (NLD), Austria (AUS)) represent the peripheral countries. Central countries have stronger connections and play an influencing (transmitter) role, while peripheral countries are generally the receivers.

Denmark and Germany, as the central actors of the network, exert extensive economic influences. Denmark particularly influences Sweden, Norway, and the Netherlands, while Germany has strong ties to France and Belgium. The thickness of the lines reflects the intensity of influences between countries. In contrast, peripheral countries such as Austria and Switzerland have more limited connections. The graph clearly shows the core-periphery dynamics in the economic system and the roles of countries in economic relations.

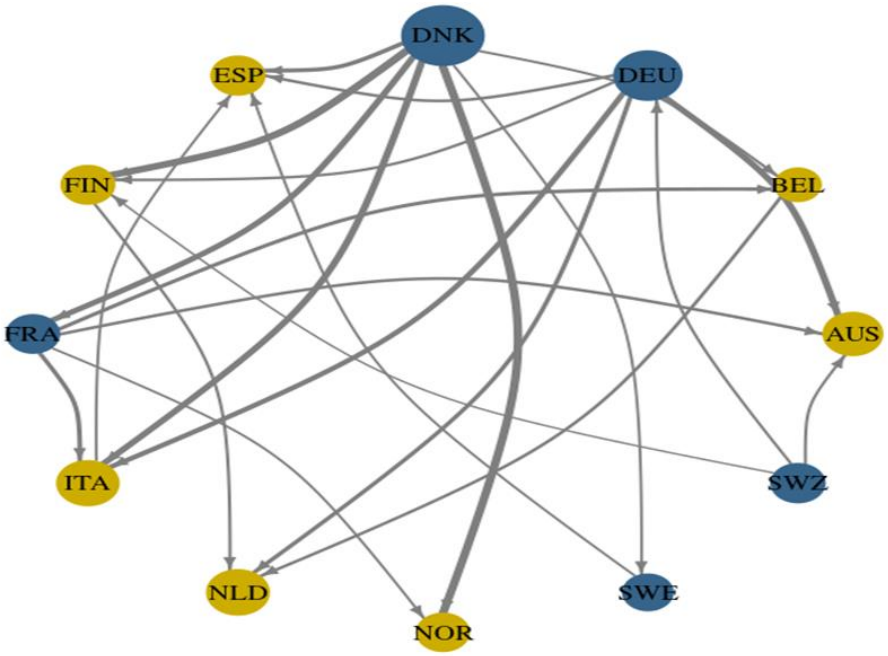

Figure 4. Net Pairwise Directional Connectedness

5.3. Result of Quantile-on-Quantile Method

This section outlines the main empirical findings of the QoQ analysis examining the interaction between the TCI and GPR across four groups: global, U.S., Russian, and Euro-area GPRs. The analysis explores how different quantiles of TCI respond to the corresponding quantiles of GPR, with the slope coefficient, $\beta_1(\theta, \tau)$, capturing the effect of the τ-th quantile of GPR on the θ-th quantile of TCI.

To account for the delayed effects of GPR on TCI, lagged values of GPR were included in the analysis, determined by Schwarz lag selection criteria. Furthermore, since the coefficient ranges of the GPR indices differ significantly across groups, the heatmap visualization focuses on the Euro area GPR, which exhibits the highest coefficients in the QQ interaction with TCI. This allows for a clearer interpretation of the most pronounced relationships between geopolitical

risks and connectedness. Figures 5 illustrate several key findings from the analysis. The results demonstrate that the relationship between TCI and GPR varies significantly across different groups, including global, U.S., Russian, and Euro-area GPRs.

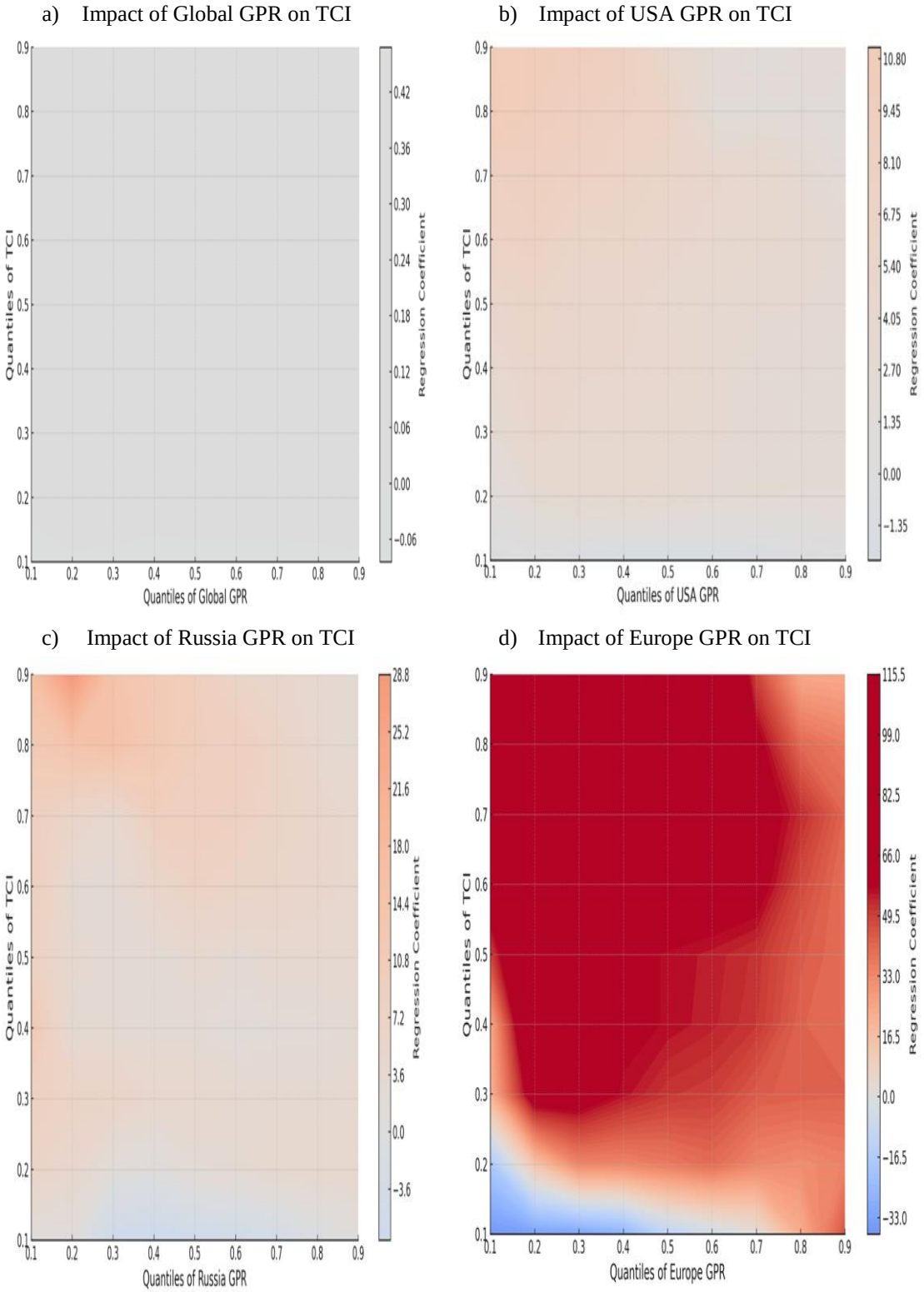

Figure 5. Quantile-on-Quantile Analysis: TCI vs. Geopolitical Risks (Russia, USA, Global, Euro)

At high quantiles, the results indicate that geopolitical risks significantly amplify the interconnectedness among economies, implying that implementing proactive measures is important, as these risks can exacerbate inflation spillover effects. For example, during the Russia-Ukraine conflict, energy price volatility had a disproportionate impact on inflation dynamics in European economies.

In global GPR, the effect on TCI is almost negligible. The dominance of gray tones in the graph indicates that global risks do not exhibit a significant relationship with TCI. This result suggests that the effect of global risks is diluted and that analyses conducted at the regional level may be more explanatory. These results are consistent with Chatziantoniou and Gabauer (2021), who found the influence of global GPR on market interconnectedness, particularly on TCI, is less significant globally but more pronounced regionally.

In the US, the relationship between geopolitical risks and TCI is generally observed to be positive in low and medium quantiles (light orange tones). However, these effects generally exhibit a weaker intensity. In high quantiles, this positive effect is seen to be slightly more pronounced. However, a strong relationship does not emerge as in Europe. This finding supports the results of Eldor and Melnick’s (2004) results, implying that political events have a weaker direct impact on stable markets than major geopolitical shocks.

The impact of Russian GPR on TCI is relatively weak but still positive in Russia compared to Europe. The effect is weakly positive at lower and medium quantiles (0.2-0.7). Besides, at higher quantiles, the impacts do not increase. Yet, Russian GPR is comparatively stronger than the US and Global GPR in terms of TCI, highlighting the pivotal energy role of Russia and regional risks (Ahmed et al., 2022; Foglia et al., 2023).

Geopolitical risks have varying effects with quantiles on TCI in Europe. European GPR is negative (blue areas) at low quantiles (0.1-0.3). In addition, it is relatively strong (dark red areas) at medium and high quantiles (0.5-0.9). Hence, we conclude that economic interconnectedness is weaker during periods of low geopolitical risk in Europe. As geopolitical risks increase, economic systems become more tightly connected and markets more integrated. Particularly at the highest quantiles (0.7-0.9), the impact of GPR is significant, suggesting that in high-risk environments, the European economy becomes more interconnected, and risk management mechanisms are more actively implemented. The varying effects of Eurozone GPR, with negative impacts at lower quantiles and strong positive impacts at higher quantiles, support findings on Europe’s interconnected financial and energy markets. Dai et al. (2022) and Chatziantoniou and Gabauer (2021) show that increased geopolitical risks might cause strict economic connections and active risk management strategies within the Eurozone.

6. Policy Implications and Conclusion

This study analyzes how the inflation spillover in Europe is affected by GPR using the Connectedness model and QoQ methods. The results show that despite the limited impact of the Global and the US GPR index, Russia and Europe’s indices have a significant effect on the TCI. Particularly, as Russia has a central role in energy markets, its GPR index is prominent and has a powerful regional influence. The dependence on the Russian energy supply makes the effect more pronounced, especially in energy-importing European countries. There is a strong correlation between Russia’s GPR and inflation at higher percentiles, implying that economic systems in

these regions are more sensitive to energy supply shocks and that geopolitical risks can significantly shape inflation dynamics. Hence, energy price volatility is likely to exert pressure on inflation through spillover effects on production costs and consumer prices. Therefore, Russia's geopolitical risks vary on regional risk exposure and the fragility of energy supply chains. In brief, QoQ analysis suggests that effects are heterogeneous on average and at different quantile levels. That is the magnitude and direction of geopolitical shocks on inflation spillovers differ depending on the circumstances.

In line with Foglia et al. (2023), the findings show that the Global and US geopolitical risks have a weak effect on regional spillovers. In addition, the study shows that Russia, being a prominent energy supplier, has a significant influence on inflation spillovers in Europe. This finding is supported by the works of Ahmed et al. (2022) and Stern (2014), who suggest that energy-importing countries are vulnerable to supply shocks. Moreover, as Dai et al. (2022) underpin that high energy prices lead to higher production costs and consumer price pressures in times of high geopolitical risk and tensions, this paper has similar findings in quantile-specific sensitivity to geopolitical risks. Consistent with López and Papell (2012) and Dai et al. (2022), who suggest energy security and infrastructural investment requirements diminish economic fragility, diversifying energy sources, and investing in renewable energy sources are essential for the European economy.

These findings highlight the importance of policies to diversify energy supply. Renewable energy investments and infrastructure development projects that will increase energy supply security in Europe can reduce inflationary pressures caused by geopolitical risks. In addition, integrating a framework that evaluates the impact of geopolitical risks into monetary policies can create an economic structure that is more resilient to the spread of inflation. Strengthening regional cooperation and crisis management mechanisms can also contribute to maintaining economic stability in high-risk environments.

Central banks might regularly overview inflation targeting strategies and might use dynamic models. Therefore, they would be able to anticipate energy price fluctuations and geopolitical shocks. Moreover, central banks might adopt flexible interest rate policies to overcome energy-driven inflationary pressures. In addition, central banks should organize foreign exchange reserves to diversify the currencies used for energy imports.

Regarding energy policies, policymakers might invest in renewable energy and energy diversification projects to reduce dependence on Russia for energy supply. In the longer term, European economies should establish common reserve systems and promote economic diversification in non-energy sectors to enhance energy security.

Declaration of Research and Publication Ethics
This study which does not require ethics committee approval and/or legal/specific permission complies with the research and publication ethics.

Researcher's Contribution Rate Statement
I am a single author of this paper. My contribution is 100%.

Declaration of Researcher's Conflict of Interest
There is no potential conflicts of interest in this study.

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Ekonomi, Politika & Finans Araştırmaları Dergisi, 2025, 10(1): 160-183
Journal of Research in Economics, Politics & Finance, 2025, 10(1): 160-183
Araştırma Makalesi / Research Article, https://doi.org/10.30784/epfad.1602204

THE COMPARISON OF ARTIFICIAL NEURAL NETWORKS AND PANEL DATA ANALYSIS ON PROFITABILITY PREDICTION: THE CASE OF REAL ESTATE INVESTMENT TRUSTS*

Kârlılık Tahmininde Yapay Sinir Ağları ve Panel Veri Analizinin Karşılaştırılması: Gayrimenkul Yatırım Ortaklıkları Örneği

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Keywords:
Profitability Prediction, Artificial Neural Network, Panel Data

JEL Codes:
G17, C33, C45

Abstract

In recent years, machine learning techniques have come to the forefront for profitability forecasting due to their flexibility in computation, ability to work with large and diverse data types, and capability to predict real-time changes. In addition, predicting profitability in practice is challenging and requires expertise. The primary aim of this study is to determine the most suitable profitability prediction model using Artificial Neural Network (ANN) algorithms, one of the machine learning techniques. Furthermore, the ANN prediction model was applied to the data set for the 2010-2019 quarters created from the financial statements of Real Estate Investment Trusts (REITs) companies traded in Borsa Istanbul (BIST) and the prediction success of the ANN technique was interpreted by comparing the findings obtained with the findings obtained as a result of panel data analysis. The comparison of these values with the findings of the panel data analysis has led to the conclusion that ANN prediction models can make more successful forecasts than panel data analysis models.

Anahtar Kelimeler:
Kârlılık Tahmini, Yapay Sinir Ağı, Panel Veri

JEL Kodları:
G17, C33, C45

Öz

Son yıllarda makine öğrenmesi teknikleri, hesaplamadaki esneklikleri, büyük ve çeşitli veri türleriyle çalışabilmeleri ve gerçek zamanlı değişiklikleri tahmin edebilme yetenekleri nedeniyle kârlılık tahmininde ön plana çıkmıştır. Ayrıca uygulamada kârlılığı tahmin etmek zordur ve uzmanlık gerektirir. Bu çalışmanın temel amacı, makine öğrenmesi tekniklerinden biri olan Yapay Sinir Ağları (YSA) algoritmalarını kullanarak en uygun kârlılık tahmin modelini belirlemektir. Ayrıca Borsa İstanbul'da (BİST) işlem gören Gayrimenkul Yatırım Ortaklıkları (GYO) firmalarının mali tablolarından oluşturulan 2010-2019 çeyrek dönemlerine ait veri setine YSA tahmin modeli uygulanmış ve elde edilen bulgular, panel veri analizi uygulanması sonucu elde edilen bulgularla karşılaştırılarak YSA tekniğinin tahmin başarısı yorumlanmıştır. Bu değerlerin yapılan panel veri analizi bulgularıyla karşılaştırılması neticesinde, YSA tahmin modellerinin, panel veri analiz modellerine göre daha başarılı tahmin yapabildiği sonucuna ulaşılmıştır.

* This study has been derived from Ayşegül Peker's doctoral thesis titled "Profitability Estimation with Artificial Neural Networks and Comparison with Panel Data Analysis: The Case of Real Estate Investment Trusts."

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Received Date (Makale Geliş Tarihi): 16.12.2024 Accepted Date (Makale Kabul Tarihi): 28.02.2025

1. Introduction

Machine learning techniques have been actively used to analyze financial markets in recent years due to the improvement in computational capability, information processing capability, and ease of access to data. There have been various attempts to make predictions about financial market data, ranging from the traditional time series approach to artificial intelligence (Min, 2020). The ANN is one of the most widely used methods of artificial intelligence, emerged by imitating the human brain (Eğrioğlu et al., 2019).

ANNs are computer-assisted systems used to generate, recognize, predict, and analyze new information using the ability to learn the qualities of the human brain (Yavuz and Deveci, 2012). Due to their generalization, non-linearity, parallelism, flexibility, missing data, fault tolerance, and ability to work with many variables and parameters, ANNs are very successful in providing adaptive solutions based on learning in the analysis of problems that cannot be solved using traditional modeling methods (simple regression models, large-scale structural macro-econometric scale models, Box-Jenkins (ARMA) model and VAR (Vector Autoregressive) modeling techniques, etc.) (Sönmez et al., 2015). A further advantage is that it does not require assumptions about data distribution and variables (Yavuz and Deveci, 2012).

ANNs have been developed as a better alternative to traditional and parametric methods with their nonlinear properties. As machine learning has found a space in every field today, many techniques have developed along with it. One of the fields benefiting the most from these techniques is the finance sector. The integration of ANNs into financial applications emerged in the late 1980s and early 1990s. These applications generally focused on stock prediction or financial earnings forecasting (Schöneburg, 1990; Callen et al., 1996). Although the use of traditional econometric modeling techniques has increased due to the increasing competition in financial markets with the development of technology, they have become insufficient over time. Therefore, ANNs, a more advanced technique, can be used to replace or supplement existing traditional modeling techniques. With the turn of the 2000s, studies advanced with larger datasets and financial indicators, comparing ANN models with traditional models such as logistic regression, multiple regression, and Generalized AutoRegressive Conditional Heteroskedasticity (GARCH) (Fernandez-Rodriguez et al., 2000; Olson and Mossman, 2003; Bakar and Tahir, 2009). After 2010, the use of advanced methods, such as deep learning techniques and hybrid models, became more widespread (Saberi et al., 2016; Lado-Sestayo and Vivel-Bua, 2020; Alaameri and Faihan, 2022; Vukovic et al., 2023). When the conducted studies are evaluated, it is generally observed that ANN tends to provide higher performance compared to traditional methods. ANN, in particular, demonstrates superiority in handling the complexity of financial data due to its ability to better model nonlinear relationships (Heo et al., 2020; Ho et al., 2020). However, there are instances where traditional methods, such as multiple regression, have yielded better results in certain studies (Mohamad et al., 2013).

The application of ANNs in different financial areas such as stock performance, financial time series prediction, bankruptcy prediction, bond rating improvement, credit risk analysis, and investment management prediction has yielded very successful results (Burrell and Folarin, 1997). This article aims to predict the regression model for profitability using financial ratios with ANN, one of the machine learning techniques, and to compare it with the results of panel data analysis.

A review of the literature reveals that a significant portion of studies employing ANN focus on predicting bank profitability and stock prices (Desai and Bharati, 1998; Sönmez et al., 2015; Ömürbek et al., 2019; Marak et al., 2022). Considering the more limited datasets available in studies conducted in Turkey, it can be said that research predominantly focuses on the banking sector. This sector is followed by the industrial and manufacturing sectors, REITs, and the technology sector, respectively. In terms of initial public offerings (IPOs), the energy and natural resources sector ranks first, followed by REITs. In recent years, REITs in Turkey have been among the most invested sectors in developing countries like ours. The primary reason for this is that real estate is a traditional investment instrument and generally provides protection against inflation. The value of real estate properties and rental income tend to increase in parallel with inflation rates. REITs typically distribute rental income and capital gains as dividends, ensuring a stable cash flow, particularly in the long term. From this perspective, compared to other sectors, REITs offer more predictable and reliable investment models. Furthermore, for small investors, REITs provide the opportunity to participate in individual capital, large-scale investments, and long-term property ownership. Despite the global increase in studies analyzing the profitability of REIT firms, it is evident that research in this area in Turkey is relatively new, beginning to gain prevalence only in the 2000s (Çelik and Arslanlı, 2020; Aktaş and Darwish, 2020; Tekin, 2021; Coşkuner et al., 2024).

The aim of this study is to estimate a regression model for profitability using ANN, one of the machine learning techniques, based on financial ratios, and to compare the results with panel data analysis. The scope of the application includes REITs listed on BIST and registered with the Capital Markets Board (CMB), which hold a significant market share. REITs are obligated to regularly distribute dividends to fund owners, making them more predictable and reliable compared to other sectors. Additionally, rental income and asset appreciation from REIT investments provide a long-term and balanced investment instrument. Their operation through physical real estate investments also makes them less susceptible to speculative movements in financial markets. Furthermore, REITs are significant as they offer investors the opportunity to invest without requiring substantial capital. In the literature, almost all studies conducted on REIT firms focus on identifying the factors affecting profitability. The motivation for this study arises from the significant role that REITs play in real estate-rich countries like Turkey and the absence of studies that predict the profitability of these firms using ANN models. In this respect, the contribution of the study to the literature is considered significant. Furthermore, the study compares ANN models with panel data analysis models. The lack of research that compares these two models for profitability analysis further highlights the contribution this study will make to the existing literature.

2. Literature Review

It has been observed that studies comparing ANN and panel data analysis methods are limited both globally and in Turkey. Brief mentions and explanations of studies comparing these two methods are provided below. Heo et al. (2020) conducted a comparison using panel data analysis and ANN models to develop alternative methods for explaining and predicting household financial ratios. They found that ANN models provided a better overall model fit when defining and forecasting financial ratios. Similarly, Ho et al. (2020) analyzed the shifting apparel import patterns of the United States (USA) from China and 14 Belt and Road (B&R) countries in Asia.

They applied panel regression models and ANN analyses to data from 1998 to 2018, using their developed model to predict the trade patterns for 2019. Their results demonstrated that the predictive power of the ANN model was superior. Kıral and Çelik (2020) utilized a panel data regression model to identify factors affecting housing prices in Turkey. They then applied an ANN analysis to forecast housing prices based on the identified factors. Their findings indicated that the factors determined by the two methods were inconsistent. Similarly, Parlakkaya et al. (2022) examined the factors influencing the capital structures of conventional and participation banks in the Turkish banking sector. Using financial data from banks between 2010 and 2020, they analyzed the data using both panel data regression and ANN models. The limited studies combining ANN and panel data analysis have contributed to shaping one of the main ideas for our research.

Although REITs in Turkey began operating in the mid-1980s, academic studies on the subject became widespread in the 2000s. Studies specifically focusing on profitability analyses of REITs in both Turkey and the world emerged more prominently toward the late 2010s. A review of the existing literature reveals that various methods have been used to measure REIT profitability. Jakpar et al. (2018) analyzed the factors determining the return on equity (ROE) of eight REITs in Malaysia between 2008 and 2015 using panel data analysis. Similarly, Ocakdan (2019) examined the profitability of 33 REITs in Turkey during the period 2014–2018. His study focused on the annual variations in profitability ratios and analyzed the impact of tax and interest burdens on profitability. Çelik and Arslanlı (2020) aimed to identify the financial ratios affecting asset profitability and market value in REIT firms. Using panel data analysis, they found significant negative relationships between long-term debt-to-total assets, ROE, current ratio, and market value, as well as a significant positive relationship between total assets and market value. Furthermore, positive significant relationships were observed between stock returns, current ratio, ROE, and asset profitability. In their study, Aktaş and Darwish (2020) analyzed financial statement ratios influencing the asset and equity profitability of 32 REITs operating in Turkey. Using panel data analysis on annual data from 2014–2019, they concluded that long-term debt ratios negatively impacted both asset and equity profitability, while other independent variables had no significant effects. Tekin (2021) investigated the factors influencing asset and equity profitability of 21 REITs in Turkey using quarterly data from 2010 to 2019 and applied panel data analysis. Öndeş and Barakalı (2023) examined the effect of interest rate changes on profitability in the real estate sector, utilizing quarterly data from 2011 to 2021. Their findings revealed that commercial and residential interest rates influenced asset profitability. Cunha et al. (2023) explored whether equity profitability in non-publicly traded REITs was affected by housing price increases and GDP data. Analyzing 10 years of data from Portuguese REITs, they used the Canonical Cointegration Regression (CCR) technique for panel data analysis and concluded that housing price increases did not influence equity profitability. Lastly, Coşkuner et al. (2024) compared the factors affecting the profitability of REITs in Turkey and Malaysia. Their study focused on asset and equity profitability as dependent variables and employed a random forest regression method to determine the significance of influencing factors. The results indicated that the most impactful variables for both countries' REITs were the total debt-to-total assets ratio and the logarithm of total assets.

Various analytical methods have been used to measure profitability, yet studies focusing on profitability analyses of REIT firms remain limited. Specifically, it can be clearly stated that profitability forecasting for REIT firms in Turkey using the ANN analysis model has not been

conducted previously. From this perspective, employing ANN analysis for profitability forecasting is another factor that has contributed to the formation of the core idea of our study and has helped shape its framework.

3. Methods

3.1. Artificial Neural Networks

An ANN is a system that imitates the information-processing components of a biological nerve cell and is developed accordingly. A neuron is the basic information processing unit in a neural network system. This basic information processing is called a *perceptron*. As in a basic biological neuron structure, the neural cell receives inputs, combines them, processes them, and performs a generally non-linear process. The processed information then results in the final output (Anderson and McNeill, 1992). The structure of an artificial neural cell is shown in Figure 1 (Csáji, 2001):

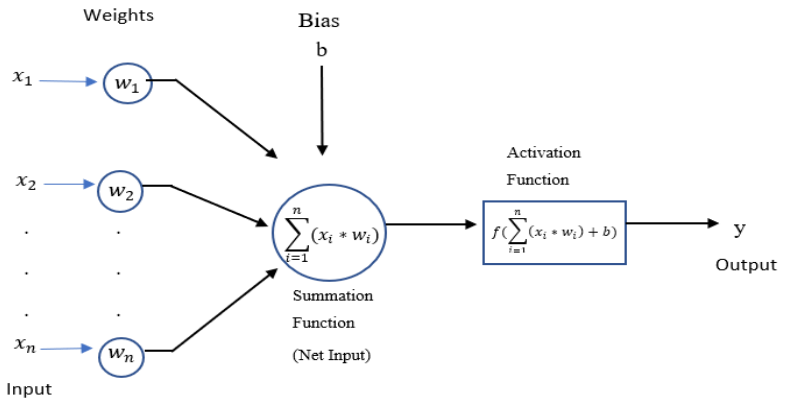


Figure 1. Structure of Artificial Neural Cell

As in a biological neural network, there are sections in an ANN. In ANNs, these sections are called process elements. There are 5 basic sections in each process element. These sections are (Öztemel, 2020):

Stage 1. The input layer is the signals or samples coming from the external environment and representing the values assumed by the variables (Silva et al., 2017).

Stage 2. Weights are adaptive coefficients within the network structure to determine the intensity of the input data recorded by the artificial neural cell (Anderson and McNeill, 1992).

Stage 3. The summation function is the function that calculates the net input to the nerve cell (Öztemel, 2020). The calculated Net Input value is summed with the bias threshold value and passed through the activation function. The bias value is a constant added to the inputs and weights. It is used to adjust the activation function that affects the neuron's output (Alaloul and Qureshi, 2020). The net input formula is as follows.

$$Net\ Input = \sum_{i=1}^{n}(x_i * w_i) + b \quad (1)$$

Stage 4. The activation function is a mathematical function that takes the value obtained from the summation function as input and then converts the value processed in the processing unit of the neural network into the final output (Alaloul and Qureshi, 2020).

Stage 5. The output layer is the final value processed and produced by the nerve cell (Silva et al., 2017).

ANNs consist of 3 parallel layers input layer, hidden layer, and output layer. ANNs are considered in two types of structures layer and multilayer. They can also be classified as feed-forward (non-recurrent) and feed-back (recurrent). While the feedback structure is known as recurrent or auto-relational, the feed-forward structure is known as non-recurrent or non-relational. (Sharma et al., 2012).

In single-layer networks, there is only one input and one output layer. Information flow is always unidirectional from the input layer to the output layer (Silva et al., 2017). In the multilayer network model, each layer consists of units that directly receive their information and send it to the next layer. It consists of an input layer, one or more hidden layers, and an output layer (Kröse and Smagt, 1996).

Single-layer network models are given in Figure 2 and multilayer network models are given in Figure 3 (Silva et al., 2017);

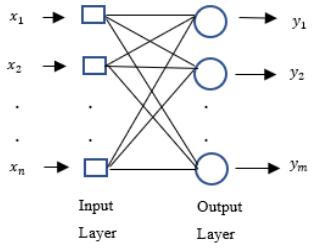


Figure 2. Single Layer Network

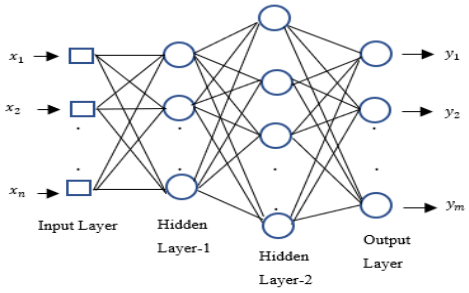


Figure 3. Multilayer Network

According to the direction of data flow, ANNs are classified as feed-forward and feed-back. Feed-forward neural networks are widely used systems with the most powerful structure for nonlinear regression models (Shanmuganathan, 2016). Neural network architecture with a strong structure extending from input units to output units, where neurons are grouped in layers, data flow is provided only by forward connections, but there is no feedback (Kröse and Smagt, 1996). Feedback ANNs are the most widely used method for training the model. The main difference compared to the feed-forward network is that the targeted and obtained output values are propagated back to the layers and the weights are adjusted again (Kukreja et al., 2016).

3.2. Performance Measurements

Various models are compared to assess the prediction accuracy. The best performance metric compatible with these models is selected. Therefore, there are many metrics used to measure performance. Each of these metrics is a function of the actual and predicted values of the time series (Khalil, 2022).

Mean Square Error (MSE), Mean Square Error (MAE), Root Mean Square Error (RMSE) and Coefficient of Determination (R^2) are the most commonly used performance measures in time series analysis (Monteiro and Costa, 2018). Although many model performance measures have been used to assess model performance, there is no consensus on the most appropriate metric for model errors (Chai and Draxler, 2014).

Mean Squared Error (MSE) is a measure of the mean squared deviation of predicted values. The mathematical representation of MSE is given below (Adhikari and Agrawal, 2013).

$$MSE = \frac{1}{n}\sum_{t=1}^{n} E_t^2 \tag{2}$$

Mean Absolute Error (MAE) measures the mean absolute deviation of the predicted values from the original values. The mathematical representation of MAE is given below (Adhikari and Agrawal, 2013).

$$MAE = \frac{1}{n}\sum_{t=1}^{n} |E_t| \tag{3}$$

Root Mean Squared Error (RMSE) measures are calculated by taking the square root of the MSE metric. All the properties of MSE also apply to RMSE. (Adhikari and Agrawal, 2013).

$$RMSE = \sqrt{MSE} = \sqrt{\frac{1}{n}\sum_{t=1}^{n} E_t^2} \tag{4}$$

Determination Coefficient (R^2) is the linear correlation between observations and values corresponding to model predictions (Monteiro and Costa, 2018).

$$R^2 = 1 - \frac{\sum_i^n (y_i - \hat{y}_i)^2}{\sum_i^n (y_i - \bar{y}_i)^2} \tag{5}$$

The determination coefficient shows the explanatory power of dependent variables for independent variables.

3.3. Panel Data Analysis

The term panel or longitudinal refers to a data set allowing the observation of more than one individual, country, firm, or unit over a while (Hsiao, 2014). Panel data consists of N number of units and T number of observations corresponding to these units (Tatoğlu, 2021). Panel data regression is different from normal time series or cross-section regression. The panel data regression model is constructed as follows (Baltagi, 2005).

$$y_{it} = \alpha + \beta X'_{it} + u_{it} \qquad i=1,\ldots\ldots,N;\ t=1,\ldots\ldots,T \tag{6}$$

According to this equation, the following are defined; y_{it}; dependent variable, i; households, individuals, companies, countries, etc. (cross-sectional unit), t; time (time series), α; a fixed unit of measurement, β; slope coefficient of variables, X'_{it}; explanatory variables for i'th observations at time t, u_{it}; error component.

Error component is expressed;

$$u_{it} = \mu_i + v_{it} \tag{7}$$

μ_i; unobservable individual-specific effect, v_{it}; intrinsic error (residual error term)

In panel data analysis, the most appropriate method should be determined according to the condition and characteristics of the data. For this reason, homogeneity, horizontal cross-section dependence, and unit root tests should be performed. The most appropriate model is determined according to the results obtained. The model applied in this study is based on the Panel OLS technique. Panel OLS consists of pooled least squares, fixed, and random effects models. At this stage, it is important to choose one of the appropriate models. In the present study, the appropriate model was determined as the fixed effects model.

The Fixed Effects Model (FEM) is widely used when neglected variables that are constant over time and differ across units, called unobservable heterogeneity (individual-specific effect-μ_i) or fixed effects, are to be controlled.

The fixed effects model regression equation is defined as follows (Baltagi, 2005).

$$y_{it} = \alpha + \beta x_{it} + \mu_i + v_{it} \tag{8}$$

In case of averaging over time;

$$\bar{y}_i = \alpha + \beta \bar{x}_i + \mu_i + \bar{v}_i \tag{9}$$

equation 8 is then subtracted from equation 9.

$$y_{it} - \bar{y}_i = \beta(x_{it} - \bar{x}_i) + (v_{it} - \bar{v}_i) \tag{10}$$

4. Estimation Results and Comments

The financial statement data of REITs traded on the BIST for the quarterly periods of 2010-2019 are used to predict profitability. Due to the 2008 economic crisis and its impact in 2009, the pandemic in 2020, and the extremely rapid increase in housing prices in the following years, the analysis scope period was determined as the quarter periods of 2010-2019 to obtain healthier data. Data were obtained from the Finnet Financial Analysis program, the Public Disclosure Platform ("PDP"), the Turkish Statistical Institute ("TSI"), and the Central Bank of the Republic of Turkey ("CBRT") official websites. As some of the 48 companies traded on the BIST have recently started their operations and a few companies did not have complete data within the period of the analysis, the data of 27 companies were analyzed. The companies included in the analysis are given in Table 1.

Table 1. REIT Companies in the Scope of Analysis

BIST Index Code	REIT Companies
AKFGY	Akfen Real Estate Investment Trust Inc.
AKSGY	Akiş Real Estate Investment Trust Inc.
AKMGY	Akmerkez Real Estate Investment Trust Inc.
ALGYO	Alarko Real Estate Investment Trust Inc.
ATAGY	Ata Real Estate Investment Trust Inc.
AGYO	Atakule Real Estate Investment Trust Inc.
AVGYO	Avrasya Real Estate Investment Trust Inc.
DZGYO	Deniz Real Estate Investment Trust Inc.
DGGYO	Doğuş Real Estate Investment Trust Inc.
EKGYO	Emlak Konut Real Estate Investment Trust Inc.
HLGYO	Halk Real Estate Investment Trust Inc.
IDGYO	İdealist Real Estate Investment Trust Inc.
ISGYO	İş Real Estate Investment Trust Inc.
KLGYO	Kiler Real Estate Investment Trust Inc.
KGYO	Koray Real Estate Investment Trust Inc.
MRGYO	Marti Real Estate Investment Trust Inc.
NUGYO	Nurol Real Estate Investment Trust Inc.
OZKGY	Özak Real Estate Investment Trust Inc.
OZGYO	Özderici Real Estate Investment Trust Inc.
PEGYO	Pera Real Estate Investment Trust Inc.
RYGYO	Reysaş Real Estate Investment Trust Inc.
SRVGY	Servet Real Estate Investment Trust Inc.
SNGYO	Sinpaş Real Estate Investment Trust Inc.
TRGYO	Torunlar Real Estate Investment Trust Inc.
TSGYO	Tskb Real Estate Investment Trust Inc.
VKGYO	Vakif Real Estate Investment Trust Inc.
YGYO	Yeşil Real Estate Investment Trust Inc.

Considering the studies on the measurement of profitability and performance of REITs, the variables to be evaluated within the scope of the analysis are given in Table 2. According to Table 2, 2 dependent variables and 25 independent variables were determined. Using the determined ratios and various variables and parameters, return on assets and ROE was tried to be estimated.

Table 2. Variables Used in the Analysis

Dependent Variables			
Profitability Ratios	B1	Return on Assets	Net Profit/Total Assets
	B2	Return on Equity	Net Profit / Total Equity
Independent Variables			
Liquidity Ratios	L1	Current Ratio	Current Assets/Short-Term Liabilities
	L2	Acid-Test Ratio	(Current Assets-Stocks)/Short Term Liabilities
	L3	Cash Rate	(Cash and Cash Equivalents + Marketable Securities)/Short Term Liabilities
Financial Structure Ratios	F1	Debt to Equity Ratio	Total Debt/Total Resources
	F2	Debt/Equity Ratio	Total Debt/Total Equity
	F3	Equity Ratio	Equity/Total Assets
	F4	Short Term Debt Ratio	Short-Term Debt/Total Resources
	F5	Long-Term Debt Ratio	Long-Term Debt/Total Resources
	F6	Currency Risk	(Absolute(Foreign Currency Assets - Foreign Currency Liabilities))/ Total Equity
	F7	Equity Multiplier	Total Assets/Total Equity

Table 2. Continue

Activity Ratios	E1	Receivables Turnover Rate	Net Sales/Average Trade Receivables
	E2	Net Working Capital Turnover	Net Sales/Average Net Working Capital
	E3	Asset Turnover	Net Sales/Average Assets
	E4	Equity Turnover Rate	Net Sales/Average Shareholders' Equity
Market Performance Ratios	P1	Price/Earnings Ratio	Market Capitalization/Net Profit
	P2	Market Value/Book Value (PD/BV) Ratio	Market Capitalization/ Equity
	P3	Rate of Return per Share	Net Profit/Number of Shares in Circulation
	P4	Tobin's Q Ratio	(MarketValue+(Short-Term Assets-Short-Term Assets)+Uvb)/Total Assets
Competition and Size Ratios	R1	Enterprise Size-1	Log(Total Assets)
	R2	Enterprise Size-2	Log(Total Net Sales)
	R3	Market Share	Net Sales of the Enterprise/Total Net Sales of the Enterprises in the Sector
Makro Variables	M1	Inflation	Percentage Change in CPI Compared to the Previous Period
	M2	Economic Growth Rate (GDP)	Percentage Change in GDP Compared to the Previous Period
	M3	Current Account Deficit Ratio	Current Account Balance/GDP
	M4	Interest Rate	Interest Rate Applied to Deposits

To ensure that the Panel Data Analysis and ANN models provide better results and to identify the effective variables, the Factor Analysis Principal Components method was applied. With this method, the number of variables previously identified was reduced. Table 3 shows the rotated components matrix obtained as a result of factor analysis. As a result of the factor analysis, 6 factors with an eigenvalue above 1 were taken into consideration. A total of 17 independent variables grouped under these factors were obtained. The KMO (Kaiser Meyer Olkin) was found to be 0.675 in the analysis and it was determined that the distribution was sufficient for factor analysis.

Table 3. Rotated Components Matrix

Variables	**1**	**2**	**3**	**4**	**5**	**6**
L2-Acid-Test	0.963					
L3-Cash Rate	0.960					
L1-Current Ratio	0.786					
M3- Current Deficit Ratio		0.936				
M2- Economic Growth Rate (GDP)		-0.875				
M4- Interest Rate		0.870				
E4- Equity Turnover Rate			0.963			
E3- Active Speed			0.962			
E2- Net Work. Cap. Turnover Rate			0.728			
R1- Business Size1				0.805		
R2- Business Size2				0.797		
R3- Market Share				0.767		
F7- Equity Multiplier					0.757	
F5- UVB Ratio					0.685	
F3- Equity Ratio					-0.656	
P3- Return Per Share						0.749
P4- Tobin's Q Ratio						0.696

In line with the factor analysis, since F1, F2, and F3 variables have similar characteristics in terms of measuring capital accumulation and borrowing, only the F3 variable was used in the analysis. In terms of the scope of the F3 variable, it indirectly shows the sustainability of debts compared to the F1 and F2 variables. The F4 variable was excluded from the scope of the analysis since it decreased the KMO (Kaiser Meyer Olkin) and total explained variance values. F6, E1, and P2 variables were grouped under other factors, while P1 and M1 variables were not included in the analysis since they were below 0.50 factor loadings. As a result, 2 dependent and 17 independent variables were obtained to be used in Panel Data Analysis and ANN models. After determining the variables obtained for profitability prediction, panel data analysis was first applied to the data.

Homogeneity and inter-unit correlation tests were applied to the data to select the most appropriate model for panel data analysis. It was found that the ratios affecting the B1 return on assets variable are heterogeneous, while the ratios affecting the B2 ROE variable are homogeneous.

Based on the results of the Breusch-Pagan (LM- Lagrange Multiplier) Test, Pesaran LM CD Test, and Friedman Test, the null hypothesis is rejected at $p<0.05$ significance level for return on assets and ROE dependent variables. Therefore, it is concluded that there is an inter-unit correlation. Since inter-unit correlation is detected, 2nd generation unit root tests should be applied. Among the 2nd generation unit root tests, the most appropriate test for both homogeneity and heterogeneity is Pesaran's (2007) CIPS test (Pesaran, 2007). According to Table 4, since CIPS>Critical Value in absolute value at $p<0.05$ significance level, hypothesis H_0 is rejected. It is concluded that all variables are stationary at the level.

Table 4. CIPS Unit Root Test Results Table

Variables	CIPS Value	5% Critical Value	Level
B1- Return on Assets	-3.969	-2.16	I(0)
B2 - Return on Equity	-4.887	-2.16	I(0)
L1-Current Ratio	-3.809	-2.16	I(0)
L2-Acid-Test Ratio	-3.554	2.16	I(0)
L3-Cash Rate	-3.760	-2.16	I(0)
F3-Equity Ratio	-2.591	-2.16	I(0)
F5-UVB Ratio	-2.297	-2.16	I(0)
F7-Equity Multiplier	-2.863	-2.16	I(0)
E2-Net Work. Cap. Turnover	-4.452	-2.16	I(0)
E3-Asset Turnover	-4.813	-2.16	I(0)
E4-Equity Turnover Rate	-4.127	-2.16	I(0)
P3-Return Per Share	-3.947	-2.16	I(0)
P4-Tobin's Q Ratio	-2.346	-2.16	I(0)
R1-Business Size-1	-2.863	-2.16	I(0)
R2-Business Size-2	-3.472	-2.16	I(0)
R3-Market Share	-4.795	-2.16	I(0)
M2-GDP Ratio	-5.807	-2.16	I(0)
M3-Current Deficit Ratio	-5.782	-2.16	I(0)
M4-Interest Rate	-6.137	-2.16	I(0)

Note: *$*p<0.05$*

Since all variables are stationary at a level as a result of the unit root test, the Panel OLS (Ordinary Least Squares) test should be applied. Panel OLS consists of pooled least squares, fixed,

and random effects models. The important thing here is to choose one of these models. For model selection, the results of the F test, LM (Breusch-Pagan) test, and Hausman test should be taken into consideration.

According to the test results, since the probability values of the F test, LM test, ALM (Adjusted Lagrange Multiplier) test, and Hausman test for the return on assets variable are below the p<0.01 significance level, hypothesis H_0 is rejected. The F test gives the fixed effects model and the LM/ALM test gives the random effects model. The Hausman test applied to choose between the two models resulted in the fixed effects model. For the ROE variable, the F test gives the fixed effects model and the LM/ALM test gives the pooled least squares model. The Hausman test applied to choose between the two models resulted in the fixed effects model.

Changing variance and autocorrelation tests should be applied to analyze the data correctly. Autocorrelation is tested by Durbin-Watson and Baltagi-Wu LBI (Locally Best Invariant) and variance is tested by Modified Wald Test.

Table 5. B1-Active Profitability Driscoll-Kraay Robust Fixed Effects Model Estimation Results

B1- Return on Assets	**Coefficients**	**Driscoll-Kraay Resistive Standard Error**	**t**	**P>t**	**[95%Conf.**
L1-Current Ratio	0.003	0.002	1.840	0.077	-0.000
L2-Acid-Test Ratio	0.029	0.058	0.510	0.616	-0.089
L3-Cash Rate	-0.041	0.056	-0.720	0.475	-0.156
F3-Equity Ratio	6.289	2.097	3.000	0.006**	1.978
F5-UVB Ratio	-1.339	1.703	-0.790	0.439	-4.839
F7-Equity Multiplier	-0.005	0.013	-0.390	0.697	-0.033
E2-Net Wor. Cap.Turnover	-0.006	0.005	-1.210	0.239	-0.015
E3-Asset Turnover	-0.501	0.264	-1.900	0.069	-1.043
E4-Equity Turnover Rate	0.407	0.245	1.660	0.109	-0.097
P3-Return Per Share	8.110	0.526	15.420	0.000**	7.029
P4-Tobin's Q Ratio	-1.120	0.223	-5.030	0.000**	-1.578
R1- Business Growth -1	1.340	0.866	1.550	0.134	-0.439
R2- Business Growth -2	0.135	0.191	0.710	0.484	-0.257
R3-Market Share	0.779	1.848	0.420	0.677	-3.019
M2-Eco.Growth Rate(GDP)	5.603	8.435	0.660	0.512	-11.734
M3-Current Deficit Ratio	15.604	9.222	1.690	0.103	-3.353
M4-Interest Rate	-0.112	0.044	-2.520	0.018**	-0.203
Constant	-13.683	7.313	-1.870	0.073	-28.714
F(17, 26)		133.74	MSE		
Prob > F		0.0000	MAE		0.000001908
R^2		0.5018	RMSE		
B1- Return on Assets		**Test Statistic**		**p value**	
F Test		7.39		0.000***	
LM/ALM Test		9.84		0.000***	
Hausman Test		84.02		0.000***	
Heteroscedastic Test					
Modified Wald		1990.57		0.000***	
Autocorrelation Test					
Durbin-Watson		1.5429		-	
Baltagi-Wu LBI		1.6007		-	

Note: *** p<0.01, ** p<0.05, * p<0.1

As a result of the tests applied, the Driscoll-Kraay Estimator, an estimator resistant to the fixed effects model, was applied since there was an inter-unit correlation, changing variance, and autocorrelation problems. According to the return on assets variable, the error performance and coefficient of determination of the findings obtained by applying the Driscoll-Kraay robust fixed effects model are given in Table 5.

According to Table 5, the F statistic of the model was found significant at p<0.01 level. The R^2 value is 0.5018, which indicates that the independent variables can explain 50% of the dependent variable. Among the MSE, MAE, and RMSE error metrics measuring the prediction performance according to the model, the MAE metric gave the minimum error of 0.000001908. The analysis model established according to the return on assets variable is given below.

$$B1 = -13.683 + 6.289 * F3 + 8.110 * P3 + (-1.1120) * P4 + (-0.112) * M4 \quad (11)$$

The variables F3-equity ratio, P3-return per share ratio, P4-Tobin's Q ratio, and M4-interest rate are statistically significant on the return on assets ratio. While the F3-equity ratio and P3-return per share ratio have a positive effect on return on assets, P4-Tobin's Q ratio and M4-interest rate have a negative effect on return on assets. The most influential ratio on return on assets is the earnings per share ratio. This can be explained by the increase in net profit from sales, which consequently enhances return on assets.

According to the ROE variable, the error performance and coefficient of determination of the findings obtained by applying the Driscoll-Kraay robust fixed effects model are given in Table 6. According to the Driscoll-Kraay robust fixed effects model estimation results for the ROE dependent variable, the F statistic of the model was found significant at p<0.05 level. The R^2 value is 0.7335 and this ratio shows that the independent variables can explain 73% of the dependent variable. As in the return on assets variable, the metric that best measures the prediction performance is MAE with a value of 0.00015062. The analysis model for the ROE variable is as follows.

$$\begin{aligned} B2 = {} & 93.026 + (-60.166) * F3 + (-50.108) * F5 + (-2.468) * F7 + 125.522 \\ & * E3 + (-117.593) * E4 + 29.527 * P3 + 159.530 * R3 \\ & + (-1.275) * M4 \end{aligned} \quad (12)$$

The variables F3-equity ratio, F5-Uvb ratio, F7-equity multiplier, E3-asset turnover ratio, E4-equity turnover ratio, P3-return per share ratio, R3-market share, and M4-interest rate are statistically significant on the ROE ratio. While the F3-equity ratio, F5-long-term borrowing ratio, F7-equity multiple ratio, E4-equity turnover ratio, and M4-interest rate have a negative effect on ROE, E3-asset turnover ratio, P3-return per share ratio and R3-market share ratio have a positive effect on ROE. The fact that the asset turnover ratio has a positive and significant coefficient indicates effective asset management by businesses. Similarly, the positive and high impact of the market share ratio can be explained by the ability to achieve higher product sales within the sector.

Table 6. B2 - Return on Equity Driscoll-Kraay Robust Fixed Effects Model Estimation Results

B2- Return on Assets	Coefficients	Driscoll-Kraay Resistive Standard Error	t	P>t	[95%Conf.
L1-Current Ratio	0.002	0.010	0.240	0.810	-0.018
L2-Acid-Test Ratio	-0.408	0.338	-1.200	0.239	-1.103
L3-Cash Rate	0.367	0.313	1.170	0.251	-0.276
F3-Equity Ratio	-60.166	13.121	-4.590	0.000**	-87.136
F5-UVB Ratio	-50.108	20.534	-2.440	0.022**	-92.316
F7-Equity Multiplier	-2.468	1.011	-2.440	0.022**	-4.547
E2-Net Work. Cap. Turnover	-0.216	0.174	-1.240	0.226	-0.574
E3-Asset Turnover	125.522	37.132	3.380	0.002**	49.197
E4-Equity Turnover Rate	-117.593	34.654	-3.390	0.002**	-188.826
P3-Return Per Share	29.527	7.237	4.080	0.000**	14.650
P4-Tobin's Q Ratio	-3.690	2.628	-1.400	0.172	-9.092
R1-Business Growth -1	-3.543	11.588	-0.310	0.762	-27.362
R2-Business Growth -2	1.700	0.928	1.830	0.079	-0.208
R3-Market Share	159.530	46.762	3.410	0.002**	63.408
M2-Eco.Growth Rate(GDP)	-87.043	87.231	-1.000	0.328	-266.349
M3-Current Deficit Ratio	-44.736	91.745	-0.490	0.630	-233.321
M4-Interest Rate	-1.275	0.461	-2.760	0.010**	-2.223
Constant	93.026	100.957	0.920	0.365	-114.495
F(17, 26)	42.64		MSE	-	
Prob > F	0.0000		MAE	0.00015062	
R^2	0.7335		RMSE	-	
B2- Return on Assets	**Test Statistic**			**p value**	
F Test	1.57			0.0348**	
LM/ALM Test	0.07			0.4709	
Hausman Test	36.22			0.0027***	
Heteroscedastic Test					
Modified Wald	1.1e+06			0.000***	
Autocorrelation Test				-	
Durbin-Watson	1.9068			-	
Baltagi-Wu LBI	1.9755				

Note: *** p<0.01, ** p<0.05, * p<0.1

ANN analysis backpropagation MLP (Multi-Layer Perceptron) Regressor model was applied for profitability prediction. For the analysis, modeling was performed with Python 3.8.13 programming language, and libraries with accessible open-source data processing algorithms were used. In this context, the NumPy library was utilized for processing numerical data, while the Pandas library was employed for constructing time-labeled series and structured tables. During the model training phase, the Scikit-Learn (Sklearn) library was used for model development and the evaluation of model performance metrics. For data visualization and graphical representation, the Seaborn library, along with Matplotlib and Plotly, was employed to effectively illustrate the findings. Details about the network information of the ANN models established for B1-Active Profitability and B2- ROE are given in Table 7.

Table 7. ANN Model Network Information

B1- Return on Assets		**B2-Return on Equity**	
Network Arch.	MLP Regressor	Network Arch.	MLP Regressor
Training Type	Supervised Learning	Training Type	Supervised Learning
Function Type	Multilayer	Function Type	Multilayer
Error Metrics	MSE, MAE, RMSE, R^2	Error Metrics	MSE, MAE, RMSE, R^2
No of Hidden. Layers	4	No of Hidden Layers	4
Iteration	1000	Iteration	303
Network Arch.	40-30-20-10	Network Arch.	60-45-25-10
Activation Function	Hiperbolik Tangent (tanh)	Activation Function	Rectified Linear Unit (Relu)
Momentum Coef.	0,9	Momentum Coef.	0,9
Learning Coefficient	0,001	Learning Coefficient	0,001
Scaling	Standard Scaler	Scaling	Standard Scaler

The MLP Regressor model was used for profitability forecasting. After defining the dependent and independent variables, a standardization process was applied to eliminate differences between values while preserving the data structure. Error metrics were identified before model installation. By comparing the determined metrics, the metric that gave the least error was determined. During the model development phase, the standardized data was divided into three sets: training set, validation set, and test set. Specifically, 80% of the data was allocated for training, 10% for validation, and 10% for testing. In defining the ANN architecture, different models were tried by adjusting hyperparameters such as a hidden layer, learning rate, momentum coefficient, and activation function while training the network. At this stage, weights were assigned. The next step is the validation phase, where hyperparameters are adjusted until the network achieves minimum error after training. Finally, in the testing phase, the model's generalization ability was evaluated.

Different forecasting models are tested for return on assets and ROE variables. The performance results of the models are evaluated comparatively with MSE, MAE, and RMSE error metrics and R^2 values that measure model adequacy.

According to Table 8, the MSE metric has the best performance with the minimum error for the B1 return on assets prediction. Among the models, the best R^2 result, which shows the accuracy and explanatory power, is given by Model 4. According to this model, the network architecture has 4 layers and the hidden layers are realized as 40-30-20-10. The training performance of the model was 90% and the validation performance was 87%. It can be said that the model, whose test performance was 85%, achieved success. The overall performance of the model was 87%.

Table 8. B1 Return on Assets Error and Performance Measures Table

	Performance	MSE	MAE	RMSE	R^2
Model: 1 Number of Hidden Layers: 15-3	Test	0.15613	0.28104	0.39514	0.83873
	Training	0.23365	0.29677	0.48338	0.79084
	Verification	0.11332	0.24476	0.33664	0.83677
	General	0.23160	0.29607	0.48124	0.76839
Model: 2 Number of Hidden Layers: 35-20-15	Test	0.20911	0.27854	0.45728	0.83277
	Training	0.17696	0.25907	0.42067	0.83365
	Verification	0.11702	0.24212	0.34208	0.84089
	General	0.17288	0.26226	0.41579	0.82711
Model: 3 Number of Hidden Layers: 30-25-20-10	Test	0.14700	0.24624	0.38341	0.84816
	Training	0.12780	0.22081	0.35749	0.87782
	Verification	0.09078	0.20486	0.30130	0.87657
	General	0.13177	0.22707	0.36301	0.86822
Model: 4 Number of Hidden Layers: 40-30-20-10	Test	0.18206	0.24954	0.42668	0.85139
	Training	0.11081	0.21459	0.33288	0.90080
	Verification	0.12791	0.23220	0.35765	0.87172
	General	0.12316	0.22403	0.35095	0.87683
Model: 5 Number of Hidden Layers: 55-35-28-10	Test	0.14838	0.25016	0.38520	0.84674
	Training	0.16283	0.23883	0.40353	0.84349
	Verification	0.08285	0.20281	0.28784	0.88734
	General	0.15867	0.23644	0.39834	0.84132

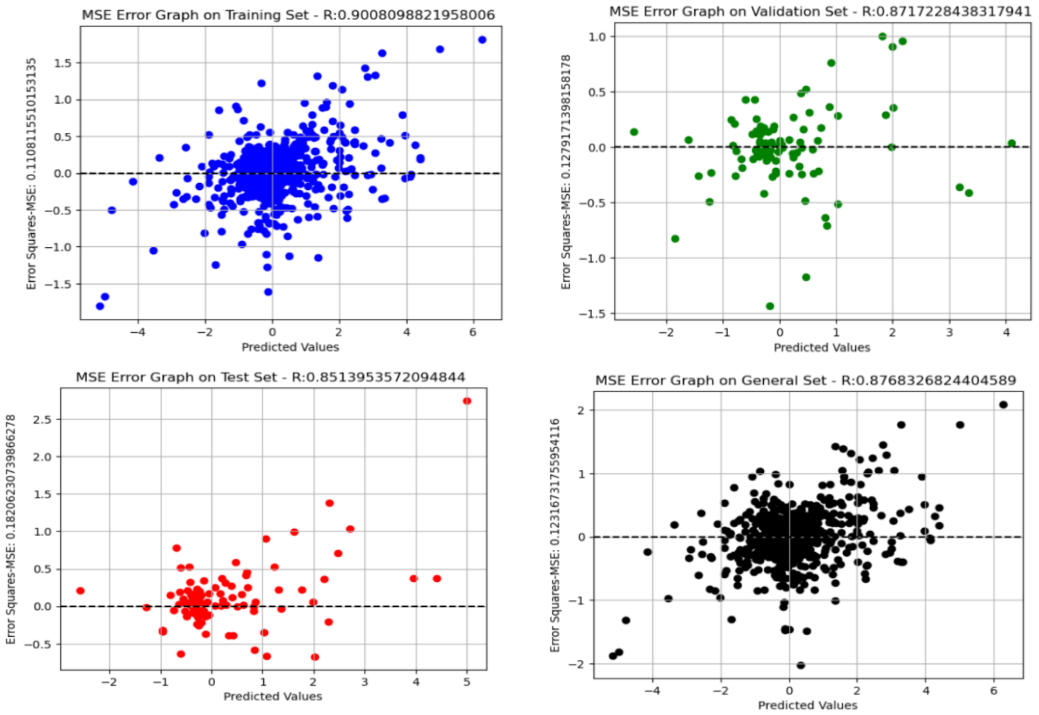
Model error and performance measures for ROE are given in Table 9. According to Table 9, the best performance with the minimum error for the B2 ROE prediction belongs to the MSE metric, just like the return on assets variable. Among the models, the best R^2 result indicating accuracy and explanatory power is given by Model 5. According to this model, the network architecture has 4 layers and the hidden layers are realized as 60-45-25-10. The training performance of the model was 98% and the validation performance was 94%. It can be said that the model, whose test performance was 96%, achieved success. The overall performance of the model was realized as 98%.

Table 9. B2 Return on Equity Error and Performance Measures Table

	Performance	MSE	MAE	RMSE	R^2
Model: 1 Number of Hidden Layers: 25-7	Test	0.06476	0.06669	0.09832	0.94828
	Training	0.01938	0.07422	0.13923	0.98276
	Verification	0.03356	0.09546	0.18319	0.91979
	General	0.02783	0.08169	0.16682	0.97216
Model: 2 Number of Hidden Layers: 15-8-7	Test	0.01202	0.07616	0.10965	0.93567
	Training	0.01616	0.07749	0.12715	0.98316
	Verification	0.01947	0.09748	0.13955	0.93342
	General	0.15168	0.09404	0.38947	0.84831
Model: 3 Number of Hidden Layers: 30-10-3	Test	0.01199	0.06193	0.10951	0.93584
	Training	0.01510	0.06963	0.12291	0.98427
	Verification	0.02621	0.09648	0.16191	0.91037
	General	0.02068	0.07091	0.14383	0.97931
Model: 4 Number of Hidden Layers: 40-35-20-10	Test	0.01451	0.07826	0.12047	0.92236
	Training	0.01753	0.08693	0.13242	0.98440
	Verification	0.02716	0.10350	0.16480	0.90715
	General	0.01931	0.07533	0.13897	0.98068
Model: 5 Number of Hidden Layers: 60-45-25-10	Test	0.01200	0.07602	0.10956	0.96415
	Training	0.01613	0.07163	0.12701	0.98664
	Verification	0.02211	0.08204	0.14872	0.94714
	General	0.01824	0.07396	0.13509	0.98175

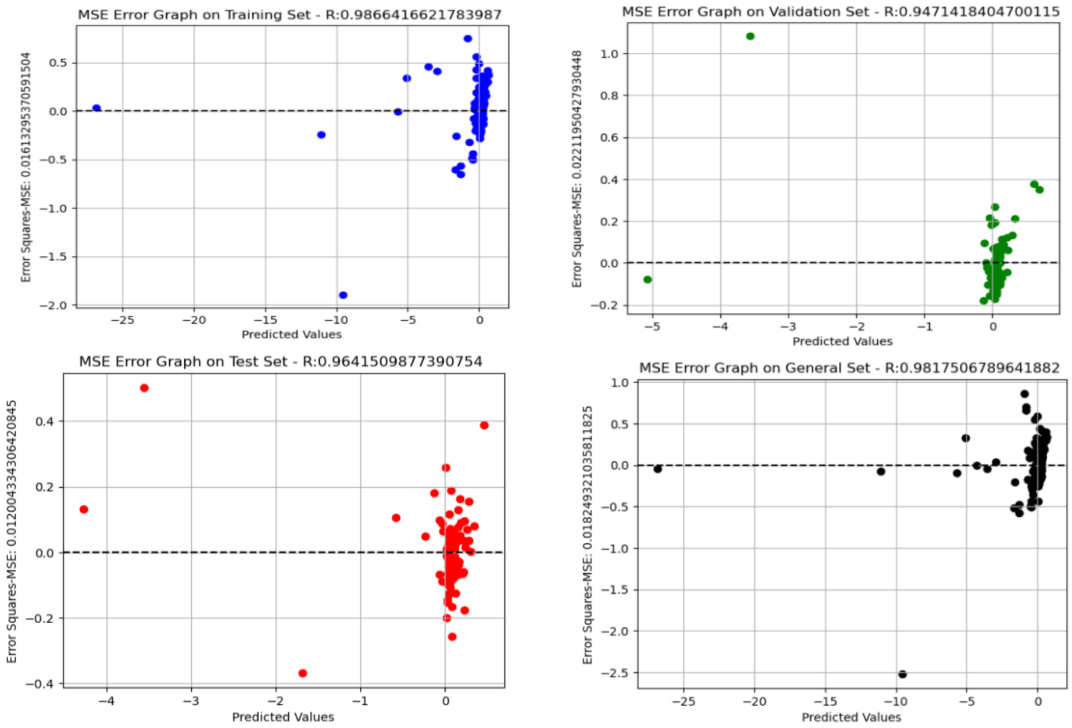
It is concluded that the metric with the least error for the dependent variables, return on assets and ROE, is MSE. The training, validation, test set, and overall performance error distributions for these variables are given in Graphs 1 and 2.

In Graph 1, the training set shows a good performance with an R^2 value of 90% in the models established according to the return on assets variable. The fact that the validation set also performs close to the training set can be interpreted as the model is well trained and has no fitting problem. The fact that the test set has a value above 80% shows that the generalization and prediction ability of the model is good. The overall performance of the model was realized as 87.



Graph 1. B1 Return on Assets Training, Validation, Test Set, and Overall Performance Error Scatter Graph

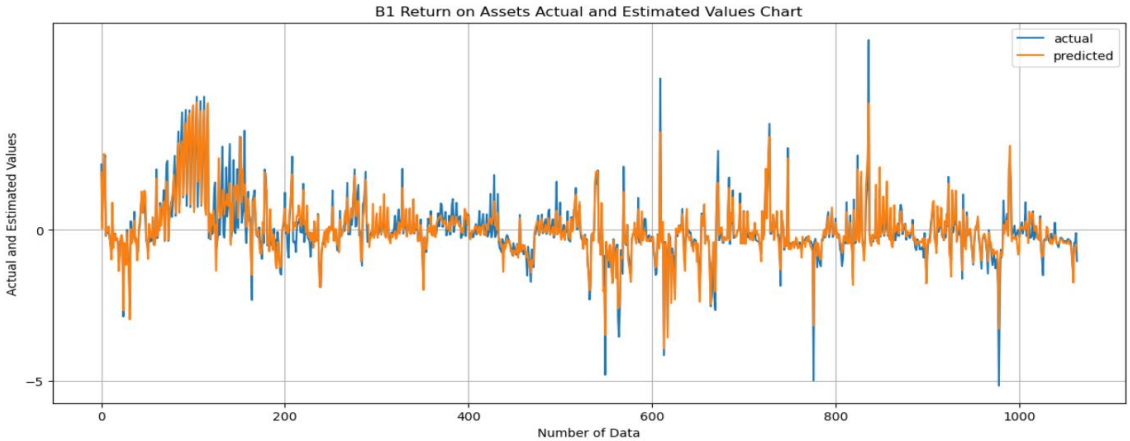
According to Graph 2, the best performance for the ROE variable belongs to the training set with 98%. The validation set, which performs around 94%, shows that the model fits very well. This shows that no overfitting or underfitting was encountered in the model and that the model was trained quite well. The test set with an R^2 value of 96% indicates that the real data and the prediction data are well matched and the prediction success of the model is high. The overall performance of the model was 98%.



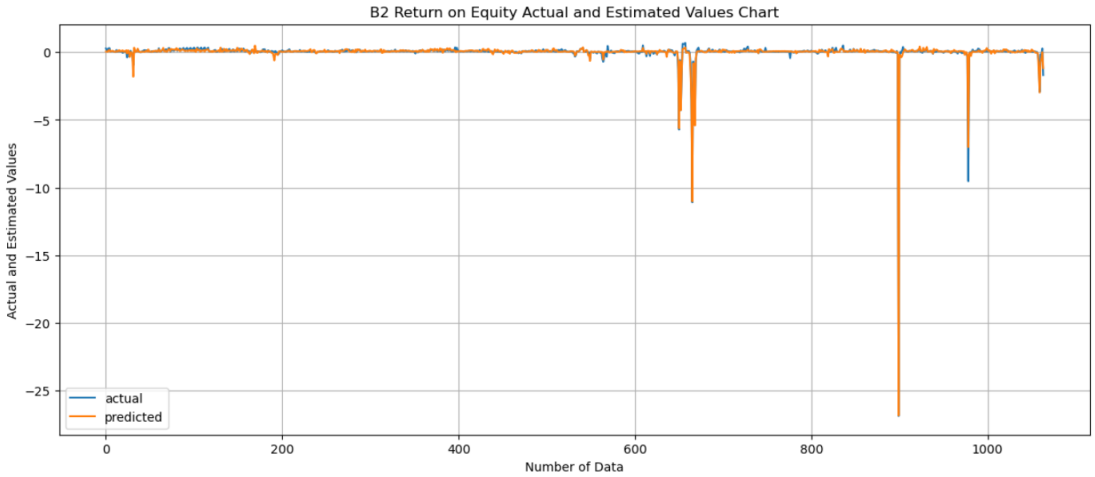
Graph 2. B2 Return on Equity Training, Validation, Test Set, and Overall Performance Error Scatter Graph

The models established for profitability prediction were found to have a high success rate. Accordingly, the agreement between the actual and predicted values of return on assets and ROE variables are given in Graph 3 and Graph 4.

Graph 3 and Graph 4 show that the actual and forecast values of the data set are quite close to each other. Many factors are effective for profitability prediction. Considering that only financial statement data are used for the 17 independent variables used for the analysis, it is seen that the prediction performance in explaining return on assets and ROE is successful.



Graph 3. B1 Return on Assets Actual and Predicted Values Deviation Graph



Graph 4. B2 Return on Equity Actual and Predicted Values Deviation Graph

It has been observed that the selected explanatory variables provide better results in predicting ROE. This situation can be explained by the fact that, as seen in Turkey, real estate investments increase in value over time, and this increase in value leads to a rise in the equity of REITs, thereby enhancing firms' ROE. Additionally, REITs often rely on debt financing for their real estate investments, which brings interest costs. However, if the income generated from REIT investments exceeds the borrowing costs, ROE may increase. The leverage effect resulting from debt financing can enhance equity returns.

5. Comparison of Models

Table 10 presents the comparison findings for the results of both prediction analyses. According to Table 10, the MLP Regressor model, established to predict return on assets and ROE, obtained better results. According to the regression models, the models predicting ROE yielded the best R^2 result. The overall performance value of R^2 for the MLP Regressor model for the prediction of return on assets is 87%, while the R^2 value for the Driscoll-Kraay robust fixed effects model is 55%. For the prediction of ROE, the MLP Regressor model results in an overall performance value of R^2 of 98%, while the R^2 value for the Driscoll-Kraay robust fixed effects model is 73%. While the MAE metric gives the least error for the Driscoll-Kraay robust fixed effects model, the MSE metric gives the least error for the MLP Regressor model. Compared to the Driscoll-Kraay robust fixed effects model, the MLP regressor model has better prediction performance. This can be interpreted that the MLP regressor model performs a good learning from the data by using the parameters.

Table 10. Comparison of Driscoll-Kraay Robust Fixed Effects Model and MLP Regressor Model

	B1- Return on Assets		B2- Return on Equity	
Performance Metrics	**Driscoll-Kraay Resistive Fixed Effects Model**	**MLP Regressor**	**Driscoll-Kraay Resistive Fixed Effects Model**	**MLP Regressor**
MSE	-	0.12316	-	0.01824
MAE	0.000001908	0.22403	0.00015062	0.07396
RMSE	-	0.35095	-	0.13509
R^2	0.5578	0.87683	0.7266	0.98175

6. Conclusion, Discussion and Recommendations

The analyses conducted using the Driscoll-Kraay Robust Fixed Effects Model, a panel data analysis technique, and the MLP Regressor model compared both methods. For profitability prediction, the study employed the MLP Regressor (Multilayer Perceptron Regressor) algorithm, one of the machine learning techniques based on ANN. Accordingly, the objective of the study is to identify the best model for profitability prediction by comparing the findings obtained from REITs listed on BIST, which hold a significant market share, using the MLP Regressor algorithm and the Fixed Effects Model, a traditional econometric method within panel data analysis techniques. Within the scope of the study, return on assets (ROA) and ROE were used as dependent variables for profitability prediction. ROA reflects the profitability derived from a firm's total assets, while ROE indicates whether companies effectively utilize their equity and demonstrates their growth strategies. Both variables are critical for assessing firms' financial health, potential risks, and performance. They are particularly significant as guiding factors for strategic decision-making in REIT firms.

The scope of the research encompasses 27 REITs listed on BIST during the quarterly periods from 2010 to 2019. The analysis is limited to data from 2010 to 2019 due to the economic crisis prior to 2010 and the rapid increase in real estate prices following the pandemic in 2019, which define the boundaries of the study. Additionally, out of 48 REITs listed on BIST, only 27 with complete and accessible data were included in the analysis, representing another limitation of the study. It is evident that the MLP Regressor analysis provides a prediction result closer to the actual values compared to the Fixed Effects Model. The explanatory power of the ANN analysis is strong for both dependent variables. This can be attributed to the ANN's ability to effectively model complex and nonlinear relationships, as well as its capacity to handle outliers and missing data while maintaining a strong learning capability.

A review of the literature reveals that ANN outperform traditional methods such as linear regression. For instance, Schöneburg (1990) predicted stock prices with 90% accuracy, while subsequent studies (Desai and Bharati, 1998; Saberi et al., 2016) highlighted the strong predictive capability of ANNs in financial indicators. The findings of this study align with previous research, demonstrating that ANNs exhibit superior predictive power compared to traditional models.

This study stands out as one of the limited works in the literature comparing ANN and panel data analysis methods. Similar to the studies conducted by Heo et al. (2020) and Ho et al. (2020), this research has found that ANN-based algorithms outperform traditional econometric models in prediction accuracy. This result aligns with other studies in the literature, highlighting ANN's ability to effectively model complex and nonlinear relationships. For instance, the findings of Kıral and Çelik (2020) and Parlakkaya et al. (2022) revealed discrepancies between panel data analysis and ANN outcomes, with ANN demonstrating stronger predictive success. This advantage is particularly attributed to ANN's capability to handle diverse data types and effectively manage outliers, further supporting its superiority.

In the literature, the number of studies that combine ANN analysis with panel data analysis is quite limited. Future research could integrate these two methods using hybrid models to obtain more robust and comprehensive results. Additionally, the success rate of ANN models is closely related to the size of the dataset and the selection of independent variables. For instance, Saberi et al. (2016), Lado-Sestayo and Vivel-Bua (2020), Alaameri and Faihan (2022), and Vukovic et al. (2023) achieved high accuracy rates by utilizing deep learning models. In this context, it is

recommended that deep learning techniques be more extensively employed in predicting corporate profitability in Turkey.

The findings obtained from this study provide valuable insights for investors and REIT firms. From an investor's perspective, profitability forecasting is crucial as it allows for a comprehensive assessment of REIT firms' performance, thereby guiding investment decisions. Measuring key indicators such as ROA and ROE enables investors to evaluate firms' profitability potential, growth expectations, and risk analysis. As confidence in highly profitable and sustainable REITs increases, investment decisions can be made more efficiently in terms of time and cost. For REIT firms, profitability forecasting plays a critical role in strategic planning and portfolio management. These forecasts facilitate the optimization of financial performance, the identification of growth opportunities, and the development of new projects. Moreover, by analyzing the impact of hyperparameters and weights on profitability through established models, more effective modeling and forecasting can be achieved, serving as a guide for both new investors and existing REIT managers. The findings obtained are significant for creating a competitive advantage and ensuring sustainable success in the REIT sector.

In conclusion, this study demonstrates the advantages of employing ANN methods for profitability prediction in the REIT sector by linking its findings to the limited existing literature. The results indicate that future analyses could benefit from utilizing ANN and other machine learning techniques with broader datasets and deep learning methods to enrich REIT analyses. This approach not only contributes to the academic literature but also provides more flexible and reliable modeling opportunities for practical applications in the industry. Better prediction performance can be achieved with the use of machine learning algorithms and techniques created for profitability prediction. This allows investors to make more reliable, updatable, and faster predictions in the future. Thus, it can automate many steps in issues such as data preprocessing, variable selection, and modeling processes that require expertise. Machine learning algorithms also offer companies the opportunity to make flexible modeling due to their ability to adapt to different data types and structures. Thanks to its ability to make predictions by updating in real-time, to analyze data flows, and to adapt to changing conditions faster, machine learning is expected to be used for different purposes in the future, providing faster and more reliable results and increasing its importance and the benefits it will provide. The results indicate that future analyses could benefit from utilizing ANN and other machine learning techniques with broader datasets and deep learning methods to enrich REIT analyses. It can be suggested that more applications be conducted using broader data models in the REIT sector, where there is a noted gap in the use of deep learning methods in the literature. This approach not only contributes to the academic literature but also provides more flexible and reliable modeling opportunities for practical applications in the industry.

Declaration of Research and Publication Ethics
This study which does not require ethics committee approval and/or legal/specific permission complies with the research and publication ethics.

Researcher's Contribution Rate Statement
The authors declare that they have contributed equally to the article.

Declaration of Researcher's Conflict of Interest
There is no potential conflicts of interest in this study.

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Ekonomi, Politika & Finans Araştırmaları Dergisi, 2025, 10(1): 184-201
Journal of Research in Economics, Politics & Finance, 2025, 10(1): 184-201
Araştırma Makalesi / Research Article, https://doi.org/10.30784/epfad.1615246

TIME-VARYING GRANGER CAUSALITY BETWEEN INDUSTRIAL PRODUCTION AND NON-PERFORMING LOANS IN TÜRKİYE

Türkiye'de Sanayi Üretimi ve Takipteki Alacaklar Arasında Zamanla Değişen Granger Nedensellik

Gökhan SÜMER*

Abstract

Banks play a crucial role in bridging fund suppliers and demanders, thereby facilitating economic development by channeling idle funds into the economy. For banks to effectively perform their functions, the financial transmission mechanism is essential. Non-performing loans (NPLs) significantly impact bank profitability, credit positions, and overall economic development. This study investigates the relationship between industrial production and non-performing loans in Turkey using a time-varying Granger Causality test. Monthly data from January 2005 to July 2024 was utilized to examine the interconnection between the industrial production index and non-performing loans. The research uniquely contributes to the existing literature by applying a sophisticated time-varying Granger Causality methodology, investigating the dynamic relationship between economic activity and credit risk, and providing insights into the temporal variations of industrial production and non-performing loans within the Turkish banking sector. Key methodological approaches include utilizing a recursive evolving window algorithm, employing bootstrap simulations to enhance estimation precision, and analyzing causal relationships through multiple computational techniques. Findings underscore the importance of adaptive risk management strategies and the need for flexible macroprudential policies capable of responding to the evolving economic landscape.

Keywords:
Time-Varying Granger Causality, Non-Performing Loans, Industrial Production

JEL Codes:
G21, E32, C22

Öz

Bankalar, fon arz edenler ile talep edenler arasında köprü görevi görerek, âtıl fonları ekonomiye kanalize ederek ekonomik kalkınmaya önemli katkı sağlamaktadır. Bankaların etkili bir şekilde işlevlerini yerine getirebilmeleri için finansal iletim mekanizması oldukça önemlidir. Takipteki krediler (TK), banka karlılığı, kredi pozisyonları ve genel ekonomik gelişme üzerinde önemli bir etkiye sahiptir. Bu çalışmada, Türkiye'de sanayi üretimi ile takipteki krediler arasındaki ilişki, zamanla değişen Granger Nedensellik testi kullanılarak analiz edilmiştir. Ocak 2005 ile Temmuz 2024 arasındaki aylık veriler kullanılarak sanayi üretim endeksi ile takipteki krediler arasındaki etkileşim incelenmiştir. Araştırma, mevcut literatüre benzersiz bir katkı sunarak; zamanla değişen Granger Nedensellik yöntemini uygulamış, ekonomik faaliyet ile kredi riski arasındaki dinamik ilişkiyi incelemiş ve Türk bankacılık sektöründe sanayi üretimi ve takipteki krediler arasındaki zamansal değişimleri sunmuştur. Temel yöntemsel yaklaşımlar arasında; bir evrimsel pencere algoritması kullanımı, tahmin hassasiyetini artırmak için bootstrap simülasyonları ve nedensel ilişkileri analiz etmek için birden fazla hesaplama tekniği yer almaktadır. Bulgular, uyumlu risk yönetim stratejilerinin önemini ve değişen ekonomik ortamı karşılayabilecek esnek makro ihtiyati politikalara duyulan ihtiyacı vurgulamaktadır.

Anahtar Kelimeler:
Zamanla Değişen Granger Nedensellik, Takipteki Krediler, Sanayi Üretimi

JEL Kodları:
G21, E32, C22

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Received Date (Makale Geliş Tarihi): 07.01.2025 *Accepted Date (Makale Kabul Tarihi): 26.03.2025*

1. Introduction

The impact of banks, which are the key actors in the financial sector, on economic development continues to grow day by day. It is crucial for the banking sector, which forms the foundation of financial life, to present an efficient and effective appearance for the development of the national economy (Ferreira, 2017: 203-204). In the early 20th century, Schumpeter demonstrated that the banking system contributes to economic growth by supporting the real sector through credit (İçke, 2014).

While banks profit from individuals or entities that demand funds, they are also exposed to various risks such as exchange rates, interest rates, maturity, liquidity, and repayment in the course of these activities. When individuals or legal entities that need funds fail to pay all or part of the principal or interest of the loans they have used, the loans granted by banks fall into arrears (Genç and Şaşmaz, 2016). In other words, it is the delay in collection and the occurrence of losses for the lender when the debtor fails to fulfill their obligations on time or at all under the contract between the bank and the borrower (Selçuk and Darıcı, 2003: 174).

Bank loans not only influence employment and growth but also have an impact on regional and sectoral development through selective credit policies. The exercise of authority over loans is crucial for these positive effects to emerge. The timely and complete fulfillment of obligations related to loans is one of the conditions for the system to operate healthily. Increasing arrears in bank loans will affect bank profitability, risk appetite, and the amount of funds to be allocated. Therefore, non-performing loans have negative effects on economic development (Koyuncu and Saka, 2011; Selimler, 2015).

Non-performing loans cause banks to face difficulties in managing their assets, liabilities, and liquidity. The problem of non-repayment of loans in the banking sector can quickly spread throughout the entire financial system, potentially leading to a financial crisis. High default rates on loan repayments lead to a decrease in the supply of funds, a decline in bank profitability, and disruption of the sector's credit creation function. Barr et al. (1994) argue that high non-performing loan rates indicate increased risks in the markets, leading banks to tighten credit allocations and credit terms. Cucinelli (2015) suggests that an increase in defaults, along with a deterioration in the quality of banking sector assets, will have negative effects on financial stability and economic growth (Hasan et al., 2009; Zhang et al., 2016).

The contributions of loans granted by banks to the economy have been the subject of much research. The rate of non-performing loans has also been the focus of numerous studies. In many studies, the interactions between loan volume, non-performing loan rates, unemployment, GDP, interest rates, and inflation have been examined using various methods. This study differs from others in that it analyzes the relationship between industrial production and non-performing loans in Turkey using a time-varying Granger Causality test. The study examines the relationship between the industrial production index and non-performing loans using monthly data from January 2005 to July 2024.

Section 2 introduces literature reviews. Section 3 presents the econometric method used in the study, which is the time-varying Granger causality test developed by Shi et al. (2020). Section 4 describes the data and empirical results, including the sources of the data, the time period covered, and the variables used in the analysis. Section 5 discusses the findings and their

implications. Finally, Section 6 concludes the paper with a summary of the main results and suggestions for future research.

2. Literature Review

The relationship between economic activity and credit risk, particularly non-performing loans (NPLs), has been a focal point of extensive research in both developed and emerging markets. Banks play a critical role in economic development by channeling funds from savers to borrowers, and the health of the banking sector is closely tied to the broader economic environment. Non-performing loans, which arise when borrowers fail to meet their repayment obligations, are a key indicator of credit risk and have significant implications for bank profitability, financial stability, and economic growth. Over the years, numerous studies have explored the determinants of NPLs, examining the interplay between macroeconomic factors, banking sector-specific variables, and broader economic conditions. This literature review systematically organizes these studies into thematic categories, providing a comprehensive overview of the existing research and highlighting the diverse methodologies and findings that have shaped our understanding of the dynamics between economic activity and credit risk. By categorizing the literature into macroeconomic factors, banking sector-specific factors, regional and cross-country analyses, methodological approaches, and the broader economic impact of NPLs, this review aims to offer a structured and coherent foundation for the empirical analysis presented in this study.

2.1. Studies on Macroeconomic Factors and Non-Performing Loans (NPLs)

One of the earliest studies to highlight the relationship between macroeconomic conditions and bank failures was conducted by Barr et al. (1994), who emphasized the role of non-performing loans as a key risk factor. Following this, Koyuncu and Saka (2011) investigated the impact of NPLs on domestic credit and private sector investments in Turkey, finding a statistically significant negative relationship. More recently, Sevinç (2021) analyzed the relationship between NPLs and macroeconomic variables in Turkey, concluding that economic growth and inflation reduce NPLs, while unemployment and exchange rates increase them. In a similar vein, Qureshi and Hasmi (2023) studied the impact of interest rates, inflation, and GDP on NPLs in Pakistan, finding a negative relationship between inflation, GDP, and NPLs, but a positive relationship between interest rates and NPLs. Adam et al. (2024) further contributed to this line of research by investigating the impact of inflation and national income on NPLs in private banks in Indonesia, finding a positive effect of inflation but an insignificant effect on national income. Finally, Yalçın (2024) explored the long-term relationship between exchange rates, consumer loan interest rates, and NPLs in Turkey, identifying a positive relationship between exchange rates and NPLs, and a negative relationship between policy interest rates and NPLs.

2.2. Studies on Banking Sector-Specific Factors and NPLs

Early work on the Turkish banking sector by Selçuk and Darıcı (2003) focused on the impact of delayed loan collections on bank performance. Later, Kılcı and Baygın (2019) used the TAR-MTAR cointegration test to analyze the relationship between credit interest rates and NPLs

in Turkey, finding a long-term relationship. More recently, Erdoğan (2024) analyzed the relationship between NPLs and loan provisions, total assets, and capital adequacy ratios in Turkish banks, finding a positive and significant relationship. Karaaslan (2023) also investigated the determinants of NPLs in the Turkish banking sector, finding a significant positive relationship between unemployment and NPLs, and a negative relationship between GDP and NPLs. Additionally, Umarbeyli and Kırıkkaleli (2023) examined the relationship between NPLs and bank concentration in Turkey, finding a positive relationship between NPLs and bank concentration.

2.3. Studies on Regional and Cross-Country Analysis of NPLs

Tanaskovic and Jandric (2015) were among the first to examine the macroeconomic and institutional determinants of NPLs in Middle Eastern and Southeastern European countries, finding a positive relationship between GDP, exchange rates, and NPLs. Following this, Artenisa and Hyrije (2023) studied the impact of GDP, credit, and interest rates on NPLs in six Western Balkan countries, finding a significant positive impact of GDP and central government debt on NPLs. More recently, Nwonye et al. (2023) analyzed the impact of macroeconomic indicators and governance on NPLs in 30 Sub-Saharan African countries, finding a relationship between GDP growth and a reduction in NPLs.

2.4. Studies on Methodological Approaches to NPLs

Shi et al. (2020) developed a time-varying Granger causality test, which is used in this study to analyze the dynamic relationship between industrial production and NPLs. Following this, Us (2020) applied a panel VAR approach to analyze NPLs in the Turkish banking sector, concluding that NPLs respond strongly to shocks in macroeconomic indicators. More recently, Tunay and Tunay (2024) used a Bayesian analysis to study the interactions between NPLs and macroeconomic shocks in Turkey, finding a strong mutual interaction between NPLs and economic activity.

2.5. Studies on the Impact of NPLs on Economic Development

Cucinelli (2015) argued that an increase in NPLs deteriorates the quality of banking sector assets, negatively affecting financial stability and economic growth. More recently, Yıldız (2024) concluded that NPLs negatively affect profitability ratios in the banking sector and lead to long-term losses in the national economy by reducing credit availability for production and investment.

3. Econometric Method

This study seeks to rigorously examine the causal relationship between non-performing loans and the industrial production index within a time-varying dynamic framework. The dynamic time-varying causality test established by Shi et al. (2020) is employed, demonstrating significant efficacy in identifying heterogeneities in time series data. The methodology fundamentally involves a Granger causality analysis within the context of the lag-augmented VAR (LA-VAR)

model. The study yields results utilizing three distinct algorithms: forward-recursive, rolling window, and recursive evolving.

This methodology is extensively recognized in the literature for its capacity to distinctly illustrate variability in causal links, particularly during times of frequent economic shocks and structural fractures. The "recursive evolving rolling window" technique proposed by Shi et al. (2020) is recognized for yielding more dependable outcomes than conventional methods, owing to its adaptability in collecting heterogeneities within time series data. Simulations employing the bootstrap approach enhance the precision of estimating the test statistic's distribution, hence mitigating the likelihood of erroneous results.

First, the LA-VAR model is shown in equation (1). The dependent variable y_t is a n-dimensional vector.

$$y_t = \alpha_0 + \alpha_1 t + \sum_{i=1}^{k} \beta_i y_{t-i} + \sum_{j=k+1}^{k+G} \beta_j x_{t-j} + \varepsilon_t \quad (1)$$

where $\beta_{k+1} = \beta_{k+2} = \cdots = \beta_{k+d} = 0$. G, represents the maximum lag within the stationary vector y_t. Then, the basic regression model is shown in equation (2) below:

$$y_t = \Gamma\tau_t + \Phi x_t + \Psi z_t + \epsilon_t \quad (2)$$

$\Gamma = (\alpha_0, \alpha_1)_{n\times(q+1)}$, $\tau_t = (1, t)'_{2\times1}$, $\Phi = (\beta_1, \dots, \beta_k)_{n\times nk}$ and $\Psi = (\beta_{k+1}, \dots, \beta_{k+G})_{n\times nk}$, $x_t = ({y_{t-1}}' \cdots {y_{t-k}}')'_{nk\times1}$, $z_t = ({y_{t-k-1}}' \cdots {y_{t-k-l}}')'_{nG\times1}$ are defined.

The following equation (3) represents the null hypothesis:

$$H_0: R\phi = 0 \quad (3)$$

To examine whether Granger non-causality can be rejected, the relevant null hypothesis is determined using row vectorization on the matrix $\boldsymbol{\phi} = \text{vec}(\boldsymbol{\Phi})$, with the following restrictions, and the matrix R has dimensions $m \times n^2k$. The coefficients of the last G lagged vectors, represented by the matrix Ψ, are ignored because it is assumed that their components are equal to zero. Furthermore, equation (1) can be rewritten as equation (4):

$$y_t = \Gamma\tau_t + \Phi x_t + \Psi z_t + \epsilon_t \quad (4)$$

where $Y = (y_1, y_2, \dots, y_T)'_{T\times n}$, $\tau = (\tau_1, \dots, \tau_T)_{T\times2}$, $X = (x_1, \dots, x_T)_{T\times nk}{}'$, $Z = (z_1, \dots, z_T)_{T\times nG}{}'$ and $\varepsilon = (\varepsilon_1, \dots, \varepsilon_T)_{T\times n}{}'$. $Q_\tau = I_T - \tau(\tau'\tau)^{-1}\tau'$ and $Q = Q_\tau - Q_\tau Z(Z'Q_\tau Z)^{-1}Z'Q_\tau$ are defined. Thus, the parameter function for the least squares method is given by equation (5):

$$\hat{Q} = Y'QX(X'QX)^{-1} \quad (5)$$

To test the null hypothesis H_0, the Wald statistic W is proposed in equation (6):

$$W = (R'\hat{\phi})'\left[R\{\hat{\Sigma}_e \otimes (X'QX)^{-1}\}R'\right]^{-1}R\hat{\phi} \quad (6)$$

where, $\hat{\Phi} = \text{vec}(\Phi)$ and $\hat{\Sigma}_\epsilon = \frac{1}{T}\hat{\epsilon}'\hat{\epsilon}$. As stated by Tada and Yamamoto [45] and Dolado and Lütkepohl [46], the asymptotic distribution of the Wald statistic is distributed as χ^2_m, where m is the number of restrictions.

In terms of Granger causality tests, the Wald statistics from the recursive perspective are measured from sub-samples of the data being examined. f_{r1} and f_{r2} are assumed to be the intersection points of the forecast observations, representing the start and end points, and are defined as $f_{rw} = f_{r2} - f_{r1}$. The Wald statistic measured from this sub-sample is denoted as $W_{f_{r1},f_{r2}}$. $\tau_{r1} = [f_{r1}T]$,$\tau_{r2} = [f_{r2}T]$ and $\tau_{rw} = [f_{rw}T]$ are defined, where T represents the sample size. $\tau_{r0} = [f_{r0}T]$ indicates the minimum number of observations required to estimate the VAR.

In the forward-expanding window algorithm, the starting point τ_{r1} is fixed at the first observation (i.e., $\tau_{r1} = 1$), and the regression window expands between τ_{r0} and T. This process is equivalent to τ_{r2} moving from τ_{r1} to T. It is assumed that the window size for the recursive regression remains constant. The starting point τ_{r1} changes from the initial observation to $T - \tau_{r0} + 1$; in short, $\tau_{r2} = \tau_{r1} + \tau_{r0} + 1$. The recursive evolving window algorithm defines the terminal sample of the regression similarly to the recursive algorithm.

However, in contrast to the recursive algorithm, where the starting sample τ_{r1} maintains a fixed distance from τ_{r2}, in this case, τ_{r1} changes from the initial observation to $\tau_{r2} - \tau_{r0} - 1$. For each corresponding sample, a series of Wald statistics f_{r0} is obtained. The test statistic is defined as the supremum of the Wald statistic series, which forms equation (7):

$$SW_{f_r}(f_{r0}) = \sup_{f_{r2}=f_r, f_{r1}\in[0,f_{r2}-f_{r0}]} \{W_{f_{r1},f_{r2}}\} \quad (7)$$

The inference on Granger causality is based on the supremum Wald statistic $SW_{f_r}(f_{r0})$ for the observation $[f_rT]$. For practical forecasting, the optimal lag order of the VAR model was selected based on information criteria, and the restricted model was calculated. The test statistic was then measured. According to simulations conducted by Shi et al. (2020), the recursive evolving window algorithm was found to outperform the other two procedures[1].

Finally, some key comparative analyses are presented below to validate the superiority of the model: The current causal effect model evaluates the dependency of variables from a static perspective. The time-varying characteristics of the time series data have not been taken into account. In other words, potential structural change phenomena in the data's behavior cannot be captured with precision, which could lead to misleading results. Additionally, introducing the Fourier function in the model, in order to capture potential trends and variable effects in the data, brings a high prediction cost in terms of nonlinear forecasting. The two major advantages of the model proposed by Shi et al. (2020) are as follows:

First, the model not only captures the full potential informational content of the data but also reduces concerns about structural changes through the recursive evolving window method. Second, compared to general nonlinear models, this model offers a predictable nature, which leads to a reduction in forecasting costs $\{W_{f_{r1},f_{r2}}\}_{f_{r2}=f_r}^{f_{r1}\in[0,f_{r2}-f_{r0}]}$.

4. Data and Empirical Results

The Non-Performing Loans (ta_t) variable used in this study is obtained from the monthly bulletin of the Banking Regulation and Supervision Agency of Turkey (BDDK). The data is listed under the title 'Consumer Loans - Total - Non-Performing Consumer Loans and Non-Performing

[1] Interested readers are encouraged to refer to the works of Shi et al. (2020).

Individual Credit Cards (million TL) - Total.' The industrial production index (sue_t) is used as an indicator of the economy. This variable is obtained from the Central Bank of the Republic of Turkey's Electronic Data Distribution System (EVDS). The study covers the period from January 2005 to July 2024. In the analysis, the natural logarithms of both variables ($lnta_t$ and $lnsue_t$) are taken for calculations.

Figure 1 shows the time series of the natural logarithm of non-performing loans (LNTA) and the natural logarithm of the industrial production index (LNSUE) for the period from January 2005 to July 2024.

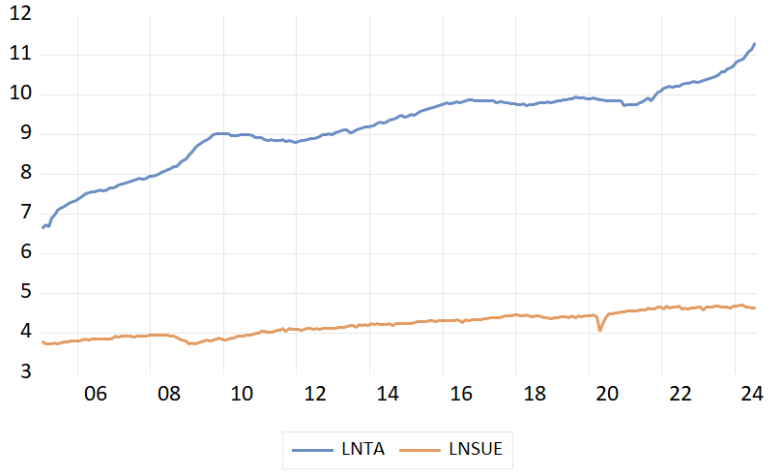

Figure 1. Time Series Graph of LNTA and LNSUE Variables.

Both series exhibit a significant upward trend and are not stationary. This makes it difficult to analyze them using traditional econometric methods that assume stationarity. However, as previously mentioned, the LA-VAR model will be used for a more flexible analysis that preserves the dynamic characteristics of the series. The LA-VAR model examines time-varying Granger causality, revealing how the causal relationship between variables changes over time. This allows for a more detailed investigation of the relationship between non-performing loans and the economic structure represented by the industrial production index, without the need to make the series stationary, thus preserving their dynamic properties. In summary, to evaluate the Granger causality between Non-Performing Loans and the Industrial Production Index more precisely, three statistical approaches proposed by Shi et al. (2020) will be used: forward, rolling window, and recursive algorithms.

4.1. Stationarity Analysis

In the study, unit root and stationarity tests, including the Augmented Dickey-Fuller (ADF), Phillips-Perron (PP), and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests, are used to examine the behavior of both series over time. The results are presented in Table 2. Before the first differencing process, $lnta$ and $lnsue$ exhibit non-stationary characteristics. Both time series remain non-stationary until the first differencing process. After the first differencing process, each series becomes stationary. Therefore, in line with the framework outlined in Shi et al. (2020), the

LA-VAR model is applied in this study to investigate the potential existence of causality from a dynamic perspective.

Table 1. Stationarity Test Results for the Series

	ADF		PP		KPSS	
Level	**Constant**	**Constant+Trend**	**Constant**	**Constant+Trend**	**Constant**	**Constant+Trend**
$lnta$	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)
$lnsue$	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)
	ADF		**PP**		**KPSS**	
Δ	**Constant**	**Constant+Trend**	**Constant**	**Constant+Trend**	**Constant**	**Constant+Trend**
$lnta$	I(0)	I(0)	I(0)	I(0)	I(0)	I(0)
$lnsue$	I(0)	I(0)	I(0)	I(0)	I(0)	I(0)

Note: Level and Δ indicate the level and first differencing process, respectively. I(0) and I(1) signify stationary and first-differenced stationary, respectively.

4.2. Time-Varying Granger Causality Tests

Firstly, the results of the time-varying Granger causality tests between the two variables were obtained for the entire period from January 2005 to July 2024. Here, the relevant Wald test statistics and bootstrap critical values obtained using all three approaches are presented. The results are shown in Table 3.

Table 2. Results of Time-Varying Granger Causality Tests

H_0: lnsue ↛ lnta	**W forward**	**W rolling**	**W recursive**
Test Statistic	58.358	78.991	78.991
	Bootstrap Critical Values		
Confidence Level	**W forward**	**W rolling**	**W recursive**
90%	7.398	7.134	7.889
95%	9.456	9.107	9.578
99%	13.815	13.815	13.815
H_0: lnta ↛ lnsue	**W forward**	**W rolling**	**W recursive**
Test Statistic	14.494	20.227	24.377
	Bootstrap Critical Values		
Confidence Level	**W forward**	**W rolling**	**W recursive**
90%	7.876	7.615	8.023
95%	10.466	10.127	10.714
99%	16.098	15.868	16.38

Note: p(3) d(1) trend and [199 replications]. W represents the test statistic.

The results in Table 3 show a bidirectional time-varying Granger causality between the two series at the 90%, 95%, and 99% confidence levels for all 3 algorithms used. However, the Turkish economy has undergone structural changes over the last thirty years. Therefore, assuming a time-invariant relationship between non-performing loans and the industrial production index throughout the sample period may overlook fundamental changes in the relationship. To capture possible structural changes in the relationship between the two variables, a time-varying Granger causality test has been applied.

The progression of the Wald test statistics for the hypothesis that the industrial production index is not a Granger cause of non-performing loans is shown in Figures 1, 2, and 3, based on

the results from each of the three algorithms. The minimum window size is chosen to be 72 observations. In estimating the LA-VAR model, the lag length is selected using the Bayesian Information Criteria (BIC) with a maximum lag order of 2. The bootstrap critical values are obtained using 199 replications.

Figure 2 represents the Wald test statistics for the causality test from *lnsue* to *lnta* based on the recursive algorithm. The black solid line represents the Wald test statistics over time, while the high and low dashed lines represent the 95% and 90% confidence level bootstrap critical values, respectively.

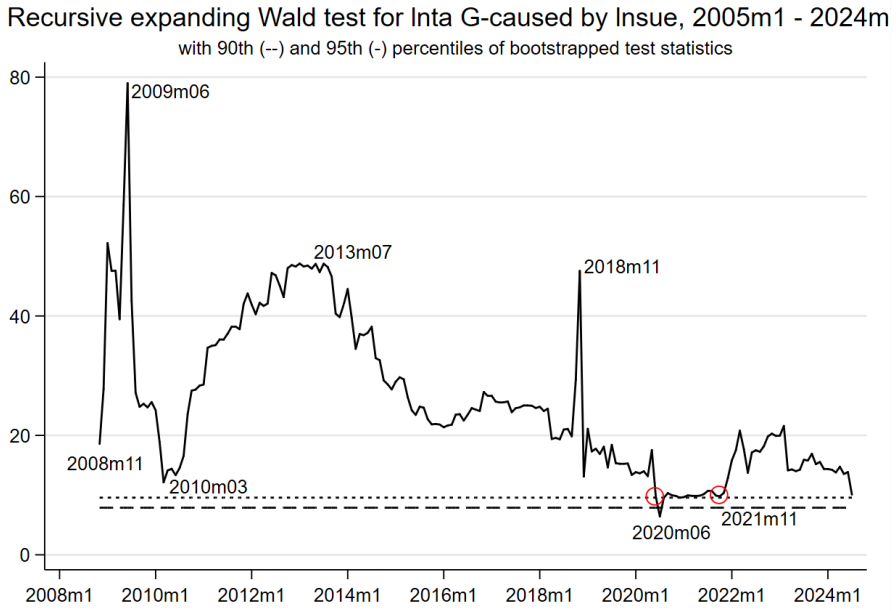

Figure 2. Recursive Expanding Wald Test for the Granger Causality of *lnsue* to *lnta*

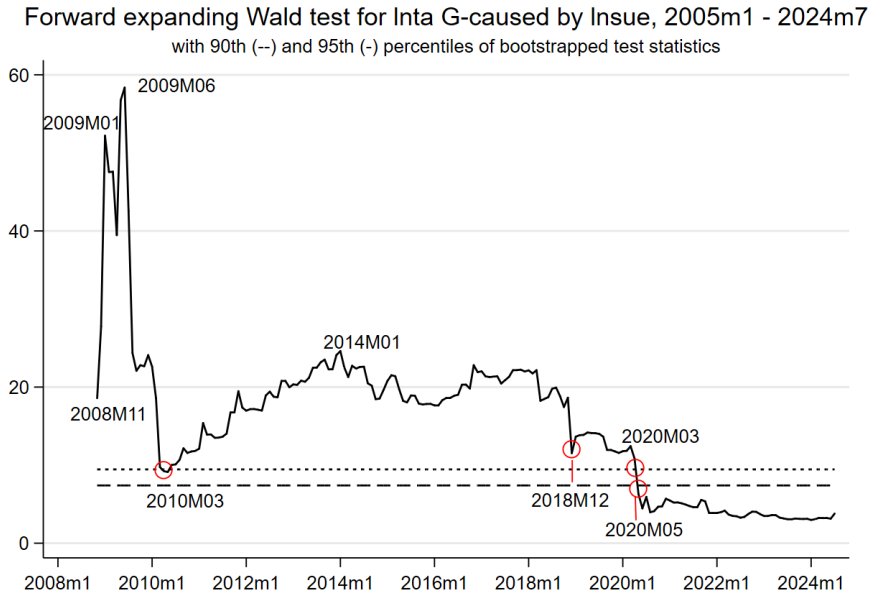

Figure 3. Forward Wald Test for the Granger Causality of *lnsue* to *lnta*

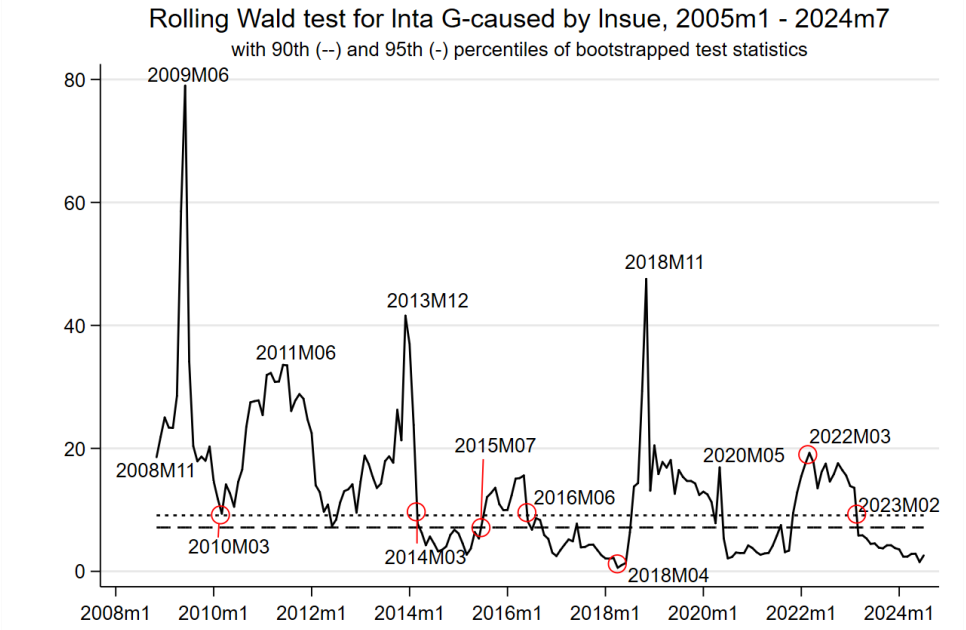

Figure 4. Rolling Wald Test for the Granger Causality of *lnsue* to *lnta*

The Wald test statistics show significant peaks around mid-2009, mid-2013, and late 2018. These peaks indicate periods where strong causality from lnsue to lnta was observed. During the global financial crisis of 2008-2010, the Wald test statistics exceeded the 95% critical value, revealing a strong causal relationship. During this period, the increase in non-performing loans alongside the decline in industrial production can be seen as a predictable outcome. From 2010 to 2013, as Turkey entered an economic recovery phase with reforms, the causality remained above the 90% critical value, though not as strong as during the crisis.

From 2013 to 2018, while Turkey experienced strong economic growth, fluctuations in the test statistics were observed due to structural challenges such as high inflation. During this period, the test statistics approached the 95% critical threshold, indicating that the impact of industrial production on non-performing loans increased during certain periods. Between 2018 and 2020, political and economic uncertainties, along with the pandemic, led to a significant rise in causality, causing Wald test statistics to surpass the 90% and 95% critical values. During this time, the sharp decline in industrial production had a strong impact on non-performing loans.

Between 2020 and 2021, the economic contraction caused by the pandemic led to test statistics fluctuating around critical values, indicating that the causality relationship temporarily weakened due to the pandemic's effects. Finally, between 2021 and 2024, as the economy slowly recovered, the test statistics showed occasional peaks. This reflects ongoing challenges related to inflation and governance, suggesting that the dynamic relationship between industrial production and non-performing loans has persisted.

The time series of the Wald test statistics obtained for each of the three algorithms regarding the hypothesis that non-performing loans are not the Granger cause of the Industrial Production Index are shown in Figures 4, 5, and 6, respectively. The minimum window size is selected as 72 observations. In estimating the LAVAR model, the lag length is chosen based on

the Bayesian Information Criteria (BIC) with a maximum lag order of 2. The bootstrap critical values are obtained with 199 replications. Figure 4 represents the causality test from *lnsue* to *lnta* based on the iterative algorithm, with the black solid line showing the Wald test statistics over time. The high and low dashed lines represent the bootstrap critical values for the 95% and 90% confidence levels, respectively.

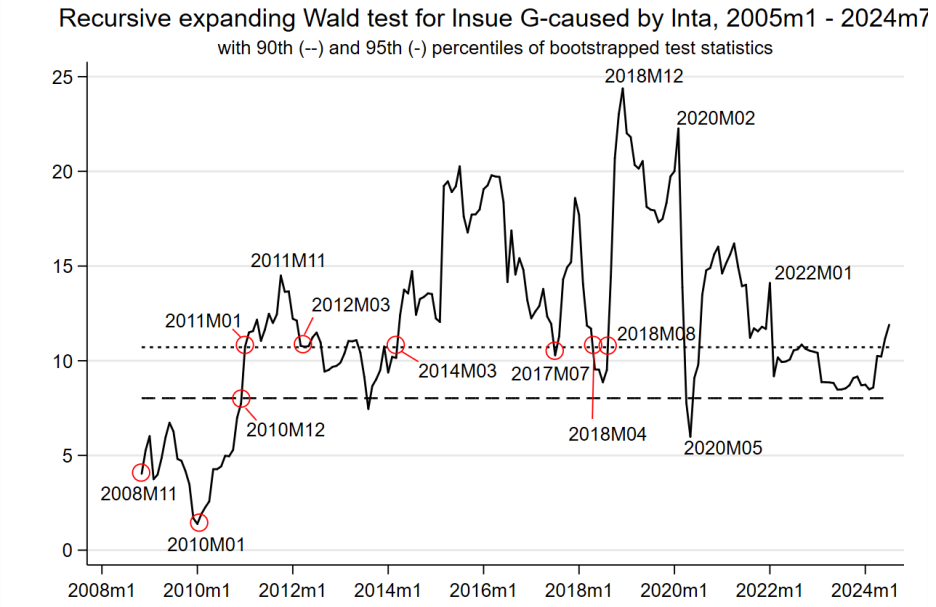

Figure 5. Recursive Wald Test for the Granger Causality from *lnta* to *lnsue*

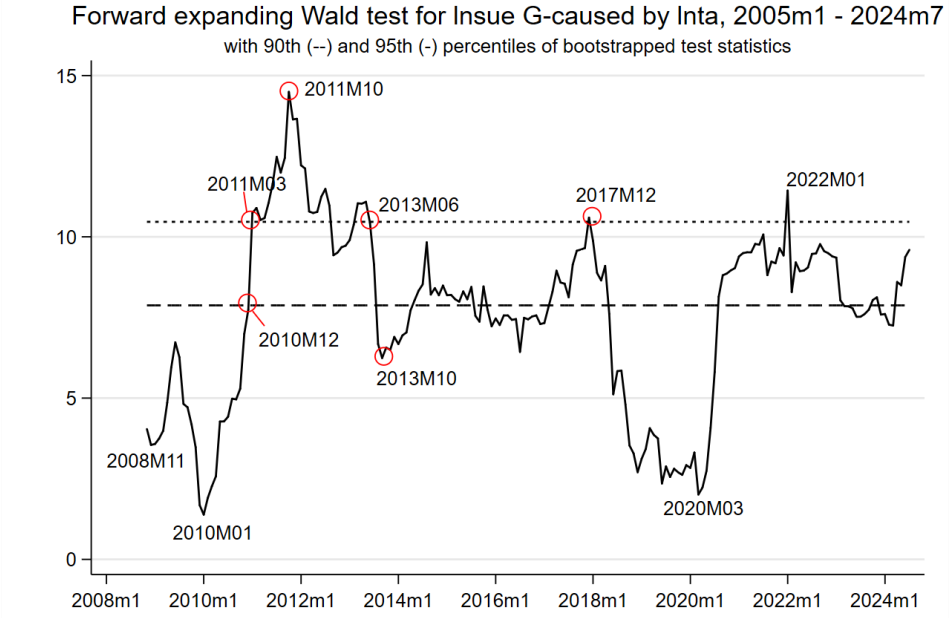

Figure 6. Forward Wald Test for the Granger Causality from *lnta* to *lnsue*

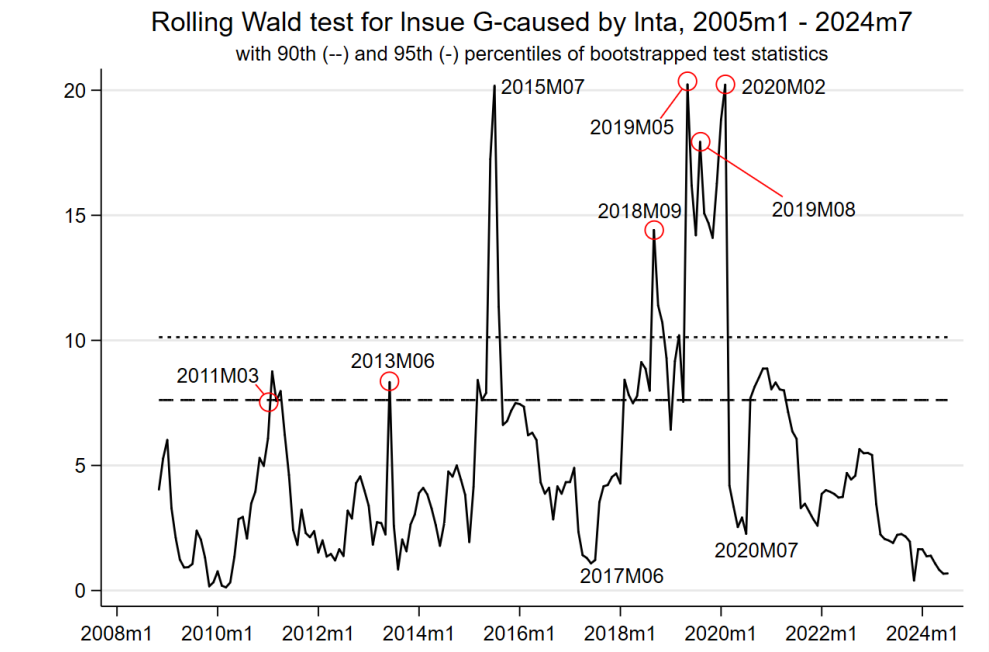

Figure 7. Rolling Wald Test for the Granger Causality from *lnta* to *lnsue*

The figure shows the temporal changes in the Wald test statistics for testing whether *lnta* (Non-performing Loans) is the Granger cause of *lnsue* (Industrial Production Index). The black line represents the Wald test statistics, while the dashed lines indicate the bootstrap critical values at the 90% and 95% confidence levels.

The first notable observation is that the Wald test statistics start at a low level towards the end of 2008. However, as we approach 2010, the statistics approach the 90% critical value, and the causality strengthens due to the economic fluctuations following the global financial crisis. During this period, it can be inferred that non-performing loans may have had a certain impact on industrial production.

Since the beginning of 2011, the Wald test statistics have exceeded the 90% critical value, indicating the existence of causality from non-performing loans to industrial production. Notably, the increase in test statistics towards the end of 2011 could be a significant indicator that uncertainties in the financial sector impacted the real sector.

Between 2014 and 2018, fluctuations in the test statistics are observed. During this period, strong economic growth and structural challenges such as high inflation caused volatility in the test statistics. In particular, towards the end of 2018 and 2020, when the statistics surpassed the 95% critical value, it is evident that non-performing loans had a strong impact on industrial production.

Since the beginning of 2020, due to the impact of the pandemic, the Wald test statistics have surpassed the critical values, which can be interpreted as an indication that financial difficulties affected industrial production. During this period, the effect of non-performing loans on industrial production became more pronounced due to economic contraction and uncertainty.

From 2022 onwards, the Wald test statistics have fallen below the critical values, signaling that the impact of non-performing loans on industrial production weakened during the post-

pandemic economic recovery process. However, some increases in the test statistics suggest that the economic recovery is volatile, and financial uncertainties may still affect industrial production. In conclusion, the graph demonstrates that the causality effect of LNTA on LNSUE fluctuated over time.

The next step is to present the relevant coefficient estimates obtained using rolling window regression in Figures 8 and 9, respectively.

Figure 8 Estimated Coefficients from the Rolling Window Regression for $lnsue$

This rolling window regression graph clearly shows how the impact of the industrial production index ($lnsue$) on non-performing loans ($lnsta$) has changed over time. In summary, the changes in the coefficients over different periods can be interpreted as follows:

2009–2010: The coefficient sharply drops to around -0.6. This reflects the post-global financial crisis period, showing a strong negative impact of the decline in industrial production on non-performing loans. The crisis and credit tightening, along with economic pressures and financial difficulties, were significant factors in this period.

2011–2015: The coefficients fluctuate between -0.4 and -0.1, remaining mostly negative. During this period, the negative impact of industrial production on non-performing loans persists, but the effect gradually diminishes. This may indicate a prolonged recovery phase in Turkey's economy, where financial instability still made the economy vulnerable.

2016–2018: The coefficients approach positive values, reaching around 0.3–0.4. In this period, the negative impact of industrial production on non-performing loans has decreased or even turned into a neutral-positive relationship. This suggests improvements in financial stability or that economic growth has become more resilient to financial risks.

2019–2020: The coefficients again decrease, reaching near zero or slightly negative values. This period marks the beginning of the COVID-19 pandemic, during which economic shocks may have created a negative relationship again. Credit issues resurfaced, and production disruptions occurred, contributing to the negative trend.

2021–2024: The coefficients stabilize near zero with a slight positive trend. This likely reflects the post-pandemic recovery period, where industrial production became more resilient,

and the direct negative impact of non-performing loans on production decreased. However, some minor increases indicate that economic uncertainty and financial risks may still have an influence.

In conclusion, these periodical changes reflect the dynamics of Turkey's economic structure and the effects of financial pressures on industrial production, showing how these effects have evolved over time.

Figure 9 Estimated Coefficients from the Rolling Window Regression for $lnta$

This rolling window graph shows how the effect of non-performing loans ($lnta$) on the industrial production index ($lnsue$) has changed over time. In summary:

2009–2010: The coefficient sharply drops to around -0.6. This period reflects the aftermath of the global financial crisis, indicating that the increase in non-performing loans had a strong negative effect on industrial production, likely due to credit tightening and economic pressures.

2011–2015: The coefficients fluctuate between -0.4 and -0.1, remaining mostly negative. This suggests that non-performing loans still have a negative effect on industrial production, but the effect gradually diminishes. It may reflect a long recovery process in the economy, which remained vulnerable to financial instability.

2016–2018: The coefficients approach positive values, reaching around 0.3–0.4. This could indicate a period where the negative effect of non-performing loans on industrial production decreased or even turned into a neutral-positive relationship. This may suggest improvements in financial stability or that economic growth became more resilient to financial risks.

2019–2020: The coefficients decrease again, approaching zero or slightly negative values. This period coincides with the onset of the COVID-19 pandemic, where economic shocks may have caused a negative relationship again, as credit issues resurfaced, and disruptions in production occurred.

2021–2024: The coefficients stabilize near zero with a slight positive trend. This suggests that the effect of non-performing loans on industrial production could be neutral or slightly positive. This may reflect the post-pandemic recovery period, where industrial production has

become more resilient, and the direct negative impact of non-performing loans on production has decreased.

5. Conclusion and Policy Implication

The study examined the relationship between industrial production and non-performing loans in Turkey using a time-varying Granger Causality test for the period from January 2005 to July 2024. The analysis revealed several key findings that have important implications for policymakers, financial institutions, and researchers.

The study identified a dynamic and time-varying relationship between economic activity, as measured by the industrial production index, and credit risk, represented by non-performing loans. This relationship is not constant over time, highlighting the importance of considering temporal variations in economic analysis. The recursive evolving window algorithm proved to be more effective in capturing the heterogeneities in the time series data compared to traditional methods, providing a more nuanced understanding of the causal relationship between industrial production and non-performing loans.

The findings underscore the importance of adaptive risk management strategies in the banking sector. Financial institutions and regulators should adopt more dynamic approaches to risk management, considering the time-varying nature of the relationship between economic activity and credit risk. Policymakers should develop and implement early warning systems that can detect changes in the causal relationship between industrial production and non-performing loans, allowing for timely interventions. These systems could help mitigate the impact of economic downturns on the banking sector's loan portfolio quality.

The government and central bank should consider implementing countercyclical policies to mitigate the impact of economic downturns on the banking sector. These policies could include measures such as adjusting capital requirements or providing liquidity support during periods of economic stress. Banks should also incorporate time-varying models in their stress testing frameworks to better assess their vulnerability to economic shocks. This would enable them to identify potential risks and take proactive measures to mitigate them.

Encouraging banks to diversify their loan portfolios across different sectors may help reduce the overall impact of industrial production fluctuations on non-performing loans. Sectoral diversification can spread risk and reduce the concentration of credit risk in any single sector. Regulators should design flexible macroprudential policies that can be adjusted based on the evolving relationship between economic activity and credit risk. These policies should be tailored to the specific needs of the Turkish banking sector and should be responsive to changes in the economic environment.

The Banking Regulation and Supervision Agency (BDDK) should strengthen its monitoring capabilities to track the dynamic relationship between economic indicators and banking sector health. Enhanced monitoring would enable the BDDK to identify emerging risks and take timely action to address them. By implementing these policy recommendations, policymakers and financial institutions can better manage credit risk, enhance financial stability, and support sustainable economic growth in Turkey.

In conclusion, this study provides critical insights into the complex dynamics between economic activity and credit risk in an emerging market context. The findings highlight the importance of adopting flexible and adaptive policies to address the challenges posed by non-performing loans and to support the resilience of the banking sector. Future research could explore the impact of other macroeconomic and institutional factors on non-performing loans, as well as the effectiveness of different policy interventions in mitigating credit risk.

Declaration of Research and Publication Ethics
This study which does not require ethics committee approval and/or legal/specific permission complies with the research and publication ethics.

Researcher’s Contribution Rate Statement
I am a single author of this paper. My contribution is 100%.

Declaration of Researcher’s Conflict of Interest
There is no potential conflicts of interest in this study.

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Journal of Research in Economics, Politics & Finance, 2025, 10(1): 202-233
Araştırma Makalesi / Research Article, https://doi.org/10.30784/epfad.1621455

THE IMPACT OF ARTIFICIAL INTELLIGENCE ON EMPLOYMENT: A PANEL DATA ANALYSIS FOR SELECTED COUNTRIES*

Yapay Zekânın İstihdam Üzerindeki Etkisi: Seçilmiş Ülkelere Yönelik Panel Veri Analizi

Cemre Nur ÇETİN** & **Erol KUTLU*****

Abstract

Various artificial intelligence technologies such as robotics, machine learning, natural language processing, deep learning, and automation have developed rapidly in recent years and their use has become increasingly widespread in all areas that can affect the economy. These technologies have the capacity to optimize production processes, enhance efficiency levels, and play a decisive role in shaping trade and economic growth. Furthermore, they possess significant potential to exert notable impacts on employment and income inequality. The rise of artificial intelligence has sparked widespread debate, particularly regarding its potential impact on employment dynamics. The study analyzes the effect of artificial intelligence on employment in 29 countries from 2017 to 2021 using the System-GMM estimator. The results showed a statistically significant positive effect of artificial intelligence on employment. The analysis also considers the potential impact of labor productivity on employment in relation to artificial intelligence technologies by including an interaction term in the same model. The estimation results show that while the impact of artificial intelligence and labor productivity on employment is positive when considered individually, the interaction term diminishes this positive effect.

Keywords: Artificial Intelligence, Technological Change, Employment, Productivity, Panel Data

JEL Codes: C33, J23, J24, O33

Öz

Robotik, makine öğrenimi, doğal dil işleme, derin öğrenme ve otomasyon gibi çeşitli yapay zekâ teknolojileri son yıllarda hızla gelişmiş ve ekonomiyi etkileyebilecek tüm alanlarda kullanımları giderek yaygınlaşmıştır. Bu teknolojiler, üretim süreçlerini optimize etme, verimlilik düzeylerini yükseltme ve ticaret ile ekonomik büyüme üzerinde belirleyici bir rol oynama kapasitesine sahiptir. Bunun yanı sıra, istihdam ve gelir eşitsizliği üzerinde de kayda değer etkiler yaratabilme potansiyeli bulunmaktadır. Yapay zekânın yükselişi, özellikle istihdam dinamikleri üzerindeki potansiyel etkisi konusunda yaygın tartışmalara yol açmıştır. Çalışma, yapay zekânın 2017-2021 yılları arasında 29 ülkede istihdam üzerindeki etkisini Sistem-GMM tahmincisini kullanarak analiz etmektedir. Sonuçlar, yapay zekânın istihdam üzerinde istatistiksel olarak anlamlı pozitif bir etkisi olduğunu göstermiştir. Analiz, aynı modele bir etkileşim terimi dahil ederek yapay zekâ teknolojileriyle ilişkili olarak işgücü verimliliğinin istihdam üzerindeki potansiyel etkisini de dikkate almaktadır. Tahmin sonuçları, yapay zekâ ve işgücü verimliliğinin ayrı ayrı ele alındığında istihdam üzerindeki etkisinin pozitif olduğunu, etkileşim teriminin ise bu pozitif etkiyi azalttığını göstermektedir.

Anahtar Kelimeler: Yapay Zekâ, Teknolojik Değişim, İstihdam, Verimlilik, Panel Veri.

JEL Kodları: C33, J23, J24, O33

* This paper is derived from the PhD thesis entitled "The Impact of Artificial Intelligence on Employment: A Panel Data Analysis for Selected Countries" completed by Cemre Nur CETİN under supervision of Prof. Dr. Erol KUTLU.

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Received Date (Makale Geliş Tarihi): 17.01.2025 Accepted Date (Makale Kabul Tarihi): 27. 03.2025

1. Introduction

The remarkable advancement of artificial intelligence (AI) technologies, such as machine learning (ML), deep learning (DL), machine vision, natural language processing (NLP), and robotics has given rise to intense discussions concerning their potential influence on labor. The debates have led to a divergence of opinion in the literature regarding the impacts of AI on employment. This paper aims to examine the multifaceted potential effects of AI on employment and, in this context, contribute to a better understanding of the complex relationship between AI and employment. The study makes this contribution not only through a theoretical framework that encompasses all the potential impacts of developments in AI technologies on labor and labor market dynamics but also through an empirical analysis that provides robust insights into these dynamics based on real-world data.

AI is a technology that has become widespread in modern society. It is the driving force behind the fourth and fifth industrial revolutions, and its evolution since the 1950s has led to a penetration rate that will affect nearly every aspect of the economy. Based on Andrew NG's (2018) definition of AI as the "new electricity," it is not difficult to estimate the potential benefits that AI can provide. However, it is also crucial to debate the potential harms that may occur alongside these benefits. Because it is crucial to consider both the potential benefits and the possible harms of AI, Ernst and Mishra (2021) portray AI in two distinct contexts: utopia or dystopia. To this end, Ernst and Mishra depict AI in two contexts: utopia or dystopia.

The potential benefits that AI has brought and is expected to bring since its inception have encouraged companies, research institutions such as universities, and governments to increase their investments in AI. In recent years, there has been a notable increase in investment in AI technologies, particularly by firms. The growing investments in AI technologies by firms are driven by a desire to expand production, reduce costs, and maximize profits. As illustrated in Figure 1, the total amount of global private investments in AI increased from 5.1 billion dollars in 2013 to 132.3 billion dollars by 2021. The most striking increase in Figure 1 is the doubling of the investment amount in a single year, from 2020 to 2021. In the present era, the level of investment has diminished, yet it remains considerable, amounting to $95.99 billion. Despite recent small declines, private AI investment has grown significantly globally over the last decade.

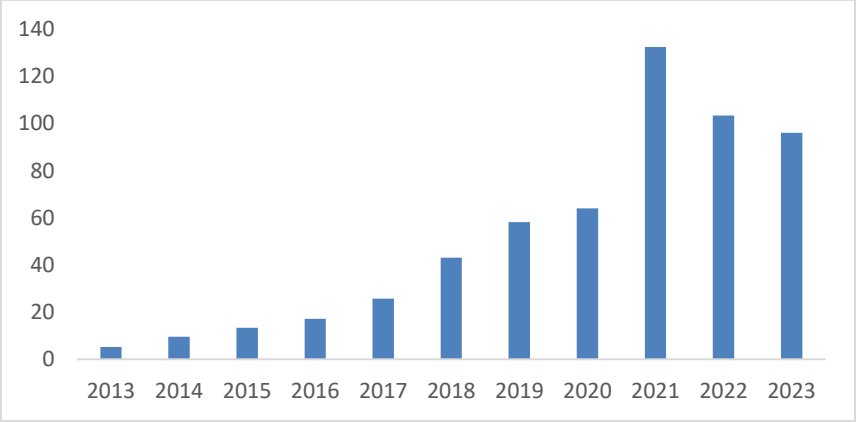

Figure 1. Private Investment in AI (billions in U.S. dollars)
Source: Maslej et al. (2024).

Figure 2 illustrates the disaggregated investment data presented in Figure 1, organized by country. Between 2013 and 2023, the country that invested the most in AI was the United States, with a total investment of $335 billion. China followed with an investment of $103 billion, while the United Kingdom invested $22 billion. AI can contribute to enhanced economic activity on a global scale. As AI technologies evolve, this potential will be gradually accelerated (Aarvik, 2019). These potential impacts will vary according to each country's economy. These differences will be reflected in countries' economic activity and the capacity of countries to adopt the technology (Nguyen and Vo, 2022). A country's access to AI technologies provides a competitive edge that can reshape global supply chains and trade patterns. This, in turn, can facilitate the growth of both the national and global economies. Consequently, the economies of countries that own and adopt AI technologies will be at an advantage in creating and attracting talent to utilize these technologies relative to other relatively weak economies in ownership and adoption.

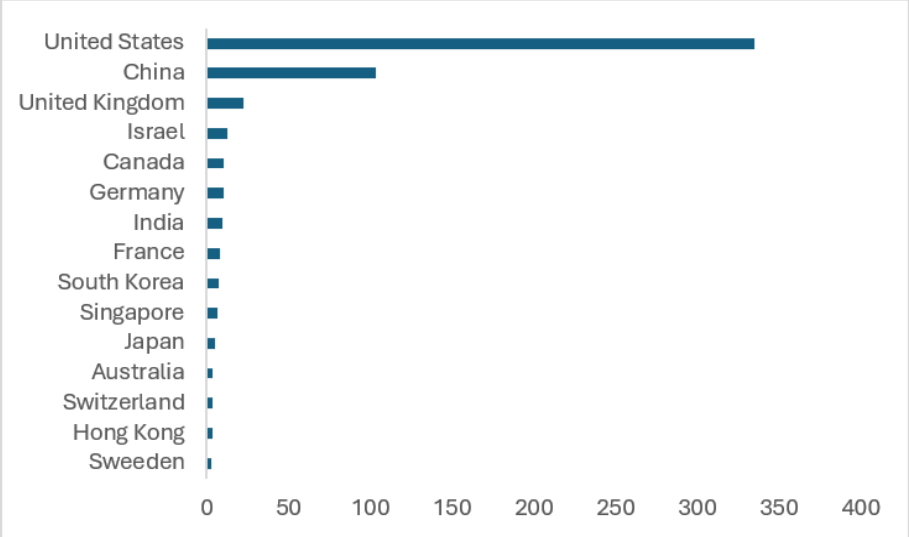

Figure 2. Regional Allocation of Private AI Investment, 2013-2023 (sum) (billions in U.S. dollars)
Source: Maslej et al. (2024).

The super growth in computing power and the interconnectivity of systems and devices have made it possible to collect and share vast quantities of data, which is now more accessible than ever before. This has created a significant momentum for AI technologies. One of the most important indicators of this is the worldwide increase in patents in the field. Firms, governments, and research organizations that invest in AI will gain a competitive advantage by becoming more innovative, as they will be able to utilize outputs such as patents that result from a range of research and development (R&D) activities. Figure 3 presents an analysis of the global increment in AI patent grants between 2010 and 2022. As illustrated in Figure 3, there has been a notable increase in the number of AI patents granted globally from 2010 to 2022. During the past decade, a notable increase has been observed in the number of patents related to AI, with a particularly sharp increase observed in the last few years. Patents represent the possession of monopoly rents derived from the invention of new technology in a Schumpeterian frame. As new technologies that enhance productivity are invented, old technologies are eliminated in a process of creative destruction. As new technologies emerge, firms tend to become more productive, which may

result in an environment of increasing returns to scale. Consequently, countries with higher patent intensity may indicate higher levels of productivity, output, and economic growth (Gonzales, 2023). The implementation of AI technologies, developed through the utilization of obtained patents, is predicted to save costs and time, consequently enhancing productivity in production and stimulating economic growth. It is therefore of great interest to examine how these effects will be reflected in the labor market.

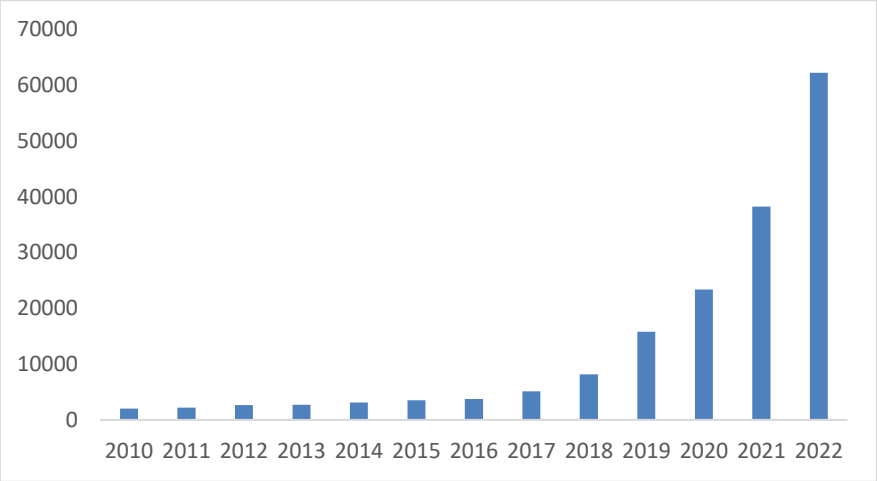

Fig. 3. Number of AI Patents Granted (in thousands)
Source: Maslej et al. (2024).

It is difficult to predict the potential social and economic implications of AI and the kind of world it might create. This study explores the question of whether current AI technologies and applications are designed to reinforce or disrupt the labor market. Considering this research question, the aim of this study is to address the existing gap in the literature by investigating the impact of AI on employment in 29 countries from 2017 to 2021 using the System Generalized Method of Moments (System-GMM) estimator. The analysis employs advanced econometric techniques to investigate the dynamic interplay between AI technologies and outcomes in the labor market. This contribution is significant in two respects. Firstly, it addresses a critical gap in the literature by focusing on the employment implications of AI on a macroeconomic scale. Secondly, it offers valuable policy recommendations for navigating the challenges and opportunities posed by technological advancements in AI. This study also makes a unique contribution to the existing literature in several key aspects. Firstly, this study employs a variable that serves as a comprehensive representation of AI. This approach differentiates the study from the existing empirical literature, which frequently relies on proxies such as R&D expenditures, high-technology exports, ICT exports, patents, or robot counts. Secondly, it focuses on the most recent period during which AI has gained significant prominence. Lastly, the study corroborates the optimistic scenario envisaged by theories, demonstrating a net positive effect of AI on employment through econometric analysis. This effect is characterized by the displacement of workers by AI being counterbalanced by new labor demand in emerging jobs and tasks. Furthermore, the analysis of the interaction between AI and labor productivity offers a refinement to the theory: it quantifies the condition that sufficient productivity gains are crucial for AI's

positive employment effect to materialize. This nuance contributes to the literature by highlighting that the balance between displacement and new job creation can tilt depending on productivity dynamics. In sum, the study not only provides a contemporary dataset comprising a more comprehensive measure for AI but also strengthens the theoretical understanding of AI's labor market impact by providing real-world evidence that supports and adds nuance to, the substitution–creation–compensation mechanism framework. Based on this curiosity and purpose, the study provides a brief introduction to the subject. The second section presents a review of the existing literature on the subject, discussing the potential effects of AI on employment, and the mechanisms through which these effects may occur. The third section presents the econometric analysis of the impact of AI on employment. While the fourth section presents the findings of this econometric analysis, the fifth section discusses the conclusions derived from that analysis, along with policy recommendations aimed at addressing the implications of AI on employment and labor market dynamics. Finally, the study presents limitations and future directions of the research.

2. Theoretical Background and Literature Review

Considering the advanced technological capabilities of countries, it is an intriguing issue to consider how AI will affect a variable such as employment in economies. The potential effects of AI technologies on labor and the labor market are complex. Therefore, the literature on the effects of AI on employment exists with differing opinions. This study aims to examine the multifaceted potential effects of AI on employment and, in this context, to present a more nuanced understanding of the complex relationship between AI and employment. It does so by relying on a theoretical framework that encompasses all the potential impacts of developments in AI technologies on labor and labor market dynamics.

It is essential to first define the theoretical framework that informs this investigation before embarking on a review of relevant literature. The impact of AI on labor is contingent upon the specific types and levels of skills possessed by workers in a given sector, as well as the pace of adoption of new technologies in a particular country. The internal dynamics of each sector and the level of technological advancement in each country may influence the way AI affects labor. So, AI can affect labor in two distinct ways: the displacement effect, whereby AI technologies replace labor and directly remove labor from the workplace, and the productivity effect, which increases the demand for labor as AI technologies boost labor productivity.

The displacement effect is the dystopian scenario of those who argue that AI will negatively impact employment. In contrast, the productivity effect is the utopian scenario of those who argue that AI's effects on employment will be positive. Considering these two scenarios, the mechanisms of AI's impact on employment appear as a substitution effect, a job creation effect, and a compensation mechanism.

2.1. Substitution Effect

The apprehension that novel technologies will displace workers is not a phenomenon exclusive to the contemporary labor force. Its historical roots can be traced back to the First

Industrial Revolution. Because over the past centuries, technological developments have precipitated the loss of employment for a considerable number of workers, giving rise to social unrest. The most illustrative example of this phenomenon is the group of textile workers in 19th-century England who self-identified as Luddites, due to the significant job losses resulting from the Industrial Revolution (Van den Berg, 2001). The Luddites are remembered today as a technophobic group, but they are living examples of the fear created by the threat of structural unemployment. The exponential pace of technological advancement indicates that society must urgently address the impending unemployment problem that AI will undoubtedly present. Because AI has the potential to displace numerous workers, resulting in significant economic and social challenges. This is achieved by substituting for the work that labor is already doing.

The substitution effect causes the elimination of jobs through the substitution of technologies for the work previously done by labor. If AI fails to enhance labor productivity, but rather replaces human labor, it may result in a reduction of the labor share in value added. This could subsequently lead to a decline in labor demand. In the absence of productivity gains that contribute to labor demand, workers will be displaced by new technologies (Acemoglu and Restrepo, 2019).

AI has the potential to displace a significant amount of both physical and mental labor. This is a distinctive feature of AI technologies that differentiates them from previous technological revolutions, which have not reached this level of sophistication. For example, in their study of occupations in the United States (US) economy, Frey and Osborne (2013) concluded that approximately 47% of total employment is categorized as elevated risk. The study predicts that these jobs are in the transportation and logistics, office and administrative support, and manufacturing sectors and finds that jobs in the service sector are highly susceptible to computerization. The authors believe that these high-risk occupations may be automated within the next decade or two, with AI substituting human labor. Unlike past technologies that mostly automated routine tasks, today's AI can handle non-routine cognitive tasks (e.g. image recognition, language translation, coding), which expands the range of occupations vulnerable to automation.

The explosive rise in the quantity of data and the rapid advances in ML and DL algorithms have significantly expanded the range of occupations that can be automated and substituted for labor. AI is enabling machines to perform an increasing range of non-routine cognitive tasks, including face and voice recognition, NLP, and computer program generation. Similarly, the advancement of skilled robotics has reached a point where machines can be equipped with the necessary technology to perform non-routine manual tasks (Fossen and Sorgner, 2022). The study conducted by Wang et al. (2023), on China's workforce finds that the majority of workers in production and transportation equipment operations, as well as the majority of service personnel, are highly sensitive to substitution. Furthermore, the findings suggest that medium-risk jobs in management and research will be subject to substitution over time. The last low-risk occupations to be substituted are those that require intuitive, professional technology and social interactions, such as managerial roles. Such positions are particularly challenging to automate, as they necessitate a high degree of social intelligence. Furthermore, certain highly professional technical occupations, such as those of lawyers and doctors, are also low-risk jobs that require creativity and social intelligence. In contrast, occupations that entail manual labor are classified as low-

skilled and are particularly vulnerable to AI-driven substitution, posing a significant risk to their continued existence. As AI develops, industrial robots with enhanced senses and dexterity may enter more industries to perform a wider range of non-routine manual tasks, thereby threatening more low-skilled labor (Wang et al., 2023). While some studies have reached the conclusion that AI technologies are responsible for the displacement of jobs, there is currently no conclusive evidence that the overall impact on employment is significant for all countries. Because the impact of AI-driven substitution varies markedly between high-income and low-income economies. Advanced economies, with their higher adoption of AI and larger shares of white-collar jobs, face greater exposure to automation. IMF estimates suggest about 60% of jobs in advanced economies are exposed to AI, compared to only 26% in low-income countries. Many jobs in rich countries - including professional and managerial roles- involve cognitive tasks that current AI can potentially learn, raising the risk of displacement even for some high-skill occupations (Georgieva, 2024). By contrast, workers in developing countries are concentrated in occupations that are less immediately susceptible to AI automation (often due to lower technology adoption and more informality), so only around 0.4% of total employment in low-income countries is at risk of automation by generative AI, versus 5.5% in high-income countries (Gmyrek et al., 2023). Paradoxically, this means poorer countries might face fewer immediate job losses from AI. However, they could suffer in the long run if they cannot adopt AI to boost productivity, as the technology diffuses globally.

Overall, the substitution effect of AI is real and significant, especially in the early phase of AI adoption, but its magnitude varies by country context and is moderated by the pace of adoption. National economies do not operate in isolation. Instead, they are integrated into a complex global system, interacting with other economies in a manner that is both reciprocal and interdependent. In light of the difficulty in determining the general and clear impact of AI on employment, it is important to consider that unemployment, which is a significant potential consequence of AI, should not be ignored, particularly in the long term.

2.2. Job Creation Effect

Despite years of recurring concerns that new technologies will result in job losses, there have been significant positive developments in society. The economy has continued to grow, technology has advanced, and workers have retained their employment. It is evident that the automation and technological advancement that have occurred over the past two centuries have not resulted in the obsolescence of human labor.

An examination of contemporary technological advancements presents that AI has the potential to significantly impact the employment landscape, as machines begin to replicate the complex cognitive processes of the human brain, thereby displacing human workers in several roles. This could not only enhance productivity but also generate a multitude of knowledge-intensive roles, thereby influencing the structure of the labor market (Acemoglu and Restrepo, 2019). The initial effect of a new technology like AI is, without a doubt, the displacement of human labor. However, over time, as productivity and capital deepening increase, the growing economy will create new demands for labor. Adjustments to the labor market, though slow, will create new roles in which labor exhibits a comparative advantage over machines (Crafts, 2022).

The job creation effect leads to the creation of new types of jobs in which labor has a comparative advantage. History reveals that technological advancements have consistently led to the emergence of new business opportunities, often creating roles that did not previously exist. The advent of AI has given rise to a multitude of novel job opportunities, including those in the fields of data analysis, engineering, data labeling, and data protection. The recurrence of historical patterns suggests that concerns about AI technologies may be unwarranted.

The advent of AI-derived automation technologies coincided with the emergence of new tasks in which labor retained a competitive advantage due to the simultaneous development of other technological innovations. For example, the advent of agricultural mechanization in the latter half of the nineteenth century initially resulted in a decline in employment opportunities within the agricultural sector. However, this shift led to the emergence of new job roles in manufacturing and services, thereby increasing the demand for labor. In general, new technologies have displaced labor from specialized work. However, at the macroeconomic level, labor has benefited from technological advances through the creation of new jobs. At this pivotal moment, without sufficient consideration of the invention and creation of demand in lieu of the displacement of labor, this will be an inadequate form of AI from a social and economic perspective. In contrast to the objective of promoting productivity growth, employment, and shared prosperity, the widespread implementation of automation is likely to result in suboptimal economic growth and increased inequality (Acemoglu and Restrepo, 2019). It is also important that the new positions and responsibilities established are highly productive with respect to human labor. The potential for AI to create labor-intensive tasks that can only be performed by humans represents a crucial mechanism for counteracting the displacement effect of AI and ensuring that the productivity benefits of AI are equitably distributed among workers (Lane and Saint-Martin, 2021). While AI is responsible for the creation of new jobs and tasks, it is important to consider the potential mismatch between the requirements of these new roles and the skills of the workforce. The new qualifications or skills required for new jobs and tasks may prove to be slow to align with the existing labor force. In order to achieve balanced growth, it is essential that both the new technologies, the new jobs and tasks they create, and the labor supply move in tandem with these trends (Acemoglu and Restrepo, 2018b).

It is also important to note that the job-creation capacity of AI is not uniform worldwide. This capacity depends on a country's economic structure, skill base, and innovation ecosystem. High-income countries are generally better positioned to generate new AI-related industries and roles. They have the education systems to produce AI researchers and skilled workers, the financial markets to fund AI startups, and consumers with the purchasing power to demand AI-enabled products and services. Thus, robust job growth is observed in fields such as software development, AI research, digital marketing, and fintech in many advanced economies – areas that were scarcely present decades ago. Moreover, AI's productivity boost in traditional industries (like manufacturing or healthcare) can lead to expansion and hiring in those sectors in advanced economies, as firms can scale up output. In contrast, lower-income countries often face greater challenges in realizing AI-driven job creation. Their workforce may not have as many advanced STEM skills, limiting local development of AI innovations. They may also lack the infrastructure (e.g. reliable internet, electricity) needed to implement AI at scale, as well as financing for entrepreneurial ventures. The uneven ability to capitalize on the job creation effect of AI is one reason experts caution that AI could widen global inequality – advanced economies reap most of

the new jobs and growth, while poorer ones lag behind. This makes capacity-building (education, digital infrastructure, innovation support) crucial for low-income countries to fully participate in AI-driven job creation (Georgieva, 2024).

2.3. Compensation Mechanism

It is anticipated that the widespread use of AI and the subsequent increase in the use of related technologies may result in potential job losses in the short term. However, it is believed that these losses will be compensated for by offsetting mechanisms that will increase the demand for labor in the long term, due to the higher productivity that can be achieved using these technologies.

The compensation mechanism occurs in the form of an increase in productivity brought about by AI technologies, which saves labor, expands the scale of the relevant industry, and compensates for the decrease in the number of jobs per output through the expansion of scale. The application of AI technologies enables firms to expand their production capabilities, saving the time and cost associated with production processes. Consequently, the necessary conditions for the increase in the number of production lines and jobs will be provided, thereby increasing consumer demand by selling products produced at lower prices with the expansion in productivity. Therefore, the compensation mechanism will function effectively in firms with an increased production scale (Sarker, 2022).

The compensation mechanism, which also functions in the form of the creation of new tasks requiring significant labor through the re-engagement of labor in new activities or lines of business, has also been defended by Acemoglu and Restrepo (2018b, 2019) on the grounds that the effects of productivity, capital accumulation, and the spread of automation can eventually compensate for any reduction in labor demand.

The advent of AI technologies has the potential to change the relationship between capital and labor. By reducing costs in production and increasing the demand for labor in non-automated jobs, AI technologies may lead to substituting capital for labor, particularly if they make certain tasks cheaper than labor. This results in a reduction in the price of goods and services whose production process is automated, while simultaneously increasing the demand for those goods and services (Autor, 2015). The reduction in prices for goods and services in sectors where the production process is automated has the effect of increasing the wealth of households, which in turn leads to an increase in the overall demand for goods and services. This increase in the overall demand for goods and services consequently gives rise to an increase in the demand for labor (Wolla et al., 2019). The resulting demand for labor in other sectors can serve to offset the negative displacement effect of automation. One historical case study exemplifying this phenomenon is the adaptation of the US and many European economies to mechanization in agriculture. As a consequence of the reduction in food prices resulting from the advent of mechanization, consumers were able to demand a greater quantity and variety of non-agricultural products (Herrendorf et al., 2014), while simultaneously creating employment opportunities for a significant proportion of the workers who had been initially displaced by the mechanization process. However, since this compensatory effect works by increasing the demand for goods and services, it tends to increase inequality. If the increase in real incomes generated by AI falls into

the hands of those with a low marginal propensity to consume, these stabilizing compensatory forces will be weakened and operate much more slowly. Consequently, there is a possibility that this imbalance in the distribution of AI-generated earnings may impede the creation of new employment opportunities (Acemoglu and Restrepo, 2018b).

Another compensation mechanism depends on firms' decision to support new investments. A delay in the reflection of the reduction in the costs brought about by AI technologies on the decline in prices may result in excess profits for innovative entrepreneurial firms. Conversely, the transformation of these profits into investments is delayed in the context of new production and job opportunities. If these investments are only capital-intensive, the offsetting effect will be partial at best. An even more problematic scenario is that profits may not consistently inform new investment decisions. The actions of firms that act in accordance with Keynes' "animal spirits," leading to a pessimistic outlook, have the potential to create significant structural technological unemployment by interfering with the functioning of the compensation mechanism (Piva and Vivarelli, 2017).

It is evident that there is no assurance that compensation mechanisms will function with absolute reliability. It is possible that critical issues may result in a reduction in the effectiveness of these mechanisms. In oligopolistic or less competitive market structures, the translation of low costs into low prices is not always guaranteed, which may reduce the effectiveness of the compensation mechanism. Secondly, the initial impact of labor-saving technology is a decline in overall demand from those who have been laid off. It is therefore evident that the compensation mechanism must be capable of doing more than merely offsetting the initial decline in aggregate purchasing power. The postponement of this compensation mechanism is important; however, it can also result in the emergence of structural unemployment, which persists over an extended period (Piva and Vivarelli, 2018).

Recent decades have seen productivity growth alongside a falling labor share of income, meaning workers have not captured the gains proportionately. This suggests that while output has grown, wages and employment haven't grown as fast. Nonetheless, the fundamental logic of the compensation effect remains a cornerstone for optimistic projections: AI-driven productivity growth can lead to larger economic output that ultimately requires more workers in the aggregate, even if specific jobs are lost (Autor, 2015; Piva and Vivarelli, 2017; Acemoglu and Restrepo, 2018a). The strength of this mechanism may vary by country's income level. In high-income countries, consumers are wealthier and more likely to increase spending when prices drop, fueling demand for new goods and services. These economies also tend to have diverse industries, so workers displaced in one sector (e.g. manufacturing) can often find work in expanding sectors (e.g. healthcare, tech services) if retrained. In lower-income countries, a smaller middle class and limited consumer spending power mean the demand stimulus from cheaper goods might be weaker. Additionally, if much of the AI-driven productivity gain in a developing country's export sector results in cheaper export prices, the benefit (higher real income) accrues to consumers abroad rather than locally. This could dampen the local compensation effect. On the other hand, developing economies stand to gain from technology-driven lower prices for capital goods and software, which could make it easier to start new enterprises and industries, potentially creating jobs if other conditions (like skills and infrastructure) are in place (Bonsay et al., 2021). Overall,

the compensation mechanism highlights that the net employment impact of AI is not just a function of substitution and new job creation, but also of macroeconomic feedback loops.

The efficacy of compensation mechanisms remains uncertain, contingent upon a multitude of variables, including the degree of competition, the elasticity of demand, and the shaping of business expectations (Piva and Vivarelli, 2017). Considering the aforementioned considerations, an emphasis on empirical analysis is therefore recommended.

2.4. Literature Review

The influence of AI on economic processes is pervasive, encompassing a multitude of domains, including employment, inequality, productivity, and economic growth. While the general outlook and potential economic implications of AI are predominantly conceptualized in academic literature, empirical studies remain scarce, representing a significant gap in research that necessitates further investigation.

Acemoglu and Restrepo (2018a) examine the effects of automation, AI, and robotics technologies on employment by transforming the static model, which posits a fixed capital accumulation and exogenous technology, into a dynamic model by endogenizing capital accumulation. By setting the model in a framework that allows for the automation of jobs and tasks performed by labor and novel versions of existing jobs and tasks where labor possesses a comparative advantage, the authors observed that in the static model, automation reduces employment, labor share and wages. Conversely, when new roles and tasks are created or novel versions of existing roles and tasks where labor possesses a comparative advantage, the opposite effects are present (Acemoglu and Restrepo, 2018a). In their study on the effects of automation and AI on labor demand, wages, and employment, Acemoglu and Restrepo (2018b) conclude that automation and AI, as machines, replace labor through the displacement effect, which tends to reduce labor demand and wages. They argue that although increased production from additional capital accumulation leads to higher wages per worker, the share of labor in national income declines—an outcome that is eventually offset by a productivity effect resulting from cost savings and increased demand for non-automatable jobs. A hypothesis suggesting that a negative impact on employment is expected in settings where AI primarily replaces human labor is based on these views. This displacement effect is likely to be more pronounced in high-income countries with advanced technological infrastructures, where the automation potential is higher.

Gries and Naudé (2018) examined the potential impact of AI as a technology service that can substitute or complement labor in an economic growth model with constraints on aggregate demand. Their findings suggest that strong substitution elasticities may result in a reduction in employment, wages, and the labor share of income, which will lead to inequality. Furthermore, the authors conclude that in the absence of benefits to labor income from the economic gains generated by AI progress, consumption may stagnate, which may act as a constraint on growth. Nevertheless, the authors also observe that due to the gradual diffusion of AI, there will be no spike in unemployment. Additionally, wages may decline to sustain employment levels in conjunction with sluggish GDP and productivity growth, as economies fail to capitalize on the potential for expansion in the supply of these technologies (Gries and Naudé, 2018). Building on this, a hypothesis posits that the positive effects of AI on employment -through enhanced

productivity and job creation- will dominate when AI is used to complement human labor. However, these positive effects may be moderated by the substitution effect in sectors where routine tasks are automated. This duality helps explain the mixed empirical evidence in the literature, where some studies report net job losses while others observe job creation, depending on the economic context and stage of AI adoption.

Webb (2020) used the similarities between job descriptions and patent definitions of occupations in his methodology to estimate the effects of different digital technologies on occupations. By employing AI, software, and industrial robotics as exposure measures, Webb presents empirical evidence on the relationship between AI technologies and employment and wage dynamics at the occupational and industry levels in the US for the period between 1980 and 2010. The results show that the labor market effects of software and robots are quite unlike those of AI, as AI-related occupational exposure differs among various socioeconomic groups. In consequence, low-skilled and low-wage male workers are more exposed to robots, while those in middle-skilled jobs are more vulnerable to software, and those in high-skilled jobs are more vulnerable to AI. Furthermore, it was determined that AI was more likely to affect workers with higher education levels and older ages than previous technological impacts. This was observed to result in a negative impact on the wages and employment of occupations that were exposed to the technologies under study. The main contribution of Webb's study is that AI is qualitatively unlike software and robots and, as a result, is likely to affect different types of jobs and people. Building on the work of Webb (2020), Fossen et al. (2022) examined the individual-level wage changes of AI, software, and industrial robots for the US economy for the period covering 2011-2021. The objective of this study is to examine the impact of the accessibility of AI technologies on workers' wages and how this effect compares with earlier innovations, namely software and industrial robots. The findings indicate that while software and industrial robots have resulted in a labor displacement effect, characterized by a decline in wages, AI has had the opposite effect, leading to an increase in wages through a productivity effect, which has resulted in the creation of new job opportunities for labor.

Fossen and Sorgner (2022) examine the effects of emerging digital technologies on individual-level wage and employment patterns in the US economy between 2011 and 2018. The authors utilize a range of indicators to assess the effects of emerging digital technologies on the labor market, including the probabilities of computerization of occupations, the occupational effects of AI, the appropriateness of tasks for ML, and their within-occupation variance. Their findings indicate that labor-displacing technologies are related to a slowing of wage growth and a higher probability of occupational change and unemployment. Conversely, digital technologies that reinstatement effects, the measure of the occupational effects of AI in this study, are found to improve individual labor market outcomes. It is concluded that advances in AI do not displace human labor on average but rather reinstate it and that AI technologies generate new work tasks for human labor. The study also noted that, unlike previous technological advances, the next-generation digital technologies have affected high-skilled labor the most.

Bonsay et al. (2021) examined the relationship between AI (represented by high-tech exports), labor productivity, and unemployment with economic growth for the period covering 1988-2019 for 4 Asian countries that ranked high in the AI Readiness Index. The results show that AI, which facilitates technological progress in the economy, attracts and encourages foreign

direct investment for expansion, especially technology transfer, job creation, and economic growth; helps open new markets to various free trade agreements; and increases growth through trade liberalization. Among the 4 Asian countries, Japan's more appropriate use of AI technology compared to other countries has both accelerated labor productivity and struck a balance to prevent technological unemployment. This supports the hypothesis, which asserts that AI-driven productivity gains can compensate for initial job losses. In high-income contexts, where technological adoption and human capital are robust, the compensatory effects of AI are expected to generate net employment growth. Conversely, in lower-income countries, the compensation mechanism may be weaker due to slower AI diffusion and limited capacity for innovation.

Frey and Osborne (2013), seeking an answer to the question of how sensitive jobs are to computerization, calculated the risk of automation of 702 occupations in their study. Consequently, the researchers determined that 47% of jobs in the US economy will be replaced by AI, which represents 47% of total employment in the US economy and is therefore at high risk of being automated. Frey and Osborne also examined the risk of automation in terms of wages and education level and found a strong negative correlation between the two variables. The researchers highlighted that unskilled workers can only be employed in non-automated roles or in positions that require creativity in response to new technologies unless they enhance their educational qualifications. However, for this to occur, employees must develop their social skills. Arntz et al. (2016) criticize Frey and Osborne's study for adopting an occupation-based approach rather than a task-based approach. Arntz et al. (2016), who focus on tasks within an occupation in relation to the fact that workers with the same occupation perform different tasks within the job, calculate the likelihood of jobs being subject to automation for 21 OECD countries and conclude that jobs can be automated at an average rate of 9%. In comparison to the findings of Frey and Osborne (2013), the authors conclude that jobs are considerably less likely to be automated, attributing this difference to the task-based approach. In addition to this result, it was found that the risk of automation of jobs performed by low-skilled workers is higher than that of jobs performed by high-skilled workers. Empirical findings from Frey and Osborne (2013) and task-based critiques by Arntz et al. (2016) further reinforce that the risk of automation is heterogeneous, depending on the nature of tasks performed. Therefore, the way to deal with potential inequalities that may arise from technological change in the future is to provide low-skilled workers with the necessary training. Wang et al. (2023), in their study calculating the probability of substitution of jobs in China by AI, concluded that 54% of jobs in China are at elevated risk of substitution in the short-term future. The aforementioned jobs are predominantly manual and routine, with workers in production, transportation, manufacturing, and the service sector being particularly vulnerable to substitution. The last group of low-risk jobs that can be substituted includes 38% of the jobs in China and are mainly managerial jobs such as unit supervisors, which require intuition, social intelligence, and social interaction. When the authors compare their results with the proportion of jobs at different risk levels in the US in Frey and Osborne's (2013) study, they find that the proportions of high-risk and low-risk jobs in China are larger than those in the US, while the proportion of medium-risk jobs in China is smaller than that in the US.

Guliyev (2023) employed the System-GMM approach to examine the impact of AI on unemployment across 24 technologically advanced countries over the 2005-2021 period. The results of Guliyev indicate a negative correlation between the unemployment rate and the

implementation of AI. Mutascu (2021) investigated the effect of AI on employment for 23 technologically advanced countries for the period 1998-2016 by using Least Squares panel regression and the System-GMM method, considering actual and expected inflation levels. In contrast with the findings of most of the current literature, the results demonstrate that the impact of AI on unemployment is not linear. Furthermore, the rapid increase in the use of AI reduces unemployment at low inflation levels. Nguyen and Vo (2022) analyzed the effect of AI on unemployment for the period 2000-2019 for a total of 40 countries, 25 developed and 15 developing countries. They investigated this relationship in the context of varying inflation levels, a methodology like that employed by Mutascu (2021). The results obtained from the analysis show a non-linear relationship between AI and unemployment influenced by inflation level. In consequence, the impact of AI on unemployment is positive up to a specific threshold level of inflation. Conversely, the effects are reversed after this threshold level is reached, that is when the inflation level continues to increase. This result implies that AI can address unemployment when inflation is at the anticipated level. In this case, Nguyen and Vo reach the same conclusion as Mutascu. This nuanced relationship informs an integrated hypothesis: the net impact of AI on employment depends not only on its direct effects (substitution and job creation) but also on broader macroeconomic conditions. In high-income countries, supportive policy frameworks and robust demand can enhance the compensatory effects of AI, whereas in lower-income countries, the adverse effects may be more pronounced.

A review of the literature reveals that the most crucial point to be highlighted regarding these studies is that the projected consequences of AI technologies, regarding employment, exhibit considerable variability. The most plausible explanation is that the studies employ different variables to represent AI, utilize different data sets, use different methodologies, and examine different countries.

The empirical context is still insufficient since the future outlook for the economic effects of AI is mostly discussed in conceptual terms or at the theoretical level. A significant factor in this deficiency is the variable used to represent AI. This is why there is not yet a consensus in the literature on the net impact of AI on employment. The lack of consensus can be attributed to two primary factors: the dearth of empirical studies in the literature and the discrepancies in methodology, period, country, and variable definitions across studies. The hypotheses that this study addresses, based on its theoretical background, are formulated on the basis of this variability. By employing a dynamic panel regression model with an AI index that broadly represents the technology, the study aims to empirically test whether the net effect of AI on employment is positive and under what conditions the compensatory mechanisms may mitigate displacement effects. This approach directly builds upon and extends the findings of (Acemoglu and Restrepo, 2018a, 2018b) among others, by linking theoretical predictions with observed labor market outcomes across diverse economic contexts. The empirical analysis, described in the subsequent section, will provide evidence of the impact of AI on employment in the selected countries, thereby addressing the gaps in the existing literature and clarifying the conditions under which AI leads to net employment growth or displacement.

3. Research Design

3.1. Data Description and Source

Although there are many studies on the economic effects of technology in the literature, there is a lack of empirical studies that investigate the impact of AI technologies on the economy. In this regard, this study aims to investigate the impact of AI on employment in selected economies. The study uses panel data from 29 countries (see Table A1) from 2017 to 2021. The period and countries have been determined based on AI Index Data prepared by Stanford University. Table 1 shows the variables used in empirical analysis.

Table 1. Variable Details

Type of Variable	Variables	Abbreviation	Definition of Variables	Source
Dependent Variable	Employment Rate	emp_rate	Employment to population ratio, 15+, total (%) (modeled ILO estimate)	World Bank
Independent Variable	Artificial Intelligence	ai	Artificial Intelligence Index	Stanford University-Human-Centered AI Institute
Control Variables	GDP	gdp	GDP (constant 2015 US$)	World Bank
	Population	popg	Population growth (annual %)	World Bank
	Labor Productivity	lp	Output per worker (GDP constant 2017 international $ at PPP) -- ILO modelled estimates	International Labour Organization
	Unemployment Rate	unemp_rate	Unemployment, total (% of total labor force) (modeled ILO estimate)	World Bank

The empirical measurement of the potential impact of AI on human labor represents a crucial area of research. To investigate this effect, as shown in Table 1, the variables of employment rate, AI index, GDP, population, labor productivity, and unemployment rate are included in the econometric analysis. The data used in the study were obtained from the World Bank (WB), the International Labour Organization (ILO), and the Stanford University Human-Centered AI Institute.

The employment rate, the dependent variable, is the ratio of a country's working population to the total working-age population. AI Index, comprising 23 indicators, has been prepared by Stanford University since 2017 and is included as an independent variable in the study. The following variables are included as control variables in the analysis: GDP, output per worker, which represents labor productivity, population growth rate; and unemployment rate.

3.2. Variable Description

Dependent variable: The employment rate, the dependent variable, is represented by the ratio of employed persons to the total population. The employment rate is proxied by employment

to population ratio. ILO defines employment as persons aged 15 years and over of working age who, in a given reference period, engage in any activity to produce goods or provide services for the purpose of earning wages or making a profit. The employment rate is a key indicator of an economy's capacity to provide employment opportunities for individuals who are actively seeking work. A high employment rate is indicative of a robust labor market, where a notable size of the population in the country is employed.

Independent variable: In empirical studies that investigate the economic effects of AI, variables such as R&D expenditures, high-technology exports, information and communication technologies (ICT) exports, patent applications, and the number of robots have been used to proxy for AI. However, these variables are insufficient for representing AI. The rationale behind the utilization of the AI Index in this study is that it is believed to be an accurate proxy for AI.

The AI Index has been developed by Stanford University since 2017. AI Index consists of two categories which are R&D and Economy, covering 23 variables (see Table A2). AI index is calculated in absolute and per capita terms. As illustrated in Table A2, eight of the sixteen indicators in the R&D category and two of the seven indicators in the Economy category are derived through the calculation of identical variables on a per capita basis. This study uses the absolute value of the AI Index.

Control variables: The control variables used in the analysis are GDP, labor productivity, population, and unemployment. To represent labor productivity, output per worker is used. Labor productivity is defined as the total volume of output produced per worker in a given reference period. "Per worker" is measured as the number of working people or hours worked, while the total volume of output is measured in terms of GDP. The rate of growth of the population is used as a measure of population, and the rate of unemployment is used as a measure of unemployment. The unemployment rate is calculated by dividing the unemployed people by the labor force. ILO defines unemployment as individuals of working age who are unemployed in the reference period and who are also looking for work and are available for work.

3.3. Model Specification

The empirical studies on the relationship between AI and employment remain relatively limited, while various aspects of this area have been discussed in the existing literature. Considering this gap in the research, this study aims to contribute to the existing literature with an empirical model that examines the impact of AI on employment. Moreover, another research gap in this field is that the variables utilized to determine the effect of AI on employment are not entirely representative of AI. This study addresses this gap by using the AI Index to represent AI. To empirically examine the impact of AI on employment using a dynamic model, the first regression model is specified as follows:

$$emp\_rate_{i,t} = \beta_0 + \beta_1 emp\_rate_{i,t-1} + \beta_2 ai_{i,t} + \beta_3 lngdp_{i,t} + \beta_4 popg_{i,t} + \beta_5 lp_{i,t} + \beta_6 unemp\_rate_{i,t} + \varepsilon_{i,t} \quad (1)$$

where i, t and β represent country, time and coefficient respectively. The term $emp\_rate_{i,t}$ demonstrates the employment rate, while $emp\_rate_{i,t-1}$ denotes a one-year lag of employment

rate. $ai_{i,t}$ is the artificial index, $lngdp_{i,t}$ is the logarithm of GDP, $popg_{i,t}$ is the population, $lp_{i,t}$ is the labor productivity, $unemp\_rate_{i,t}$ is the unemployment rate, $\varepsilon_{i,t}$ is error term.

The relationship between technological developments and productivity growth has long been a topic of debate, with a complex history. The complex relationship between these two variables has once again been the subject of debate in recent years, largely due to the rapid advancement of AI technologies. Furthermore, the question of whether technological advancements (in this study—AI) are labor-friendly remains unsolved. In light of this, the potential for labor productivity to influence the relationship between AI and employment could not be ignored in this study. Accordingly, an interaction term is incorporated into Eq. (1), wherein the variables of AI and labor productivity are interacted. So, in the second model, the impact of interaction of AI and labor productivity on employment will be examined through the application of the following econometric equation:

$$emp_{rate_{i,t}} = \beta_0 + \beta_1 emp_{rate_{i,t-1}} + \beta_2 ai_{i,t} + \beta_3 lngdp_{i,t} + \beta_4 popg_{i,t} + \beta_5 lp_{i,t} + \beta_6 unemp_{rate_{i,t}} + \beta_7 ai * lp_{i,t} + \varepsilon_{i,t} \quad (2)$$

In the model presented in Eq. (2), the interaction between the ai and lp means that the partial effect of AI on employment is contingent on the value of labor productivity. To determine the statistical significance of this partial effect, it is necessary to examine the joint effect of these two independent variables on the dependent variable, rather than the individual significance of the independent variables subject to the interaction term. Table 2 presents the results of the chi-squared test of the joint effect of the AI and LP variables. The results of this test indicate that the null hypothesis (H0 = β2 = β5 = 0) is rejected when the probability value is less than 0.05. This suggests that the interaction term, which comprises AI and labor productivity variables, is jointly significant with respect to the employment rate. Given that these variables are jointly significant, it is appropriate to proceed with the analysis of the interaction term.

Table 2. Results of The Chi-square Test of The Variables of ai and lp

test ai lp		
(1)	ai = 0	chi2 (2) = 85.21
(2)	lp = 0	Prob > chi2 = 0.0000

Balanced panel data analysis is conducted on 29 countries for the period covering 2017–2021. The purpose of the study and the availability of the data were considered in the econometric model. Given that the employment rate will be influenced by values from the previous period, a dynamic panel data model was employed. The examination of labor market dynamics can yield a more precise and extensive insight into employment patterns and the factors influencing them (Zhao et al., 2022; Guliyev, 2023).

4. Empirical Analysis and Results

4.1. Descriptive Statistics

The data analysis was conducted using Stata 15.0 software, and the descriptive statistics of the variables are represented in Table 3. Table 3 presents the number of observations, mean,

standard deviation, minimum, and maximum values of the series of variables. The data set contains 145 observations for each variable and is therefore a balanced panel data set. In panel data sets, it is essential to consider the mean value to ascertain the central tendency of the variable in question. In this case, the mean value of the dependent variable, employment rate, is 57.24%, with a data range spanning from a minimum of 41.33% to a maximum of 68.58%. The mean value of the independent variable, the AI index, is 13.74, with a minimum value of 0.557 and a maximum value of 78.16. It is evident that the data exhibits a greater degree of dispersion than the mean value. This may be caused by differences in the degree of economic and technological advancement across countries, as well as the varying rates of adoption of AI technologies. Although 23 of the 29 countries included in the study are developed countries and 6 are developing countries, the significant disparity between countries in terms of AI merits attention. This conclusion is essentially consistent with the observable facts. Similarly, in the labor productivity data set, while the mean value is 95.421, the minimum and maximum values are distributed between 18.541 and 219.127.

Table 3. Descriptive Statistics

Variables	Observations	Mean	Standard Deviation	Minimum	Maximum
emp_rate	145	57.24	6.185	41.33	68.58
ai	145	13.74	15.83	0.557	78.16
lngdp	145	27.70611	1.134337	26.03897	30.64354
popg	145	0.508	0.674	-4.170	1.939
lp	145	95.421	36.250	18.541	219.127
unemp_rate	145	6.209	3.120	2.400	17.22
ai*lp	145	1243830	1674209	31035.32	9775330

Multicollinearity, referring to a situation where two or more variables in a regression model are highly correlated, is one of the key assumptions of the Classical Linear Regression Model. In accordance with this assumption, there should be no issue of multicollinearity between the explanatory variables. The phenomenon of multicollinearity arises from the reciprocal relationships that exist between explanatory variables. Consequently, the most logical and easy way to identify multicollinearity is to examine the correlation coefficient. Many researchers concur that a threshold value of 0.9 represents an optimal demarcation for the multicollinearity problem (Asteriou and Hall, 2007). The matrix illustrating the relationships between the variables employed in the model and the corresponding correlation coefficients is presented in Table 4.

Table 4. Correlation Matrix

	emp_rate	ai	lngdp	popg	lp	unemp_rate	ai*lp
emp_rate	1.0000						
ai	0.1568	1.0000					
lngdp	-0.0340	0.7378*	1.0000				
popg	0.0952	0.0564	-0.1067	1.0000			
lp	0.2339*	-0.1186	-0.3313*	-0.0206	1.0000		
unemp_rate	-0.6842*	-0.1687*	0.0001	0.0168	-0.1176	1.0000	
ai*lp	0.1946*	0.8065*	0.5283*	0.0266	0.3219*	-0.1594	1.0000

Note: * explains the significance at 5%.

In Table 4, a positive correlation is observed between emp_rate and ai, popg, and lp. Conversely, a negative correlation is observed between emp_rate and lngdp and unemp_rate. While the correlation between ai and lngdp and popg is positive, the correlation between ai and lp and unemp_rate is negative. Finally, a positive correlation is observed between ai*lp and all variables except unemp_rate.

4.2. Empirical Methodology

Dynamic models are distinguished from static models by the inclusion of lagged values of variables in their specifications. However, since the dependent variable whose lagged value is added to the model as an independent variable violates the exogeneity assumption, an endogeneity problem is possible in the model. In this case, when the model is estimated with the OLS method, the unit, time, and endogeneity effects will be neglected. Furthermore, if the Random Effects estimator is applied, the correlation of an independent variable in the model as the lagged form of the dependent variable with unobserved effects will again violate the assumption of the estimator used (Baltagi, 2021). Estimators such as OLS and Fixed Effects are known to be biased and inconsistent in the presence of dynamic effects and simultaneities in the model specification (Levine et al., 2000; Hasan et al., 2009; Hasan and Tucci, 2010; Baltagi, 2021; Zhao et al., 2022). Although the fixed effects estimator can be used in dynamic models since it allows independent variables and unit effects to be correlated, it should be employed with caution since it may result in dynamic panel bias, also referred to as Nickell bias. According to Nickell (1981), this bias occurs when N (unit cross-section) exceeds T (time cross-section) (Yerdelen-Tatoglu, 2020). In the data set used in this study, given that the unit cross-section is N=29 and the time cross-section is T=5 (i.e., N>T), it would not be appropriate to employ the OLS or fixed effects estimator.

One of the important problems that can arise in dynamic panels is the phenomenon of endogeneity bias. Static models are constrained in their capacity to incorporate the variables that may give rise to an endogeneity effect. Endogeneity bias is defined as the effect of the past on the present, and this problem arises from the correlativity between the dependent variable and the error term. There are some techniques suggested in the literature for addressing the endogeneity problem. The best option among these techniques is considered to be the use of instrumental variables (Bascle, 2008; Semadeni et al., 2014).

Anderson and Hsiao (1982) initiated the development of the first differences method for the use of endogenous instruments in panel data. Subsequently, Arellano and Bond (1991) developed the GMM estimator as a more efficient estimator than the first difference estimator. However, the GMM estimator may result in a bias problem in unbalanced panel data. In response, Arellano and Bover (1995) developed the System-GMM to address this issue, and Blundell and Bond (1998) extended the System-GMM to accommodate short panels with a large cross-section (N) (Roodman, 2006). Accordingly, the optimal estimator for addressing the endogeneity issue is the System-GMM. In light of the aforementioned explanations, the System-GMM is the most appropriate for this study. The empirical model is presented in Eq. (1), Eq. (2), and the findings are presented in the next section.

4.3. Analysis of Empirical Results

To investigate the impact of AI on employment, this study employs System-GMM, proposed by Blundell and Bond, as it offers several advantages over other alternative approaches. The fundamental criterion for the System-GMM is that N is larger than T. This study covers 29 countries over a period of 5 years, thereby rendering it an appropriate candidate for the proposed estimator. Also, System-GMM is an optimal approach for analyzing panel datasets, facilitating the identification and addressing of potential issues such as over-identifying constraints, measurement errors, endogeneity biases, and autocorrelation. In order to reap these benefits, the System-GMM is utilized. Table 5 presents the estimation results of System-GMM.

Table 5. Estimation of Results of System-GMM

Variables	**(1)**	**(2)**
L.emp_rate	-0.0574(0.486)	-0.0602(0.464)
ai	0.0298***(0.000)	0.0480***(0.000)
lngdp	-0.113(0.258)	-0.0861(0.390)
popg	0.764***(0.000)	0.766***(0.000)
lp	2.95e-05***(0.000)	3.39e-05***(0.000)
unemp_rate	-1.361***(0.000)	-1.361***(0.000)
ai*lp		-2.13e-07**(0.029)
Constant	68.43***(0.000)	67.45***(0.000)
Observations	116	116
Instruments	10	11
AR (1) (p-value)	0.0453	0.0480
AR (2) (p-value)	0.434	0.435
Sargan (p-value)	0.0930	0.107
Wald Test (p-value)	0.0000	0.0000

Note: ***, ** and * explain the significance at 1%, 5% and 10% respectively, whereas the values are in parentheses contains P-values.

Table 5 demonstrates that the impact of a one-unit increase in the previous year's employment rate on the current year's employment rate is not statistically significant, suggesting that, within the short time span of our dataset, past employment levels do not have a strong direct influence on current employment. This may be partly due to the relatively stable nature of employment rates in our sample and the dynamic characteristics of the labor market captured by our control variables. The independent variable, AI, is statistically significant at the 1% level. In this case, a one-unit increase in AI is associated with a 0.0298-point increase in the employment rate. The positive sign of this significance coefficient indicates that AI has a positive effect on employment and an increase in AI adoption is associated with higher employment levels. This suggests that AI, rather than leading to outright job losses due to automation, exhibits a job-creation effect in the observed sample of countries. One possible explanation for this result is that AI enhances productivity and innovation, which in turn drives economic expansion and job creation, particularly in sectors where AI complements human labor. This finding aligns with the compensation mechanism in labor economics, where productivity gains foster new economic opportunities that counterbalance potential labor displacement. Among the control variables included in the model, GDP is not found to be statistically significant at any level. This suggests that, after accounting for AI adoption and other labor market factors, variations in GDP alone do

not exhibit a direct impact on employment. A plausible explanation is that the effect of GDP on employment operates indirectly through factors such as capital investment, labor market regulations, or structural economic shifts, which are not directly captured in this specification. However, the population growth rate, labor productivity, and unemployment rate are found to be statistically significant at the 1% level. Accordingly, a one-unit increase in the population growth rate increases the employment rate by 0.764 points. Higher population growth is associated with rising employment levels. This is an expected result as a growing population generally translates into an expanding labor force and increased economic activity. A one-unit increase in labor productivity increases the employment rate by 0.0000295 points. Although the observed change is relatively minor, it is nonetheless evident that labor productivity exerts a positive impact on employment. The effect of another control variable, the unemployment rate, on employment is statistically significant at the 1% level and a one-unit increase in the unemployment rate decreases employment by 1.3 points. It confirms that as unemployment rises, employment decreases, which is an expected relationship reflecting labor market equilibrium conditions.

In the last rows of Table 5, the results of the sequence correlation and over-identification tests are reported. In the autocorrelation test proposed by Arellano and Bond (1991), the null hypothesis, "There is no second-order autocorrelation," is tested for the residuals in the first-difference model. As a result of this test, there should be no second-order autocorrelation for the GMM estimator to be efficient (Arellano and Bond, 1991). Arellano and Bond emphasized the importance of testing the exogeneity of instrumental variables, even when they are weakly exogenous, after GMM estimation. The results of Model (1) suggest that the AR (1) rejects the null hypothesis, whereas the AR (2) model accepts the residuals do not exhibit second-order autocorrelation. Arellano and Bond also proposed the Sargan test as a means of testing the exogeneity of the instrumental variables and stated that if the instrumental variables used in the model are exogenous, the Sargan test will prove that the residuals (error term) will be uncorrelated with the independent variable. The Sargan (1958) test for over-identifying restrictions is employed to determine whether the instruments are well-identified and whether over-identifying restrictions are valid. The null hypothesis is that the overidentifying restrictions are valid, in other words, instrumental variables are exogenous, i.e. valid. This signifies an acceptance of the null hypothesis, which asserts the validity of the instrumental variables employed in the model. The validity of the instruments is assessed using the Sargan test, which in this case indicates that the overidentifying restrictions are valid. Although the Hansen test is often recommended for evaluating instrument validity, it can be overly conservative in panels with a short time dimension and a limited number of instruments. As noted by Roodman (2006), the Hansen test may yield excessively strict results under these conditions, and similar concerns regarding instrument weakness and overidentification tests are discussed by Blundell and Bond (1998). Therefore, given the data structure ($N > T$) and the constraints on the instrument count, the Sargan test results to provide a more reliable assessment of instrument validity in the model. In Model (1), the Sargan test yields a probability value that indicates the acceptance of the null hypothesis. This demonstrates that the instrumental variables employed in the model are exogenous and, thus, valid. Considering this evidence, it can be reasonably concluded that the model setting is appropriate. Another point that is taken into consideration to ensure that the results obtained from the estimators are not biased is the number of instrumental variables used. In this instance, the number of instrumental variables must be equal to or less than N (cross-section). Because the

number of instruments in the model may exceed N as it increases with T (Yerdelen-Tatoglu, 2020). As evidenced in Table 5, the numbers of instruments are less than N. Finally, the Wald test statistic, which is employed to evaluate the overall significance of the model, has a probability value of less than 0.05, thereby indicating that the model as a whole is statistically significant.

The estimation results of the second model, including the interaction term obtained by the System-GMM method are shown in Table 5. According to the compensation mechanism, if AI adoption substantially increases labor productivity, it can create additional jobs by expanding output (offsetting the jobs lost to automation); if productivity gains are small, AI may primarily displace workers. The AI therefore interacted with labor productivity to test this interplay. The inclusion is theoretically motivated by the idea that AI's impact on employment depends on productivity gains and the interaction term examines the contingent effect of AI on employment when labor productivity increases. In theory, the net effect of AI on employment is conditioned on productivity – for instance, AI-driven automation accompanied by high productivity might eventually require fewer workers per unit output (thereby dampening employment gains), whereas, in contexts of lower productivity, labor demand might be more directly boosted through AI's complementarity (Acemoglu and Restrepo, 2018a; Bessen, 2018). This nuance is captured by the interaction term. It is clarified in the study that the partial effect of AI on employment is not constant but varies with the level of productivity. Consistent with theory, a positive coefficient for AI and a negative coefficient for the ai*lp term are shown in the estimates, suggesting that employment is generally promoted by AI, although this positive effect diminishes at higher productivity levels (where more output can be produced with fewer workers). This result accords with the theoretical expectation that the compensation effect (through productivity-led output expansion) has limits – i.e. as productivity rises, the incremental employment benefit of AI diminishes (Piva and Vivarelli, 2017). This phenomenon reflects a dual mechanism in technological adoption. On one hand, AI has the potential to create new job opportunities and improve existing ones by increasing output and fostering innovation. On the other hand, as productivity improves, the drive for cost reduction may lead firms to automate tasks previously performed by workers, thereby dampening the net positive effect on employment. This dynamic is particularly evident in developed economies, where high technological adaptation and scale economies are prevalent (Acemoglu and Restrepo, 2018a; Gries and Naudé, 2018).

An examination of the other variables in Model (2) reveals that the probability value of the first-order lagged term of the employment rate, that is, the effect of a one-unit increase in the previous year's employment rate on the current year's employment rate, is not statistically significant at any level. This indicates that the employment rates of the current period are not related to the level of previous periods. GDP is not significant at any level, while population growth rate, labor productivity, and unemployment rate are statistically significant at a 1% level. Accordingly, a one-unit increase in the population growth rate increases the employment rate by 0.766 points, while a one-unit increase in labor productivity increases the employment rate by 0.0000339 points. Although the increase is minimal, it is nonetheless evident that labor productivity exerts a beneficial influence on employment. The effect of another control variable, the unemployment rate, on employment is statistically significant at the 1% level and a one-unit increase in the unemployment rate decreases employment by 1.361 points.

Following estimation, the results are tested for the weakness of the variables to ensure the validity of the instruments and models. The AR (2) and Sargan's tests produce insignificant statistics, indicating that the estimation results in the model are unbiased. The probability value of the autocorrelation test for AR (2) errors is greater than 0.05, indicating that the null hypothesis is accepted and that the residuals do not exhibit 2nd autocorrelation. The Sargan test result shows that the null hypothesis is accepted, i.e., the over-identifying restrictions are valid, in other words, the instrumental variables are exogenous. This supports the interpretation that the estimated coefficients are free from endogeneity bias. Finally, the number of instruments is less than N, and the probability value of the Wald test statistic is less than 0.05, thereby indicating that the model as a whole is significant.

Our empirical results indicate that the overall effect of AI on employment is positive. However, previous studies have often emphasized that AI tends to automate low-skilled jobs, potentially resulting in job losses (Frey and Osborne, 2013; Wang et al., 2023). The positive impact observed in our analysis can be attributed mainly to the specific characteristics of our dataset and the model specification. High technological adaptation and economies of scale, which are prevalent, particularly in advanced economies, can not only compensate for potential job displacement but also stimulate the creation of new employment opportunities.

5. Discussion, Conclusion, and Policy Recommendations

A review of the existing literature reveals a lack of clarity regarding the impact of the proliferation of AI technologies on employment. If these technologies merely substitute for labor, they will have a negative impact, whereas, in the absence of labor displacement, they will have a positive impact. (Martens and Tolan, 2018). The advent of AI has the potential to enhance employment opportunities in several ways. Firstly, it can facilitate the creation of new roles or enhance the value of existing roles through the introduction of new technologies. Secondly, it can complement existing labor, allowing for the optimization of existing processes and the introduction of new efficiencies. One of the results of the model estimations shown in Table 5 of the previous section indicates that AI has a net positive effect on employment, suggesting that, at least in the short run, AI technologies play a complementary and creative role in labor markets. This positive effect is likely driven by compensatory mechanisms inherent in developed economies where higher labor productivity, economies of scale, and technological adaptation can foster the creation of new jobs or transform existing roles. In the analysis, the inclusion of macroeconomic controls such as labor productivity and GDP appears to capture these compensatory effects, resulting in a net employment-enhancing outcome. These results contribute to the current debate on the future of work, suggesting that AI does not necessarily lead to mass displacement of labor but can, under certain conditions, reinforce employment growth. The other result of the model estimations is that the coefficient on the variable representing the interaction between AI and labor productivity is negative. The negative coefficient of the ai*lp interaction term suggests that while AI can enhance employment through productivity gains and innovation, its job-creation effect is moderated by the level of labor productivity. In environments characterized by high productivity, the cost-saving incentives associated with AI may lead to greater automation and a subsequent reduction in labor demand, thereby mitigating the overall positive impact on employment. In high-productivity environments, where firms are likely to

adopt AI technologies primarily as instruments for further reducing production costs and increasing efficiency, the focus may shift from complementing human labor to substituting it, particularly in routine, low or moderately skilled tasks. This substitution effect can partially offset the positive, employment-enhancing impacts of AI.

While the existing literature is limited in quantity, several empirical studies have reached conclusions regarding both positive and negative effects. The importance of empirical studies in terms of reflecting real-life experiences has encouraged us to examine this issue empirically. This study makes a distinctive contribution to the literature in several ways. Firstly, it uses a variable that is widely considered to be fully representative of AI. Secondly, it covers the recent years when AI has become popular. Furthermore, the interaction between AI and labor productivity in the analysis contributes to an enhancement of the theoretical framework. It quantifies the condition that sufficient productivity gains are crucial for the positive employment effect of AI to materialize. This nuance contributes to the literature by emphasizing that the balance between displacement and job creation can vary depending on productivity dynamics. The finding that AI has a positive effect on employment is consistent with the results of several previous studies, including those conducted by Fossen and Sorgner (2022), Fossen et al. (2022), Acemoglu and Restrepo (2018a, 2018b), Guliyev (2023), Mutascu (2021), and Nguyen and Vo (2022). Specifically, the results provide empirical support for the task-based framework of Acemoglu and Restrepo (2018a, 2018b) and related theories, indicating that AI-driven automation has been accompanied by the creation of new tasks and roles for labor (consistent with the job creation effect) and productivity improvements that ultimately compensate for displacement.

Fossen and Sorgner (2022) posit that AI will create new jobs for human labor and increase wages through its productivity effect. Acemoglu and Restrepo (2018a) advance the argument that AI will create new jobs and tasks in which labor has a comparative advantage, or that new versions of existing jobs and tasks will emerge. Guliyev (2023), Mutascu (2021), and Nguyen and Vo (2022) present evidence indicating that AI has a negative effect on the unemployment rate. In this instance, it is evident that there are existing studies in the literature that align with the findings of the analysis presented in this study.

In their analysis of the occupational impact of AI on the US economy, Fossen and Sorgner (2022) conclude that, on average, advances in AI do not displace human labor but rather reinstate it. This finding aligns with the idea that AI technologies lead to the creation of new tasks for labor. Fossen et al. (2022) found that for the US economy, AI increases wages through productivity effects by creating new jobs for labor and showed that the effects due to productivity and the creation of new jobs and tasks are greater than the displacement effects of AI. In this case, the results of this study, which indicate a positive impact of AI, are consistent with the interpretation by Fossen and Sorgner that AI transforms occupations and can enhance human productivity. Moreover, the findings of our study demonstrate that the overall impact of AI on employment is positive when the effects of productivity and job creation are greater than the effects of substitution. This finding aligns with the conclusions of Fossen et al. (2022), who reported that AI can counteract labor displacement by creating new job roles, particularly in sectors with robust innovation ecosystems. Acemoglu and Restrepo (2018a, 2018b) put forth a task-based theory, the AR Model, which conceptualizes automation, AI, and robotics technologies as a takeover of tasks previously performed by human labor. They conclude that these technologies can lead to the

creation of new tasks, which in turn can result in an increase in employment and wages. They posit that the most effective means of counteracting the effects of automation is by creating new labor-intensive jobs that reintroduce labor in new roles and responsibilities, thereby increasing the overall share of labor and offsetting the impact of automation and AI technologies. In this case, if newly created jobs and tasks or transformed existing jobs go hand in hand with these technologies, the growth process will be balanced and there is no need to paint a pessimistic scenario for labor. However, automation technologies that displace workers will tend to reduce employment and wages if their productivity effects are limited. This is expected to occur if the displacement effect is larger than the productivity effect. Guliyev (2023) analyzed the impact of AI on unemployment in technologically advanced countries and found evidence of a negative relationship between the two variables, indicating that AI has the effect of reducing the unemployment rate. The author concludes that AI is capable of transforming the workforce by generating new jobs, automating routine tasks, and enhancing productivity. Furthermore, the author emphasizes that AI technologies can free labor from routine tasks, enabling it to engage in more complex and creative tasks that necessitate human capabilities such as critical thinking and problem-solving. This shift in focus is likely to enhance the overall work experience and increase job satisfaction. Moreover, AI can support firms in making more informed decisions by offering data-driven insights and analytics into their business models, which can lead to increased profitability and growth. Furthermore, the expansion of AI-driven technologies can facilitate job creation by creating new job roles and expanding existing ones. In a similar vein, Mutascu (2021) examined the influence of AI on unemployment in technologically advanced countries. He investigated this effect by considering actual and expected inflation levels in the analysis. The findings indicate that when inflation is low, the extensive utilization of AI has the potential to mitigate unemployment, provided that the tendency to increase wages is counterbalanced by expansion and the generation of new employment opportunities. Nguyen and Vo (2022) also analyzed the effect of AI on unemployment under various inflation levels, as in Mutascu. The results of the analysis indicate that AI has a positive effect on unemployment up to a certain threshold level of inflation. Beyond this threshold level, the effects are reversed. This finding suggests that AI effectively addresses unemployment issues when inflation is at the expected level. In this context, the conclusions reached by Nguyen and Vo (2022) and Mutascu (2021) are identical.

It can be posited that AI will transform all jobs, tasks, and professions, at least to some extent. This is because AI can increase the productivity of certain types of labor, while simultaneously eliminating the necessity for others. As with other technologies, AI has the potential to change the demand for certain types of labor and to enhance the skill requirements of those engaged in such work. It is evident that the impact of AI on the labor market will vary depending on the specific nature of the work. In some instances, AI may complement or strengthen certain forms of labor, while in others, it may pose a competitive challenge to existing roles. It is therefore inaccurate to assert that technological change will inevitably result in unemployment. For example, robots have the potential to compete with human labor, especially within the manufacturing sector. This could result in a reduction in wages and employment opportunities. Conversely, ML has the potential to enhance the productivity of those engaged in the software sector, while also creating new avenues for investment and production. Because of the evolution of technology, the skills required for human labor will also change. Consequently,

AI will create new employment opportunities, even if it results in the substitution of some jobs or tasks. Because creative destruction has always existed and will continue to exist.

As the use of AI technologies becomes widespread, they will also have an impact on economic policies, and the policies of countries will be shaped according to this technology. In addition to monetary and fiscal policies, governments' supervision and intervention systems will change in market regulations. In this regard, it is important to see how politicians will respond and react to both the advantages and obstacles associated with the advent of AI. So, preparations need to start now to manage the transition to such a technological innovation.

The most crucial policies to be implemented are those that focus on the supply of human capital and the supply of AI capabilities within this human capital. Because the most important problem that prevents the spread of AI is the lack of AI skills. To overcome this, it is especially useful to design education and training policies. In addition to educational policies, companies that invest in AI should also adopt the principle of enhancing employee efficiency in utilizing AI technologies. This can be achieved by modifying work environments to align with these technologies and modifying perspectives. In order to reap the full benefits of technology, it is essential to adopt a human-centered approach in all fields (Petropoulos and Kapur, 2022). Furthermore, it is crucial for policymakers to design strategies that harness the positive aspects of AI while mitigating potential adverse effects. In particular, policies should focus on human capital development by investing in education and continuous training programs that equip workers with the skills needed to complement AI technologies; and on sector-specific interventions by tailoring support for industries at higher risk of automation-induced job losses through targeted retraining and upskilling initiatives; and on strengthening social safety nets to provide support during transitional periods as labor markets adjust to technological changes. Additionally, innovation and investment incentives are essential to encourage firms to adopt AI in ways that enhance productivity without excessively substituting human labor, for instance, through measures that promote human-AI collaboration. By integrating these detailed policy measures, future research and policy formulation can better address the challenges and opportunities presented by AI-driven technological change, ensuring a balanced and inclusive growth process.

The impact of AI may depend on several factors, including the elasticity of labor demand and supply, the qualifications of the labor force, the adoption of AI technologies, and other variables. Given the current lack of clarity regarding the definitive impact of AI, there is no basis for fear or pessimistic speculation about its potential consequences. It is neither advisable to imagine negative outcomes nor to ignore the potential for job displacement due to automation, especially during the transitional phase, nor is it constructive to indulge in utopian fantasies about the impending perfection of AI. This dual outcome underscores the complex nature of AI's impact on employment. It is important to note that, in addition to our study's results indicating a positive effect, potential negative effects should not be overlooked; an important reason for emphasizing this is that our dataset spans a relatively short period of time. This period, which coincides with significant economic shocks -including those associated with the COVID-19 pandemic- may have temporarily influenced employment dynamics in certain sectors. Therefore, a longer-term analysis might reveal a more pronounced pattern of job displacement or creation resulting from AI and digitalization. While our results suggest that AI currently augments employment, they also serve as a cautionary note that the balance between AI's compensatory and substitution effects may shift over time or

across different labor market segments. It is too early to make any exact assessments at this stage. Future research should consider expanding the temporal scope of the analysis and examining sector-specific impacts, particularly focusing on retraining and upskilling processes for low-skilled workers. It is therefore recommended that national economies adopt a comprehensive approach to all potential implications and implement the necessary policies in a considered manner.

6. Limitations and Future Research Directions

The principal limitation of the study is that the subject is of such contemporary interest that the data available for analysis are insufficient to represent the full range of applications of AI. Another notable limitation of the study is the omission of potentially influential variables such as institutional factors and educational attainment. Although the model incorporates key controls like economic growth, population increase, and labor productivity, data constraints for the selected time period and countries precluded the inclusion of robust measures for education and related institutional indicators. This omission may limit the model's ability to fully capture the multifaceted dynamics affecting employment in the context of AI. Future research leveraging more comprehensive datasets should consider these factors to enhance the model's explanatory power and provide a more nuanced understanding of the interplay between technology and labor markets.

As further empirical studies are conducted, the potential for AI to substitute, complement, or create new jobs and tasks for human labor, labor demand, income inequality, and so forth will become more apparent. The impact of these effects can be more effectively evaluated in comparison to previous technological revolutions, and the distinctive attributes of AI technologies will facilitate an understanding of the differences. The issue can be examined in greater detail by focusing on AI-based applications, or it can be researched with a comprehensive data set. Furthermore, it is evident that an investigation into the influence of these technologies on employment, disaggregated by occupation, sector, skill level, and demographic characteristics such as gender, age, disability status, and migrant status, would give a more overall understanding. Given the far-reaching effects that AI is predicted to have, it is imperative that the issue be examined in greater detail with a range of parameters. When the findings of this study are considered alongside future research, it is thought that the effects of AI technologies on employment can be discussed more clearly.

Despite its limitations, it is anticipated that this study will make a notable contribution to the existing literature on the economics of AI, which is a current and significant field of study. Furthermore, it will encourage further research in this area. As the number of studies on this subject increases, it will become evident that there are numerous gaps in the existing research and that new areas of study will emerge.

Declaration of Research and Publication Ethics
This study which does not require ethics committee approval and/or legal/specific permission complies with the research and publication ethics.

Researcher's Contribution Rate Statement
First Author: Study conception and conceptualization, Investigation, Reviewing of literature, Writing – original draft, Data collection, Analysis, and interpretation of results.
Second Author: Study conception and conceptualization, Investigation, Writing – review & editing, Supervision.

Declaration of Researcher's Conflict of Interest
There is no potential conflicts of interest in this study.

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APPENDIX

Table A1. List of Countries

Australia	Denmark	Israel	Poland	Switzerland
Austria	Finland	Italy	Portugal	The Netherlands
Belgium	France	Japan	Russia	Türkiye
Brazil	Germany	South Korea	Singapore	United Kingdom
Canada	India	Malaysia	Spain	United States of America
China	Ireland	Norway	Sweden	

Table A2. Stanford AI Index Variables and Definitions

Variables	Definitions
Research and Developments	
Number of AI Journal Publications	Number of published AI journal publications in a given country.
Number of AI Journal Citations	Number of published AI journal citations in a given country.
Number of AI Conference Publications	Number of published AI conference publications in a given country.
Number of AI Conference Citations	Number of published AI conference citations in a given country.
Number of AI Repository Publications	Number of published AI repository publications in a given country.
Number of AI Repository Citations	Number of published AI repository citations in a given country.
Number of AI Patent Applications	Number of published AI patent applications in the given country.
Number of AI Patent Grants	Number of published AI patent grants in the given country.
Number of AI Journal Publications PC	Number of published AI journal publications in a given country in per capita terms.
Number of AI Journal Citations PC	Number of published AI journal citations in a given country in per capita terms.
Number of AI Conference Publications PC	Number of published AI conference publications in a given country in per capita terms.
Number of AI Conference Citations PC	Number of published AI journal citations in a given country in per capita terms.
Number of AI Repository Publications PC	Number of published AI repository publications in a given country in per capita terms.
Number of AI Repository Citations PC	Number of published AI repository citations in a given country in per capita terms.
Number of AI Patent Applications PC	Number of published AI patent applications in the given country in per capita terms.
Number of AI Patent Grants	Number of published AI patent grants in the given country in per capita terms.

Table A2. Continue

	Economy
Total AI Private Investment	Total amount of private investment funding received for AI startups.
Number of Companies Funded	Total number of newly funded AI companies in the given country.
AI Hiring Index	The AI hiring rate is calculated as the percentage of LinkedIn members with AI skills on their profile or working in AI-related occupations, who added a new employer in the same period the job began, divided by the total number of LinkedIn members in the corresponding location. This rate is then indexed to the average month in 2016; for example, an index of 1.05 in December 2021 points to a hiring rate that is 5% higher than the average month in 2016.
Relative AI Skill Penetration	The AI skill penetration rate shows the prevalence of AI skills across occupations, or the intensity with which LinkedIn members use AI skills in their jobs. It is calculated by computing the frequencies of LinkedIn users' self-added skills in a given area from 2015-2021, then reweighting those figures by using a statistical model to get the top 50 representative skills in that occupation.
AI Talent Concentration	The AI Talent Concentration is calculated using the counts of AI talent at the country level vis-a-vis the counts of LinkedIn members in the respective countries etc. A LinkedIn member is considered AI talent if they have explicitly added AI skills to their profile and/or they are occupied in an AI occupation representative.
Total AI Private Investment PC	Total amount of private investment funding received for AI startups in per capita terms.
Number of Companies Funded PC	Total number of newly funded AI companies in the given country in per capita terms.

Source: Zhang et al., 2022

Ekonomi, Politika & Finans Araştırmaları Dergisi, 2025, 10(1): 234-251
Journal of Research in Economics, Politics & Finance, 2025, 10(1): 234-251
Araştırma Makalesi / Research Article, https://doi.org/10.30784/epfad.1535893

GELİR EŞİTSİZLİĞİ, SERBEST TİCARET ve GIDA GÜVENCESİ ARASINDA NASIL BİR İLİŞKİ VAR? ORTA VE DÜŞÜK GELİRLİ ÜLKELER İÇİN BİR PANEL NEDENSELLİK ANALİZİ*

What is The Relationship between Income Inequality, Free Trade, and Food Security? A Panel Causality Analysis for Middle- and Low-Income Countries

Derya DEMİR**

Anahtar Kelimeler:
Ticari Açıklık, Gelir Eşitsizliği, Gıda Güvencesi, Yetersiz Beslenme

JEL Kodları:
D63, F13, I32, P33

Öz

Birleşmiş Milletler'in Sürdürülebilir Kalkınma hedeflerinden biri de sıfır açlığa ulaşmak, bir başka deyişle açlığa karşı küresel mücadeledir. Günümüzde dünyada yetersiz beslenen insanların sayısı artmaya devam etmektedir. Yoksulluk ve gelir eşitsizliği, gıda güvencesizliği riskini artıran önemli bir faktördür ve düşük gelirli ülkelerde orta gelirli ve yüksek gelirli ülkelere göre gıda güvencesizliği çok daha ciddi boyuttadır. 1990'lı yıllardan sonra dünya genelinde ticaretin serbestleşmesi ve tarım ürünleri ile diğer mal ve hizmetlerin ithalat ve ihracatının artmasının da gıda arzı yetersizliğini ve dolayısıyla gıda güvencesini etkileyen önemli faktörler arasında olduğu söylenebilir. Bu çalışmada 2001-2021 dönemi yetersiz beslenme yaygınlığının yüksek olduğu 19 seçilmiş ülkede gıda güvencesi, gelir eşitsizliği ve ticari dışa açıklık arasındaki ilişkininin nasıl olduğunu ortaya koymak amaçlanmıştır. Söz konusu değişkenler arasında nedensellik ilişkisi olup olmadığı Dumitrescu-Hurlin (2012) nedensellik analizi ile araştırılmıştır. Analiz sonuçları, gelir eşitsizliği ve ticari dışarı açıklığın gıda güvencesizliğinin sebebi olduğunu ortaya koymaktadır.

Keywords:
Trade Openness, Income Inequality, Food Security, Undernourishment

JEL Codes:
D63, F13, I32, P33

Abstract

One of the United Nations' Sustainable Development Goals is to achieve zero hunger, in other words, the global fight against hunger. Today, the number of undernourished people in the world continues to increase. Poverty and income inequality are important factors that increase the risk of food insecurity, and food insecurity is much more serious in low-income countries than in middle-income and high-income countries. It can be said that the liberalization of trade worldwide after the 1990s and the increase in the import and export of agricultural products and other goods and services are also important factors affecting food supply insufficiency and therefore food security. This study aims to reveal the relationship between food security, income inequality, and trade openness in 19 selected countries with a high prevalence of undernourishment in the period 2001-2021. Whether there is a causal relationship between the variables in question was investigated with Dumitrescu-Hurlin's (2012) causality analysis. The analysis results reveal that income inequality and trade openness are the causes of food security.

* Bu çalışma 16 -18 Ağustos 2024 tarihlerinde Bartın'da yapılmış olan Karadeniz Zirvesi 16. Uluslararası Sosyal Bilimler Kongresi'nde sunulan "Relationship Between Income Inequality, Trade Openness and Food Security" başlıklı özet bildiriden yararlanılarak hazırlanmıştır.

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Makale Geliş Tarihi (Received Date): 19.08.2024 Makale Kabul Tarihi (Accepted Date): 26.11.2024

1. Giriş

Dünyada nüfus devamlı artmakta ve insanların büyük kısmı artık kentlerde yaşamayı tercih etmektedir. Teknoloji büyük bir hızla gelişmiş, bu doğrultuda ülke ekonomileri de giderek birbirine bağlı hale gelerek küreselleşmiştir. Böylece ülkelerin sürekli olarak büyüyeceği beklenmiştir. Dünya ekonomisi bir bütün olarak beklendiği ölçüde ekonomik büyüme yaşamamıştır. Hem savaş ve çatışmalar hem de istikrarsızlık artık sürekli hale gelmiş, geçmiş zamanlardan çok daha fazla insan yer değiştirmek zorunda kalmıştır. Bunun yanı sıra küresel iklim değişikliğinin etkilerinin giderek artması, olağanüstü hava olaylarının meydana gelmesi, ekonomik yavaşlamalar ve gerilemeler, sağlıklı beslenmeye erişim eksikliği ve bunların karşılanamaması, sağlıksız gıda ortamları ile yüksek ve kalıcı eşitsizlik, tüm dünyada gıda güvensizliğine ve yetersiz beslenmeye yol açmaya devam etmektedir (FAO, 2024: 3).

BM Gıda ve Tarım Örgütü'nün (FAO, 2019: 27-29) 2019 yılı Dünyada Gıda Güvencesi ve Beslenme raporuna göre özellikle yoksul bireyler, aşırı yoksulluk seviyelerine ve farklı eşitsizlikler sebebiyle dışlanmaya maruz kaldıkları ölçüde, gıda güvencesi ve beslenme konusunda sorun yaşamaktadırlar. Aşırı yoksulluğun azalması, her zaman gıda güvencesinin yükselmesi ve yeterli beslenmenin sağlanması anlamına gelmez. Bunun en büyük sebebi gelir eşitsizlikleridir. Gelir eşitsizliği, çok sayıda düşük gelirli ve orta gelirli ülkede yükselmekte, dolayısıyla aşırı yoksul insanların ekonomik büyüme olsa bile bundan fayda sağlaması zorlaşmaktadır. Böylece ekonomik krizler, yavaşlama ve gerilemeler yoksul insanları daha fazla etkilemektedir. Günümüzün en önemli sorunlarından biri gelir dağılımındaki eşitsizliktir. Gelir eşitsizliği birçok düşük ve orta gelirli ülkede, başka bir deyişle dünyanın neredeyse yarısında yükselme eğilimindedir. Özellikle Afrika ve Asya kıtasındaki birçok ülkede son 15 yılda gelir eşitsizliği önemli ölçüde artmıştır. Gelir eşitsizliğinin yüksek olduğu ülkelerde ekonomik sorunlar, yoksul bireyleri gıda güvencesi ve beslenme bakımından orantısız biçimde daha fazla etkilemektedir. Çünkü düşük gelirli bireyler, elde ettikleri gelirin büyük bir kısmını gıda maddeleri almak üzere kullanmaktadırlar. Gelir eşitsizliği, gıda güvencesi riskinin daha şiddetli olmasına yol açar ve bundan orta gelirli ülkelere nispeten düşük gelirli ülkeler yaklaşık yüzde 20 daha fazla etkilenir. Gelir eşitsizliğinin yüksek olduğu bölge ve ülkelerde gıda güvencesizliği daha yaygın olup yaklaşık yüzde 21 oranındadır. Eşitsizliğin düşük olduğu bölge ve ülkelerde ise bu oran yaklaşık yüzde 7'dir. Gelir eşitsizliğinden daha öte diğer eşitsizlik türleri de kırsal ve kentsel bölgelerde yaşayan insanların yaşam standartlarının farklılığından kaynaklanmaktadır. Kırsal alanlarda yaşayan insanlar, kentte yaşayanlara göre daha düşük yaşam standardına sahiptir. Üretim varlıkları da birçok ülkede eşitsiz dağılmaktadır. Su kaynakları, toprak veya arazi, sermaye, finans, sağlık ve eğitim gibi varlıkların dağılımdaki eşitsizlikler de yoksul birey/hanelerin ekonomik büyümeden fayda sağlamasını zorlaştırmaktadır. Truthdig, artan eşitsizliğin yalnızca yoksulluğu değil, açlığı da artırdığını öne sürmüştür. Eşitsizlik bazı insanların gıdaya erişimlerini artıracak kaynaklardan mahrum kalmasına neden olacaktır (Akinbode vd., 2022: 4).

Son on yılda, çatışmaların, aşırı iklim olaylarının ve ekonomik gerilemelerin sıklığı ve yoğunluğu artmış olup dünya çapında gıda güvencesini ve beslenmeyi olumsuz etkilemektedir. Ayrıca, yüksek gelir eşitsizliği seviyeleri bu başlıca itici güçlerin etkilerini daha da kötüleştirmektedir. Özellikle düşük ve orta gelirli ülkelerin durumu endişe vericidir çünkü gıda güvencesi ve beslenme üzerindeki olumsuz etkiler bu ülkelerde çok daha fazladır. Gıda güvencesizliğinin temel sebeplerinin yetersiz beslenmeye katkısı incelendiğinde yüksek ve kalıcı

eşitsizliğin katkısının yüzde 27, çatışmaların katkısının yüzde 36 ve diğer faktörlerin katkısının yüzde 37 olduğu belirlenmiştir (FAO, 2024: 85).

Yetersiz beslenme yaygınlığı küresel düzeyde istikrarlı bir seyir izlemesine rağmen, gıda güvencesizliği yaşayan insanların mutlak sayısı artmaya devam etmektedir. Günümüzde dünyada açlık çeken insan sayısı 820 milyondan fazladır. Bu durum Birleşmiş Milletler'in (BM) 2030 yılına kadar Sürdürülebilir Kalkınma Hedeflerinden (SKH) "Sıfır Açlık" hedefine ulaşmanın güçlüğünü göstermektedir. Gıda güvencesizliği olgusu, tarihsel olarak, milyonlarca insanın gıda güvencesizliği nedeniyle ciddi yetersiz beslenmeden muzdarip olduğu bir sorun olmuştur (Fusco vd., 2020: 2). Sadece az gelişmiş ülkeler değil, gelişmekte olan ülkeler de gıda güvencesizliği sorunu ile karşı karşıyadır. Afrika'nın neredeyse bütün alt bölgelerinde yaklaşık yüzde 20 oranıyla yetersiz beslenme yaygındır ve açlık yükseliştedir. Yetersiz beslenme Latin Amerika ve Karayipler'de ise yüzde 7'nin altındadır. Asya kıtasında yetersiz beslenme nüfusun yüzde 11'ini etkilemektedir. Son yıllarda Güney Asya bölgesinde ilerleme olsa da nüfusun yaklaşık yüzde 15'i halen yetersiz beslenmektedir (FAO, 2019: 9). Covid-19 salgını açlık çeken insan sayısını artırmış aynı zamanda küresel gıda tedarik zincirlerinde ve geçici ihracat kısıtlamalarına başvuran birçok ülkenin tarımsal ticaret politikalarında da önemli değişikliklere neden olmuştur (WTO, 2020). ABD-Çin ticaret savaşı ve ardından korumacılığın yeniden canlanmasıyla birlikte serbest ticaret üzerinde de daha fazla kısıtlama ortaya çıkmıştır (Fajgelbaum vd., 2020).

Ticaret politikalarının ulusal gıda sistemlerini şekillendirmek ve gıda güvencesini teşvik etmek açısından stratejik olduğu düşünülmekte, ticari açıklığın açlık üzerindeki nihai etkisi tartışılmaya devam etmektedir. Ticaretin iki tarafının da gıda güvencesi üzerinde farklı etkileri olabilir. Örneğin, ekonomik teoriye göre ithalat, gıda bilgisi akışı, yüksek rekabet ve düşük fiyatlar nedeniyle yerel gıda pazarlarında meydana gelen değişiklikler yoluyla yetersiz beslenmeyi etkileyebilir; ihracat ise küresel pazarlara daha fazla erişim nedeniyle gıda çıkışlarına ve gelirde değişikliklere neden olabilir (Marson vd., 2023: 301).

SKH'lerin 2015 yılında hayata geçirilmesiyle birlikte, gıda güvencesi tamamen küresel bir hedef olarak kabul edilmiştir. 2030 Sürdürülebilir Kalkınma Gündem'inde tanımlanan on yedi sürdürülebilir kalkınma hedefi, "insanlar için bir eylem planı, Gezegen ve Refah" BM üyesi 193 devlet tarafından imzalanmıştır ve 2030 yılına kadar ulaşılacak 169 ilişkili hedefi içermektedir (UN, 2015). Özellikle Hedef 2 "Sıfır Açlık", açlığın sona erdirilmesi ve "tüm insanların tüm yıl boyunca güvenli, besleyici ve yeterli gıdaya erişiminin" sağlanması çağrısında bulunmaktadır (UN, 2015).

Dünyadaki açlığın ortadan kaldırılması için bu konudaki ilerlemenin takip edilmesinde kullanılan en yaygın gösterge, yetersiz beslenme yaygınlığıdır (FAO, 2019: 9). Yetersiz beslenmenin yaygınlığı, toplumdan rastgele seçilen bir bireyin, aktif ve sağlıklı bir yaşam için gerekli olan enerji ihtiyacını karşılamaya yetmeyecek miktarda kalori tüketmesi olasılığını ifade etmektedir. Gösterge, alışılmış günlük diyet enerji tüketiminin olasılık dağılımını, minimum diyet enerji gereksinimi adı verilen bir eşik seviyesiyle karşılaştırarak hesaplanır. Her ikisi de referans popülasyondaki ortalama bir birey kavramına dayanmaktadır (Marson vd., 2023: 300). Tablo 1'de dünyada ve gelir gruplarına göre ülkelerde yetersiz beslenme yaygınlığı 2002-2021 dönemi verileriyle gösterilmiştir.

Tablo 1. Gelir Gruplarına Göre Yetersiz Beslenmenin Yaygınlığı (2002-2021)

Gelir Grupları	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Dünya	13.0	12.9	12.5	12.0	11.2	10.4	9.9	9.3	8.8	8.3
Yüksek gelirli ülkeler	2.7	2.7	2.7	2.7	2.7	2.7	2.8	2.8	2.8	2.8
Orta gelirli ülkeler	14.2	14.1	13.8	13.1	12.1	11.1	10.4	9.8	9.4	9.0
Düşük gelirli ülkeler	32.5	31.6	30.5	29.8	29.1	28.5	27.8	25.6	24.0	22.7
Gelir Grupları	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Dünya	8.1	7.9	7.8	7.8	7.8	7.7	7.7	8.2	8.7	9.2
Yüksek gelirli ülkeler	2.8	2.7	2.7	2.7	2.7	2.7	2.6	2.6	2.6	2.6
Orta gelirli ülkeler	8.7	8.5	8.3	8.1	7.9	7.7	7.7	8,2	8.8	9.3
Düşük gelirli ülkeler	23.0	22.5	23.3	24.5	25.3	25.8	26.0	26.9	27.7	28.4

Kaynak: WB, 2024.

2000'li yıllarda yetersiz beslenme yaygınlığı dünya ortalaması yaklaşık yüzde 13 iken bu oran 2019 yılına kadar azalış trendi göstermiştir. Yüksek gelirli ülkelerde 2002 yılında yüzde 2,7 olan yetersiz beslenen nüfus oranı, sadece 2008-2012 döneminde 0,1 puan artmış, diğer yıllar ise azalmaya devam ederek 2021'de yüzde 2,6 olmuştur. Orta gelirli ülkeler incelendiğinde 2019 yılına kadar yetersiz beslenme yaygınlığının azaldığı, 2019 yılından itibaren tekrar yükselmeye başladığı görülmektedir. Bu yükselişte Covid-19 salgını büyük oranda etkili olmuştur. Düşük gelirli ülkelerde 2002 yılında yüzde 32,5 olan yetersiz beslenme yaygınlığı, 2014 yılına kadar (2012 hariç) sürekli azalmıştır. 2014 yılından itibaren tekrar yükselmeye başlamış ve 2021'e gelindiğinde yüzde 28,4 olarak gerçekleşmiştir (Tablo 1). Dolayısıyla dünya ortalamasındaki artışın orta gelirli ülkelerde ve büyük ölçüde düşük gelirli ülkelerde yetersiz beslenme yaygınlığının artmasından kaynaklandığı ortadadır.

Gıda güvenliği ve gıda güvencesi terimleri birbirinden farklı anlamlar taşımaktadır. Gıda güvenliği için İngilizcede "food safety" terimi kullanılmakta ve "Sağlıklı ve kusursuz gıda üretimini sağlamak amacıyla gıdaları; üretim, işleme, muhafaza ve dağıtımları sırasında gerekli kurallara uyulması ve önlemlerin alınması" şeklinde tanımlanmaktadır. Gıda güvencesi ise 1996 Dünya Gıda Zirvesi'nde "food security" terimi ile ifade edilmiştir. Gıda güvencesi terimi "Bütün insanların her zaman aktif ve sağlıklı bir yaşam için gerekli olan besin ihtiyaçlarını ve gıda önceliklerini karşılayabilmek amacıyla yeterli, sağlıklı, güvenilir ve besleyici gıdaya fiziksel ve ekonomik bakımdan sürekli erişebilme" şeklinde tanımlanmaktadır (Koç ve Uzmay, 2019, Koca ve Somuncu, 2021). Yapılan bu çalışmada, insanların aktif ve sağlıklı bir yaşam sürdürmeleri için onların beslenme gereksinimi ve tercihlerine uygun, yeterli, sağlıklı ve besleyici gıdaya her zaman fiziksel, sosyal ve ekonomik olarak ulaşabilmesi durumu olarak tanımlanan ve İngilizce kaynaklarda "food security" olarak geçen kavramın Türkçe karşılığı olarak "gıda güvencesi" kavramı kullanılmıştır. Tüketiciye sağlıklı ve temiz gıda sağlamak olarak tanımlanan ve İngilizce'de "food safety" olarak geçen kavramın Türkçe karşılığı olarak da "gıda güvenliği" kavramı kullanılmıştır.

Bu çalışmada gelir eşitsizliği, ticari dışa açıklık ve gıda güvencesi arasında nedensellik ilişkisi olup olmadığının incelenmesi amacıyla yetersiz beslenme yaygınlığının yüksek olduğu 19 ülkede 2001-2021 dönemi verileri kullanılarak Dumitrescu-Hurlin (2012) nedensellik analizi gerçekleştirilmiştir. Gelir eşitsizliği göstergesi olarak Gini katsayısı, ticari dışa açıklık göstergesi olarak toplam ticaretin Gayri Safi Yurt İçi Hasıla (GSYİH) içindeki payı, gıda güvencesi göstergesi olarak FAO'nun PoU (Prevelance of Undernourishment-Yetersiz Beslenme Yaygınlığı) göstergesi kullanılmıştır. 2001-2021 döneminin seçilme sebebi bu göstergeye ait verilerin 2001 yılından itibaren mevcut olmasıdır. Çalışmanın sonraki bölümünde teorik ve

ampirik literatüre yer verilmiş, daha sonra yatay kesit bağımlılığı ve durağanlık testleri ile nedensellik analizi gerçekleştirilmiştir.

Literatürde yapılan çalışmalardan hiçbiri gelir eşitsizliği, ticari açıklık ve gıda güvencesi kavramlarını bir arada ele almamıştır. Bu çalışma üç kavramı tek bir çalışmada bir araya getirerek gelir eşitsizliği, ticari açıklık ve gıda güvencesi değişkenlerinin karşılıklı nedensellik ilişkisini araştırması bakımından özgünlük taşımaktadır. Böylece algılanan bilgi boşluğunu kapatmayı ve insanlık için temel olan bu alanda bilginin sınırlarını ilerletmeyi amaçlamıştır. Bu doğrultuda "gelir eşitsizliği ile gıda güvencesi arasında bir nedensellik ilişkisi var mı", "ticari açıklık ile gıda güvencesi arasında bir nedensellik ilişkisi var mı?" sorularının cevabı araştırılmıştır.

2. Teorik ve Ampirik Literatür

Malthus (1826), "Nüfus Artışının İlkeleri" konulu makalesinde, hızlı nüfus artışının gıda üretimi açısından yarattığı temel sorunla insanın her zaman karşı karşıya kalacağını ileri sürmüştür. Başka bir deyişle teori, nüfus dinamikleri ile gıda kaynaklarının mevcudiyeti arasında doğrudan bir bağlantı kurmuştur. Malthus'a göre gıda üretimi, kat kat artan insan nüfusuyla karşılaştırıldığında daha yavaş büyür, bu nedenle nüfus artışının kontrol edilmesinin gerekliliğini vurgulamıştır. Scanlan'a (2003) göre dünya, gelecek nesillerin taleplerini tehlikeye atmadan insanların taleplerini karşılayabilirse gıda güvencesi sağlanabilir. Berry ve Cline (1979) ve Simon'un (1998) Tekno-Ekoloji teorisi, gıda güvencesine daha olumlu bir yaklaşım getirmektedir. Teori, insan yaratıcılığının ve teknolojisinin en değerli varlıklar olduğuna ve bunların hiçbir şekilde kıtlık sorunuyla karşı karşıya olmadığına inanmaktadır. Bu yaklaşım, gıda güvencesinin ana nedeninin gıda tedariki olduğuna inanan Gıda Reddi yaklaşımıyla uyumludur. Gıda Reddi Yaklaşımı (FDA), Yeşil Devrim ve teknolojinin gıda kıtlığının olduğu az gelişmiş ülkelere yayılmasını savunan bir yaklaşımdır (Akinbode vd., 2022: 1).

Sen (1981), gıda güvensizliğinin gıdanın piyasada bulunmamasından kaynaklanmadığını, yoksulluk ve satın alma gücü eksikliğinin insanların gıdaya ulaşmasını engellediğini savunmaktadır. Bağımlılık ve Dünya Sistemi teorisi açlıkta uluslararası faktörleri dikkate almaktadır (Akinbode vd., 2022: 1). Örneğin, ticaretin serbestleştirilmesi, ülkelerin karşılaştırmalı üstünlüklerinden daha iyi yararlanmalarına olanak tanır ve ticaret kısıtlamalarından kaynaklanan kayıpları azaltır. Bu statik birinci dereceden etkilere ek olarak, artan verimlilik artışı, ölçek ekonomileri, daha iyi teknolojilere erişim gibi çeşitli dolaylı etkiler de mevcuttur. Hem doğrudan hem de dolaylı etkiler, hane halkı gelirlerinin artmasına ve yoksulluğun azalmasına neden olur. Ticaretin serbestleştirilmesi, yoksulluğu hafifletmeye yönelik en uygun maliyetli politikalardan biridir (Winters vd., 2004). Gelişmekte olan ülkelerde ticaret engellerinin daha da azaltılmasından elde edilecek göreceli kazancın yüksek olması beklenir. Ancak, toplamda ekonomik göstergelerde iyileşme olmasına rağmen, ticaretin serbestleştirilmesi, özellikle yüksek gıda fiyatları veya belirli sektörlerdeki düşük üretici fiyatları ve ücretler gibi potansiyel olumsuz etkilerle daha az başa çıkabilen en yoksul haneler için risk oluşturabilir (Dithmer ve Abdulai, 2017: 219).

Ekonomik teoriye göre ithalat, daha yüksek rekabet ve daha düşük fiyatlar nedeniyle gıda bilgilerindeki değişimler ve iç gıda piyasalarındaki değişiklikler yoluyla yetersiz beslenmeyi etkileyebilirken, ihracat, küresel piyasalara daha fazla erişim ve daha yüksek fiyatlar nedeniyle gıda çıkışlarına ve gelirde değişimlere yol açabilir (Marson vd., 2023: 301).

Gıda güvencesizliği/açlık ile ilgili Kentleşme Teorisi, kalkınmanın her zaman kentsel alanların lehine olduğunu, çünkü ekonomik elitlerin şehirlerde siyasi güç topladığını ve kırsal alanları az gelişmiş bırakırken kentsel alanların avantajına politikalar çıkardığını öne sürmüştür. Kırsal ve kentsel alanlar arasındaki farklar, ekonominin tarım ve sanayi/imalat sektörleri arasındaki farklara benzemektedir. Sosyal katmanlaşma teorisi, eşitsizlik ve sosyal katmanlaşmanın gıda güvencesi için önemli sosyal hususlar olduğunu öne sürmektedir. Gıda güvencesizliği/açlığın kökleri iç savaşlardan ve diğer iç mücadelelerden kaynaklanıyor olabilir (Akinbode vd., 2022: 1).

Literatürdeki ampirik çalışmalarda gıda güvencesini belirleyen ya da etkileyen veya gıda güvencesi ile nedensellik ilişkisi olan faktörlere yönelik yapılan araştırmalar içerisinde bir kısmı serbest ticarete veya ticari dışa açıklığa odaklanmış çalışmalardır. Küreselleşen dünyada küreselleşmenin bileşenlerinden biri ticaretin küreselleşmesi olup bazı çalışmalarda serbest ticaretin gıda bulunabilirliğine etkisi incelenmiştir. Örneğin, Bezuneh ve Yeheyis (2012), yapısal uyumun bir parçası olarak ticaretin serbestleştirilmesinin, ticarete açıklığın ekonomik büyümeye ve kalkınmaya katkıda bulunacağı argümanına dayanarak Dünya Bankası ve IMF tarafından teşvik edildiğini ifade etmektedir. Bu doğrultuda gelişmekte olan ülkelerin çoğu ekonomilerini liberalleştirme zorluğunu üstlenmiştir. Ticaretin serbestleştirilmesinin yoksulluğu azaltması ve gıda güvencesini iyileştirmesi beklenmiştir. Seçilmiş Afrika ülkelerinde ticaretin serbestleştirilmesinin gıda bulunabilirliği üzerindeki etkisini araştıran yazarlar, liberalleşmenin çalışma ülkelerinde gıda bulunabilirliğini iyileştirdiğine dair hiçbir kanıt bulamamışlardır. Ancak ticari açıklığın gıda bulunabilirliğine ulaşma üzerindeki etkisinin açıklığa kavuşturulması gerektiğini, çünkü bunun artan ithalat yoluyla gıda kıtlığını azaltabileceğini ve aynı zamanda gelişmekte olan ülkeleri ithalata daha bağımlı hale getirebileceğini ileri sürmüşlerdir. Buna karşın Dithmer ve Abdulai (2017), 151 gelişmiş ve gelişmekte olan ülkeden (1980–2007) oluşan bir panelde, ticari açıklığın hem ortalama beslenme enerjisi hem de çeşitlilik ile pozitif yönde ilişkili olduğunu bulmuşlardır. Ampirik sonuçlar, ticari açıklığın ve ekonomik büyümenin beslenme enerji tüketimi üzerinde olumlu ve anlamlı etkiler yarattığını ve aynı zamanda beslenme çeşitliliğindeki iyileşmelere katkıda bulunduğunu ortaya koymaktadır. Çoğu coğrafi bölgenin, Sahra Altı Afrika'ya kıyasla önemli ölçüde daha yüksek gıda güvencesi seviyelerine sahip olduğu bulunmuştur. Sonuçlar, ticari açıklığın kalori tüketiminin yanı sıra beslenme çeşitliliğini ve gıda güvencesinin beslenme kalitesiyle ilgili yönlerini de iyileştirdiğini göstermektedir.

Ticari açıklığın gıda güvencesini olumlu etkilediğini vurgulayan bir başka çalışma Fusco ve diğerlerinin (2020) çalışmasıdır. Yazarlar, 2000-2012 dönemi için AB ülkelerinde ticari açıklığın gıda güvencesi üzerindeki etkisini araştırdıkları çalışmalarında ortalama protein tedariki, ortalama diyet enerji arzı yeterliliği ile üç ticari açıklık göstergesi (ticari açıklık, tarife, küreselleşme) kullanmışlardır. Sonuçlar, ticari açıklığın ortalama olarak Avrupa ülkelerinin gıda güvencesi üzerinde istatistiksel olarak anlamlı net olumlu etkiye sahip olduğunu göstermiştir. Ayrıca, en dayanıklı ülkelerin kişi başına düşen gelirin daha yüksek olduğu ülkeler olduğunu doğrulamışlardır. Sonuç olarak, bugün birçok ülke, vatandaşlarının yeterli gıda erişiminden yararlanmasını garanti altına alarak ticari açıklığın faydalarının farkına varmaktadır. Sun ve Zhang (2021) ise gıda güvencesi durumunun belirli bir düzeyde ticari açıklıktan sonra iyileşme eğiliminde olduğunu ileri sürmüştür. 2001-2018 dönemi için Orta Asya ülkelerinde gıda güvencesi durumunun iyileşme eğiliminde olduğu, kişi başına GSYİH, GSYİH büyümesi ve tarımsal verimliliğin, gıda güvencesinin iyileştirilmesine katkıda bulunduğu, tarımda istihdam, ekilebilir araziler, tarımda tatlı su çekilmesi, nüfus artışı, doğal afetler ve enflasyon oranının gıda

güvencesini olumsuz etkilediği sonucuna ulaşılmıştır. Sonuçlar, belirli bir ticari açıklık eşiğinin ötesinde, Orta Asya ülkelerinde gıda güvencesi durumunun iyileşme eğiliminde olduğunu göstermekte ve ticaret politikası reformlarının Orta Asya ülkelerinde gıda güvencesinin iyileştirilmesine yardımcı olabileceğini doğrulamaktadır. Ancak, diğer faktörlerin etkileri, ticari açıklığın olası olumsuz etkileri ve küresel gıda ticareti ağının kırılganlığı göz önüne alındığında, makul düzeyde gıda kendi kendine yeterliliğinin sağlanması, Orta Asya ülkelerinin gıda güvencesini sağlamaları açısından son derece önemlidir. Khalid ve diğerlerine (2020) göre Güney Asya Bölgesel İş birliği Teşkilatı (SAARC) bölgesi için daha yüksek tüketim ve artan ithalat gereksinimleri, kaynaklar en iyi şekilde kullanılırsa komşu ticaret ortakları aracılığıyla karşılanabilir. SAARC ülkelerinin bölgesel ticareti ile bölgenin karşılaştığı gıda güvencesi zorlukları arasındaki bağlantıyı analiz eden bu çalışma, Pakistan, Hindistan, Sri Lanka ve Bangladeş için 1990-2018 yılları arasındaki verilere göre sosyal ve ekonomik açıdan birbirine bağımlı bölgelerin ticareti serbestleştirme çabaları nedeniyle yerel gıda yoksulluğunun azaldığını ortaya koymuştur.

Bazı çalışmalarda genel ticari dışa açıklığın etkilerinin ötesinde tarım ticaretinin etkileri ele alınmıştır. Örneğin, Chikhuri (2013) çeşitli gıda güvencesi göstergelerini analiz etmiş ve Sahra Altı Afrika'da tarımsal ticaretin serbestleştirilmesi ile gıda güvencesi arasındaki bağlantıyı incelemiştir. Çeşitli ticareti serbestleştirme girişimlerinin Sahra Altı Afrika bölgesindeki temel gıda güvencesi göstergeleri üzerindeki sonuçlarının belirsiz olduğu bulgusuna ulaşmıştır. Mary (2019) ise gıda ticaretinin açıklığının yetersiz beslenme yaygınlığıyla pozitif yönde ilişkili olduğunu bulmuştur. Bu çalışmada gıda ile gıda dışı ticaretin etkileri birbirinden ayrıştırılarak gelişmekte olan 52 ülkeden (1990-2013) oluşan bir örneklem kullanılmıştır. Gıda ticaretinin dışa açıklığında yüzde 10 oranında bir artışın, yetersiz beslenme yaygınlığını yaklaşık yüzde 6 artıracağı bulunmuştur. Ayrıca gelişmekte olan ülkelerin artan açlığa tepki olarak gıda ticaretinde dışa açıklığı azalttığına dair kanıtlar da bulunmuştur; bu da korumacı politikalara işaret etmektedir. Sonuçlar, ülkelerin bir süreliğine gıdada kendi kendine yeterliliği benimsemelerinin daha iyi olabileceğini göstermektedir. Bu sonuç, Sun ve Zhang'ın (2021) gıda güvencesi durumunun belirli bir düzeyde ticari açıklıktan sonra iyileşme eğiliminde olduğu sonucuyla aynı doğrultudadır. Marson vd. (2023) da ticari açıklığın yetersiz beslenme yaygınlığını azalttığını savunan yazarlardan biridir. Yazarların 2001-2016 döneminde 81 ülkeyi örneklem olarak kullanan ve temel olarak yetersiz beslenme yaygınlığına odaklanan çalışması yeni ampirik kanıtlar sunmaktadır. İlk olarak, kişi başına düşen gerçek gelirdeki (yani gıdaya ekonomik erişim üzerindeki) değişikliklerden geçen etkiler farklılaştırılarak toplam ticaretin etkisi tahmin edilmiştir. Daha sonra, genellikle ticaret kısıtlamalarından en çok etkilenen ve yetersiz beslenmeyle en fazla ilişkili olan tahıl ticaretine odaklanılmıştır. Son olarak, tahıl ticaretinin ithalat ve ihracat açısından farklı etkileri araştırılmıştır. Ticari açıklık, gelişmekte olan ülkelerde yetersiz beslenmenin yaygınlığının azaltılmasına katkıda bulunmaktadır ve bu etkinin çoğu gelir kaynaklı değil, gıda güvencesinin diğer boyutları üzerindeki doğrudan etkilerden geçmektedir. Bu tür etkiler çoğunlukla tahıl sektörünün ticari açıklığından kaynaklanmaktadır ve ithalat bileşeninin ana rolü oynadığı ortaya çıkmaktadır.

Ticarette serbestleşmeyi savunanların aksine Fan vd. (2024), tarımsal ticarette artan açıklığın Güney Asya bölgesinde gıda güvencesini engellediğini iddia etmektedir. 2000-2019 yıllarını kapsayan panel verileri kullanan bu çalışma, Güney Asya bölgesine ait ülkelerde tarifeleri ve tarımsal üretimi kontrol ederken tarımsal ticarette açıklık ve tarımsal istihdamın gıda güvencesi üzerindeki etkisini araştırmıştır. Bu çalışma tarımsal ticarette artan açıklığın bu bölgede gıda

güvencesini engellediği sonucuna varmaktadır. Çünkü Güney Asya'daki üye ülkeler kendi iç ihtiyaçlarını karşılamak için büyük ölçüde gıda ithalatına bağımlıdır; bu da gıda ithalatının harcamalarının ihracatı artırmanın potansiyel faydalarını aştığı anlamına gelmektedir. Üstelik tarifelerin bu bölgedeki gıda güvencesi üzerinde zararlı bir etkisi bulunmaktadır. Ancak tarım sektöründeki üretim ve istihdam, kazançları artırmakta, gıda satın alma kapasitesini güçlendirmekte ve uzun vadede yeterli besin alımını sağlamaktadır. Araştırmanın bulguları, bu ulusların tarımsal ihracatı genişletmek ve ithal gıdaya bağımlılıklarını azaltmak için gıdada kendi kendine yeterliliğe öncelik vermesi gerektiğini göstermektedir. Li ve Zhang (2024) ise açlığın azaltılması için gıda arzının artırılmasının temel olduğunu, bunun önündeki önemli bir engelin de gıdanın eşitsiz dağılımı olduğunu vurgulamıştır. Bu çalışmada gıda arzını artırmanın açlık üzerindeki olumlu etkisi mi daha fazla, gıdanın adaletsiz dağılımının açlık üzerindeki olumsuz etkisi mi daha fazla, bunu tespit etmek için 2000'den 2018'e kadar 158 ülkede açlık riskini etkileyen temel faktörlerin katkılarını belirlemek amacıyla bir ayrıştırma analizi yapılmıştır. Nüfus, yetersiz beslenme, gıda arzı ve gıda dağıtımı faktörlerinin ele alındığı çalışmada PoU'nun katkısı yüzde 55, nüfusun katkısı yüzde 32 olarak tespit edilmiştir. Gıda dağıtımındaki eşitsizliğin artması, ürün grubuna göre PoU'yu yüzde 8,40 ile yüzde 13,74 arasında artırmaktadır. Gıda arzı açısından en büyük katkı da yüzde 22,98 oranı ile tahıl grubundan gelmektedir. Açlık riskinin azaltılması için özellikle tahıl gıda arzını artırmak gerektiği gibi daha adil gıda dağıtımı da gerekmektedir.

Literatürdeki çalışmalar içinde çok az çalışma eşitsizlik ve gıda güvencesi ilişkisine odaklanmıştır. Bu çalışmalardan biri Larrea ve Kawachi'nin (2005) 1998 yılında Ekvador'da yapılan Yaşam Standardı Ölçüm Araştırması verilerini kullandıkları çalışmadır. Araştırma verileri 5 yaşından küçük 3054 çocuğun antropometrik ölçümlerini içermektedir. Çalışmada Ekvador'da ekonomik eşitsizlik ile çocuklarda yetersiz beslenme ilişkisi incelenmiştir. Gini katsayısı ile çocukluk çağı bodurluğu arasındaki ilişki, kişi başına gıda tüketimi, eğitim, barınma, etnik köken, doğurganlık, sağlık hizmetlerine erişim, ishal hastalıkları, çocuk bakımı, anne yaşı ve diyet kompozisyonu dahil olmak üzere bir dizi bireysel ve hane halkı ortak değişkenleri kontrol değişkeni ile birlikte analiz edilmiştir. İl ölçeğindeki ekonomik eşitsizliğin bodurluk üzerinde istatistiksel olarak anlamlı derecede zararlı bir etkisi olduğu görülürken, belediye veya yerel düzeylerde eşitsizlik, bodurlukla ilişkilendirilmemiştir. Lukwa vd. (2020) da çocuklarda yetersiz beslenmeyi ele aldığı çalışmada Zimbabwe'de grup içi ve grup eşitsizliklerini karşılaştırmak için regresyon ayrıştırma yaklaşımını kullanarak çocuk sağlığındaki sosyoekonomik eşitsizlik eğilimini 2010/11 ve 2015 yıllarına ait Demografik Sağlık Araştırması (DHS) veri setlerini kullanarak araştırmıştır. Çalışmada yetersiz beslenmenin yoksullar arasında mı yoksa zenginler arasında mı baskın olduğunu anlamak için konsantrasyon eğrileri ve endeksleri hesaplanmıştır. Ayrıca Theil indeksi kullanılmış ve endeks nüfus alt gruplarına (ikamet yeri ve sosyoekonomik durum) göre ayrıştırılmıştır. Çalışma, hane halkı servetinin ve ikamet durumunun eşit olmayan dağılımının, çocuklarda gıda güvencesizliği ve yetersiz beslenmedeki sosyoekonomik eşitsizliklerin oluşmasında kritik rol oynadığı sonucuna varmıştır. Bu nedenle, çocuklarda gıda güvencesizliği ve yetersiz beslenme, çocuğun yaşadığı yerden (kırsal/kentsel) ve ebeveynlerin servetinden büyük ölçüde etkilenmektedir.

Akinbode vd. (2022), gelir eşitsizliği ile birlikte nüfus artışının da açlık üzerindeki etkisini inceledikleri çalışmada elde edilen sonuçlar, eşitsizlikteki her yüzde 1'lik artışa karşılık açlığın yaklaşık yüzde 0,3 oranında arttığını göstermiştir. Kişi başına düşen GSYİH, kadın okuryazarlığı, ekonomik istikrar ve ülke düzeyinde toplam gıda üretim endeksinin de kontrol değişkenleri olarak

bölgedeki açlık üzerindeki etkileri değerlendirilmiştir. Çalışma, 2007'den 2017'ye kadar 46 Sahra Altı Afrika ülkesini (verileri tam olmayan Güney Sudan hariç) kapsamıştır. Sahra Altı Afrika'da eşitsizlik açlığa diğer önemli değişkenlerden daha fazla etki etmektedir. Nüfusun, eşitsizliğin ve gelirin önemi nedeniyle nüfus artışının hala bölge halkının refahı (açlığı) açısından büyük bir sorun teşkil ettiği sonucuna varılmıştır. Toplumsal zenginliğin eşitsiz dağılımından kaynaklanan eşitsizlik, Sahra Altı Afrika'daki açlığın bir nedenidir. Bu ülkelerde yeterli gıdanın üretilmediği durumlarda, ülkenin bunu karşılayabilecek kadar zengin olması durumunda, karşılaştırmalı üstünlüğe sahip ülkelerden gıda ithal edilebilir. Ancak bölgedeki kişi başına düşen gelirin nispeten düşük olması, ekonomi için de tehlikeli olan yoğun gıda ithalatını desteklememektedir.

Literatür araştırmasında yapılan bazı çalışmalar ticari dışa açıklığın gıda güvencesini olumlu etkilediğine dair kanıt bulamamıştır. Birçok çalışmada ticari dışa açıklığın veya serbest ticaretin gıda güvencesini pozitif etkilediği sonucuna ulaşılmıştır. Az sayıda çalışma sonucu ise bu olumlu etkilerin, belirli bir ticari açıklık seviyesinden sonra gerçekleştiği yönündedir. Bazı çalışmalarda genel ticari dışa açıklığın ötesinde tarım ticareti ile gıda güvencesi arasındaki ilişki ele alınmıştır. Bazı çalışmalar tarım ticareti ile gıda güvencesi ilişkisinin belirsiz olduğu sonucuna varırken yapılan araştırmaların çoğu olumlu etkiler olduğunu ortaya koymuştur. Gelir eşitsizliği ile gıda güvencesi arasındaki ilişkiyi ele alan çalışma sayısı oldukça sınırlıdır. Dolayısıyla bu çalışmanın temel amacı literatürde görülen bu boşluktan hareketle düşük ve orta gelirli ülkeler için 2001-2021 yıllarını kapsayan dönemde gelir eşitsizliği, ticari dışa açıklık ve gıda güvencesi arasındaki ilişkinin araştırılmasıdır. Bu çalışmanın literatüre katkısı birkaç maddede ele alınabilir: (i) Gelir eşitsizliğinin gıda güvencesi üzerindeki etkisini inceleyen çalışma sayısının kısıtlı olması ve bu alana katkı sağlaması, (ii) Gelir eşitsizliği, ticari dışa açıklık ve gıda güvencesinden oluşan üç değişkeni bir araya getiren tek çalışma olması, (iii) Gelir eşitsizliği, ticari dışa açıklık ve gıda güvencesi arasındaki karşılıklı nedensellik ilişkisini araştırması, (iv) Gelir eşitsizliği, ticari dışa açıklık ve gıda güvencesi arasındaki ilişkiyi düşük ve orta gelirli ülkeler için ele alan sınırlı çalışmalardan biri olması bakımından bu çalışma literatüre katkı sağlayacaktır.

3. Yöntem ve Bulgular

Bu çalışmada gıda güvencesi, gelir eşitsizliği ve ticari dışa açıklık arasındaki nedensellik ilişkisi panel veri tekniklerinden yararlanılarak analiz edilmiştir. Çalışmada örneklem orta ve düşük gelirli 19 ülkeyi kapsadığı için panel veri analiz süreçleri takip edilmiştir. Panel veri modelleri ile sayısı birden fazla olan aynı yatay-kesit birimlerin zaman içindeki değişimleri incelenebilmektedir, bu avantajı sebebiyle literatürde yaygın olarak kullanılmaktadır (Gujarati, 2016: 420).

Bu bölümde önce değişkenlere ait özet bilgiler, tanımlayıcı istatistikler ve modele ait bilgiler verildikten sonra yatay kesit bağımlılığı olup olmadığı araştırılmış, sonra birim kök analizleri yapılmış ve Dumitrescu-Hurlin (2012) Nedensellik Testi ile değişkenler arasındaki nedensellik ilişkisi analiz edilmiştir.

3.1. Veri ve Yöntem

Çalışmada yetersiz beslenme yaygınlığının yüksek olduğu 19 ülke yer almaktadır. Bu ülkeler sırasıyla Ermenistan, Bangladeş, Bolivya, Orta Afrika Cumhuriyeti, Dominik, Honduras, Hindistan, Endonezya, Kenya, Kore, Kırgızistan, Mali, Moldova, Mozambik, Panama, Peru,

Filipinler, Tayland ve Vietnam'dır. Ülkelerin seçilmesinde yetersiz beslenme yaygınlığının yüksek olması ile gelir eşitsizliğinin yüksek olması etkili olmuştur. Bu ülkelerin seçilmesinde bir diğer etken verilerin ulaşılabilir olmasıdır. Araştırmanın bağımsız değişkeni olan gıda güvencesini temsil etmek üzere Marson vd. (2023) takip edilerek Yetersiz Beslenme (YB) değişkeni olarak FAO'nun PoU verisi kullanılmıştır. Muhtemelen kalkınma gündemlerindeki önemi nedeniyle, bu temel göstergeye ilişkin zaman serileri birçok ülke için zaman içinde yeniden değerlendirilmiş ve güncellenmiştir; dolayısıyla yetersiz beslenme yaygınlığı verileri 2000-2002 döneminden başlamaktadır (Marson vd., 2023: 307). Bu sebeple veriler, 2001 yılından itibaren analize dahil edilmiştir.

Yine Marson vd. (2023) takip edilerek Ticari Dışa Açıklık göstergesi olmak üzere GSYİH yüzdesi olarak ticaret verisi kullanılmıştır. Ticari dışa açıklık değişkenine ait veriler Dünya Kalkınma Göstergeleri veri tabanından elde edilmiştir. Çalışmada gelir eşitsizliğinin ölçümü için de Akinbode vd. (2022) takip edilerek Gini katsayısı kullanılmıştır. Gini katsayısına ilişkin veriler Standardize Edilmiş Dünya Gelir Eşitsizliği Veri Tabanından (SWIID, 2023) elde edilmiştir (Solt, 2016). Gini katsayısı, Lorenz eğrisinden türetilmektedir ve 0 (mükemmel eşitlik) ile 100 (mükemmel eşitsizlik) arasında değişen bir katsayıdır. SWIID veri seti, 1960'dan günümüze 198 ülke için Gini endeksine ilişkin verileri kapsamaktadır (SWIID, 2023). Veri seti, elde edilebilen en geniş zaman aralığında alınmaya çalışılmış, mevcut veriler çerçevesinde çalışmanın zaman aralığı 2001-2021 dönemi olarak belirlenmiştir. Değişkenlere ait bilgiler Tablo 2'de sunulmuştur.

Tablo 2. Değişkenlere Ait Bilgiler

Değişken Adı	Tanımlama	Ölçüm	Kaynak
YB	Gıda güvencesi	Yetersiz Beslenme Yaygınlığı (Nüfus yüzdesi)	WDI
TA	Ticari dışa açıklık	Ticaret (GSYİH yüzdesi)	WDI
GINI	Gelir eşitsizliği	Gini Endeksi	SWIID

Çalışmada kullanılan verilere ait özet istatistiklerin yer aldığı Tablo 3 incelendiğinde, ortalama (77.921), maksimum (186.675) ve minimum (25.993) değerleri ile TA değişkeninin diğer değişkenlere göre daha yüksek olduğu görülmektedir. Minimum değeri en düşük olan değişken YB (2.500), ortalaması en düşük olan değişken yine YB (16.912), maksimum değeri en düşük olan da YB'dir (49.100). Standart sapması en yüksek değişken 35.178 ile TA, en düşük olan ise 6.254 değeri ile GINI'dir.

Tablo 3. Tanımlayıcı İstatistikler

	YB	TA	GINI
Ortalama	16.936	77.921	41.821
Maksimum	49.100	186.675	54.400
Minimum	2.500	25.993	30.800
Standart Sapma	11.290	35.178	6.254
Korelasyon Matrisi			
	YB	**TA**	**GINI**
YB	1.000	-0.147	0.319
TA	-0.147	1.000	-0.134
GINI	0.319	-0.134	1.000

Tablo 3'te değişkenlerin korelasyon katsayıları da gösterilmektedir. Korelasyon matrisi incelendiğinde, gelir eşitsizliği ile gıda güvencesi arasında yüzde 25'in üzerinde pozitif korelasyon görülürken, gelir eşitsizliği ile ticari açıklık arasında yaklaşık yüzde 13 negatif korelasyon görülmektedir. Ancak, korelasyon katsayısı ve tanımlayıcı istatistikler değişkenler arasındaki ilişkinin açıklanmasında yeterli ölçütler olmadığı için diğer testlerin de yapılması gerekir.

Bu çalışmada yetersiz beslenme yaygınlığının yüksek olduğu seçilmiş 19 ülkede gıda güvencesi, gelir eşitsizliği ve ticari dışa açıklık arasındaki nedensellik ilişkisi araştırılmıştır. Çalışmanın ampirik modeli kurulurken Marson ve diğerlerinin (2023) çalışması takip edilmiştir. Yetersiz beslenme yaygınlığının yüksek olduğu seçilmiş ülkelerde eşitsizlik, ticari dışa açıklık ve gıda güvencesi arasındaki ilişkiyi test etmek amacıyla düzenlenen model (1), Marson vd. (2023) ve Akinbode vd. (2022), tarafından geliştirilen modeller temel alınarak oluşturulmuştur.

Aşağıda gıda güvencesi (YB), gelir eşitsizliği (GINI) ve ticari dışa açıklığın (TA) bir fonksiyonu olarak düzenlenmiştir.

YB= f(GINI, TA)

$$lnYB_{it} = \beta_0 + \beta_1 lnGINI_{it} + \beta_2 lnTA_{it} + \varepsilon_{it} \quad (1)$$

Modelde i=1'den N'e kadar olan ve ülkeleri temsil eden birimleri gösterirken; t=1,….,T'ye kadar yıllık frekansta zaman periyodunu göstermektedir. Modellerde yer alan β_0, … … , β_1; değişkenlerin katsayılarını ve ε_{it}ise hata terimini göstermektedir. Kullanılan veri seti modelde görüldüğü gibi logaritmaları alınarak modele dahil edilmiştir. Yıllık olarak veriler düzenlendikten sonra Eviews 12 programı kullanılarak analizler gerçekleştirilmiştir.

3.2. Bulgular

Birimler arasında yatay kesit bağımlılığının olup olmadığının tespiti için Breusch-Pagan (1980) LM, Pesaran (2004) CDLM, Pesaran (2004) CD ve Pesaran ve Yamagata (2008) LMAdj testleri literatürde sıklıkla kullanılan testlerdir. Testin hipotezleri aşağıdaki gibidir:

H_0: Yatay kesit bağımlılığı yoktur.

H_1: Yatay kesit bağımlılığı vardır.

Tablo 4. Yatay Kesit Bağımlılığı Testi

	LM (Breusch, Pagan 1980)	CDLM (Pesaran 2004)	CD (Pesaran 2004)	LMAdj (Pesaran ve Yamagata, 2008)
LNYB	2001.631 [0.0000]***	98.98919 [0.0000]***	98.51419 [0.0000]***	26.49102 [0.0000]***
LNGINI	2320.169 [0.0000]***	116.2138 [0.0000]***	115.7388 [0.0000]***	16.44122 [0.0000]***
LNTA	1013.804 [0.0000]***	45.57360 [0.0000]***	45.09860 [0.0000]***	5.739370 [0.0000]***

Not: ***; %1, **; %5, *; %10 anlamlılık düzeyini göstermektedir.

Yatay kesit bağımlılığı test sonuçları Tablo 4'te gösterilmektedir. Bahsedilen testlere göre panel veride değişkenlerin olasılık değerleri incelendiğinde yüzde 1 anlam düzeyinde sıfır

hipotezi reddedilmekte ve değişkenler arasında yatay kesit bağımlılığı olduğu sonucu ortaya çıkmaktadır. Dolayısıyla seçilen ülkelerin ekonomilerinde meydana gelen şoklar, diğer ülkeleri de etkilemektedir.

Yapılan tahminlerin güvenilirliği serilerin durağan olup olmadığının tespit edilmesiyle mümkün olacaktır. Birim kök testleri birinci nesil veya ikinci nesil olabilmektedir. Birinci nesil birim kök testleri birimler arasında yatay kesit bağımlılığı olmadığı varsayımına dayalıdır. İkinci nesil birim kök testleri ise birimler arasında yatay kesit bağımlılığı olduğunda kullanılmaktadır. Bu çalışmada birimler arasında yatay kesit bağımlılığı olduğu tespit edilmiştir. Dolayısıyla serilerde durağanlık durumunu araştırmak için yatay kesit bağımlılığını dikkate alan CIPS istatistiklerinden yararlanılmıştır. CIPS testinin hipotezleri aşağıdaki gibidir:

H_0 : Seride birim kök vardır (Seri durağan değildir)

H_1 : Seride birim kök yoktur (Seri durağandır)

CIPS istatistikleri Pesaran (2007) tarafından geliştirilen bireysel CADF istatistiklerine ait ortalamalardan yararlanılarak hesaplanmaktadır. CADF birim kök test istatistiği, zaman boyutu (T) kesit boyutundan (N) büyük olduğunda da küçük olduğunda da kullanılabilmektedir (Güloğlu ve İvrendi, 2008: 3). CIPS birim kök testi sonuçları Tablo 5'te yer almaktadır.

Tablo 5. CIPS Birim Kök Testi

	Düzey	**P-value**	**Fark**	**P-value**
LNYB	-2.39	< 0.05	-2.59***	<0.01
LNGINI	-1.84	>=0.10	-2.30***	<0.01
LNTA	-2.08	>=0.10	-4.07**	<0.05

Not: Gecikme uzunluğu 1 olarak belirlenmiştir. Test modeli sabit içermektedir. Sabitte kritik değerler -2.42 (%1), -2.22 (%5), -2.11'dir (%10). Kritik değer hesaplamaları Pesaran (2007) makalesinden alınmıştır. ***; %1, **; %5, *; %10 anlamlılık düzeyini göstermektedir.

Değişkenlerin düzey değerleri kullanıldığında gıda güvencesi değişkeni dışında yüzde 1 anlam düzeyinde birim kökün sıfır hipotezi reddedilememektedir. Ancak birinci farkları kullanıldığında farklı anlamlılık düzeylerinde sıfır hipotezi reddedilmekte ve bütün değişkenlerin durağan oldukları sonucuna ulaşılmaktadır. Bağımlı ve bağımsız değişkenler arasındaki ilişkinin yönünü tespit etmek amacıyla nedensellik analizi yapılmıştır. Bu çalışmada Dumitrescu ve Hurlin (2012) tarafından geliştirilen nedensellik testinden yararlanılmıştır. Bu testin hipotezleri aşağıdaki gibidir:

H_0: Tüm birimler için nedensellik yoktur.

H_1: Tüm birimler için nedensellik vardır.

Tablo 6'da Dumitrescu ve Hurlin (2012) tarafından geliştirilmiş olan nedensellik testi sonuçları gösterilmiştir. Nedensellik testi sonuçlarına göre birimler arasında nedenselliğin olmadığı sıfır hipotezi reddedilmekte ve nedenselliğin bulunduğu yönündeki alternatif hipotez kabul edilmektedir. Elde edilen bulgular ticari dışa açıklığın gıda güvencesini yüzde 1 anlam düzeyinde etkilediği yönündedir. Gelir eşitsizliği de gıda güvencesini yüzde 1 anlam düzeyinde etkilemektedir. Dolayısıyla ticari dışa açıklıktan ve gelir eşitsizliğinden gıda güvencesine doğru bir nedensellik ilişkisi söz konusudur.

Tablo 6. Dumitrescu-Hurlin Panel Nedensellik Analizi Sonuçları

Nedensellik Yönü	W-Stat.	Zbar-Stat.	Olasılık Değeri	Nedensellik
ΔLnta → ΔLnyb	2.927	4.305	0.000***	**Var**
ΔLnyb → ΔLnta	0.985	-0.380	0.703	Yok
ΔLngini → ΔLnyb	2.357	2.920	0.003***	Yok
ΔLnyb → ΔLngini	1.565	1.014	0.310	**Var**
ΔLngini → ΔLnta	1.596	1.089	0.276	Yok
ΔLnta → ΔLngini	0.666	-1.149	0.250	Yok

Not: ***; %1, **; %5, *; %10 anlamlılık düzeyinde değişkenler arasında Granger nedenselliğin olduğunu göstermektedir.

Serbest ticaret ya da ticari dışa açıklığın gıda güvencesini etkilediği bulgusu Dithmer ve Abdulai (2017), Fusco vd. (2020), Khalid vd. (2020), Sun ve Zhang'ın (2021) bulgularıyla uyumludur. Gelir eşitsizliğinin gıda güvencesini etkilediği bulgusu da Akinbode vd. (2022), Larrea ve Kawachi (2005) ve Lukwa ve diğerlerinin (2020) gelir eşitsizliğinin gıda güvencesini etkilediği bulgusunu doğrulamaktadır. Akinbode vd. (2022), toplumsal zenginliğin eşitsiz dağılımından kaynaklanan eşitsizliğin, Sahra Altı Afrika'daki açlığın bir nedeni olduğu bulgusuna ulaşmıştır. Bu çalışmada da elde edilen bulgulara göre birçoğu Sahra Altı Afrika'da bulunan orta ve düşük gelirli ülkelerde gelir eşitsizliği gıda güvencesinin/güvencesizliğinin bir nedenidir.

4. Sonuç

BM'in 2030 SKH'lerden "Sıfır Açlık" hedefine ulaşma çabalarına rağmen gıda güvencesi tüm dünyada yeterince sağlanamamakta, yetersiz beslenen nüfus düşük gelirli ve orta gelirli ülkelerde artmaktadır. Gıda güvencesinin sağlanamamasının ardında pek çok neden yatmaktadır. Bunlar arasında gıda arzının yetersizliği, gıda dağılımının dengeli olmaması, savaş ve çatışmalar sebebiyle ortaya çıkan gıda krizleriyle hem gıda tedarik zincirinin bozulması hem de gıda fiyatlarının yükselmesi sayılabilir. Bunun yanı sıra küresel iklim değişikliğinin etkilerinin giderek artması, olağanüstü hava olaylarının meydana gelmesi, ekonomik yavaşlamalar ve gerilemeler, sağlıklı beslenmeye erişim eksikliği ve bunların karşılanamaması, sağlıksız gıda ortamları ile yüksek ve kalıcı eşitsizlik, tüm dünyada gıda güvencesizliğine ve yetersiz beslenmeye yol açmaya devam etmektedir. Son on yılda, çatışmaların, aşırı iklim olaylarının ve ekonomik gerilemelerin sıklığı ve yoğunluğu artmış ve dünya çapında gıda güvencesini ve beslenmeyi zayıflatmaktadır. Yüksek gelir eşitsizliği seviyeleri bu başlıca itici güçlerin etkilerini daha da kötüleştirmektedir (FAO, 2024: 3). 1990'lı yıllardan beri Dünya Ticaret Örgütü'nün de savunduğu ticaret kısıtlamalarının kaldırılması politikalarıyla dünya üzerinde her bireyin gıdaya erişebileceği, uygun fiyatla temel ihtiyacı olan gıda maddelerini satın alabileceği düşüncesi kabul görmüştür. Bu durum gelir eşitsizliği, serbest ticaret ve gıda güvencesi ilişkisinin ele alınmasına yol açmıştır. Bu bağlamda bu üç değişkenin birbirleri arasındaki nedensellik ilişkisi incelenmeye değer bir konu olarak görülmüştür.

Yapılan bu çalışmanın amacı, seçilmiş 19 orta ve düşük gelirli ülke için 2001-2021 yılları arası gelir eşitsizliği, ticari açıklık ve gıda güvencesi arasındaki nedensellik ilişkisini incelemek olarak belirlenmiştir. Araştırmanın bağımsız değişkeni olan gıda güvencesini temsil etmek üzere FAO'nun PoU verisi kullanılmıştır. Ticari Dışa Açıklık göstergesi olmak üzere GSYİH yüzdesi

olarak ticaret verisi kullanılmıştır. Çalışmada gelir eşitsizliğinin ölçümü için de Gini katsayısı kullanılmıştır.

Panel veri tekniklerinin kullanıldığı bu çalışmada Dumitrescu ve Hurlin (2012) nedensellik testi sonuçlarına göre ticari dışa açıklıktan ve gelir eşitsizliğinden gıda güvencesine doğru bir nedensellik ilişkisinin varlığı tespit edilmiştir. Serbest ticaret ya da ticari dışa açıklığın gıda güvencesini etkilediği bulgusu Serbest ticaret ya da ticari dışa açıklığın gıda güvencesini etkilediği bulgusu Dithmer ve Abdulai (2017), Fusco vd. (2020), Khalid vd. (2020) ve Sun ve Zhang'ın (2021) bulgularıyla uyumludur. Gelir eşitsizliğinin gıda güvencesini etkilediği bulgusu da Akinbode vd. (2022), Larrea ve Kawachi (2005) ve Lukwa ve diğerlerinin (2020) gelir eşitsizliğinin gıda güvencesini etkilediği bulgusunu doğrulamaktadır. Akinbode vd. (2022), toplumsal zenginliğin eşitsiz dağılımından kaynaklanan eşitsizliğin, Sahra Altı Afrika'daki açlığın bir nedeni olduğu bulgusuna ulaşmıştır. Bu çalışmada da elde edilen bulgulara göre birçoğu Sahra Altı Afrika'da bulunan orta ve düşük gelirli ülkelerde gelir eşitsizliği gıda güvencesi/güvencesizliğinin bir nedenidir.

Elde edilen bulgular genel olarak gelir eşitsizliği ve ticari açıklığın gıda güvencesinin sebepleri olduğunu göstermektedir. Orta ve düşük gelir düzeyine sahip 19 ülke ekonomisi için 2001-2021 döneminde söz konusu olan gelir eşitsizliği ve gerçekleştirilen uluslararası ticaret bu ülkelerde görülen açlık ve yetersiz beslenmeye dolayısıyla gıda güvencesine olumlu veya olumsuz yönde katkıda bulunmaktadır. Açlık, gıda güvencesizliği ve yetersiz beslenmedeki son artışların arkasındaki çatışma, iklim değişikliği ve aşırı iklim olayları, ekonomik yavaşlama ve küçülme, yüksek ve kalıcı eşitsizlik gibi yapısal faktörler ele alınmalıdır. Söz konusu ülkelerde gıda güvencesinin sağlanması gelir dağılımda adaletin sağlanmasına bağlıdır. Gelir eşitsizliğindeki azalma ile birlikte bu ülkelerin uluslararası ticaretten faydalanarak gıdaya erişimlerinin artması bu doğrultuda gıda güvencesinin sağlanması mümkün olacaktır. Gıda tüketimini (yani gıda bulunabilirliğini, erişimini, kullanımını ve istikrarını) garantilemek için ticaretin artırılması önemli bir araç olabilir. Ancak bu ülkelerin gelir eşitsizliğini azaltmak için kaynakların eşit dağılımının desteklenmesi zaruridir. Mali reformlar uygulanarak vergi sistemlerinin iyileştirilmesi kamu harcamaları yoluyla eşitsizliğin azaltılmasını sağlayabilir.

Araştırma ve Yayın Etiği Beyanı
Etik kurul izni ve/veya yasal/özel izin alınmasına gerek olmayan bu çalışmada araştırma ve yayın etiğine uyulmuştur.

Araştırmacıların Katkı Oranı Beyanı
Yazar, makalenin tamamına yalnız kendisinin katkı sağlamış olduğunu beyan eder.

Araştırmacıların Çıkar Çatışması Beyanı
Bu çalışmada herhangi bir potansiyel çıkar çatışması bulunmamaktadır.

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WHAT IS THE RELATIONSHIP BETWEEN INCOME INEQUALITY, FREE TRADE AND FOOD SECURITY? A PANEL CAUSALITY ANALYSIS FOR MIDDLE- AND LOW-INCOME COUNTRIES

EXTENDED SUMMARY

Purpose

This study aims to examine whether there is a causal relationship between income inequality, trade openness, and food security in low- and middle-income countries with a high prevalence of undernourishment during the period 2001-2021. The countries included in the sample group of the study are Armenia, Bangladesh, Bolivia, Central African Republic, Dominica, Honduras, India, Indonesia, Kenya, Korea, Kyrgyzstan, Mali, Moldova, Mozambique, Panama, Peru, Philippines, Thailand and Vietnam. The high prevalence of undernutrition and high income inequality were effective in the selection of countries. Another factor in the selection of these countries was the availability of data.

Literature

A few studies in the literature search have not found evidence that trade openness has a positive effect on food security. Many studies have concluded that trade openness or free trade has a positive effect on food security. However, a few studies have found that these positive effects occur after a certain level of trade openness. Some studies have addressed the relationship between agricultural trade and food security beyond general trade openness. While a few studies have concluded that the relationship between agricultural trade and food security is unclear, most of the studies have revealed positive effects. The number of studies addressing the relationship between income inequality and food security is quite limited. Therefore, the main purpose of this study is to investigate the relationship between income inequality, trade openness, and food security for low- and middle-income countries in the period covering the years 2001-2021, based on this gap in the literature. The contribution of this study to the literature can be addressed in several items: (i) The limited number of studies examining the impact of income inequality on food security and contributing to this field, (ii) Being the only study that brings together the three variables of income inequality, trade openness, and food security, (iii) Investigating the mutual causality relationship between income inequality, trade openness, and food security, (iv) Being one of the limited studies addressing the relationship between income inequality, trade openness, and food security for low and middle-income countries, this study will contribute to the literature.

Methodology

To represent the independent variable of the study, food security, FAO's PoU (Prevalence of Undernourishment) data was used as the Undernourishment (UH) variable, following Marson et al. (2023). Undernourishment prevalence data start from the period 2000-2002 (Marson et al. 2023: 307). For this reason, the data were included in the analysis starting from 2001. Again, following Marson et al. (2023), trade data was used as a percentage of GDP as the Trade Openness

indicator. The data for these variables were obtained from the World Development Indicators database. In the study, the Gini coefficient was used to measure income inequality, following Akinbode et al. (2022). Data on the Gini coefficient were obtained from the Standardized World Income Inequality Database (SWIID) (Solt, 2016). The data set was tried to be taken in the widest time period available, and in the light of the available data, the time period of the study was 2001-2021.

Since the sample in the study covers 19 countries, panel data analysis processes were followed. For this purpose, first, cross-section dependency test and stationarity tests were performed. Breusch-Pagan (1980) LM, Pesaran (2004) CDLM, Pesaran (2004) CD, and Pesaran and Yamagata (2008) LMAdj tests are frequently used tests in the literature to determine whether there is cross-section dependency between units. In this study, it was determined that there is cross-section dependency between units. Therefore, CIPS statistics, which take cross-section dependency into account, were used to investigate the stationarity status in the series. When the first differences in the variables were used, it was concluded that they were stationary. A causality analysis was conducted to determine the direction of the relationship between the dependent and independent variables. In this study, the causality test developed by Dumitrescu and Hurlin (2012) was used.

Findings

According to the results obtained from the causality test, the null hypothesis that there is no causality between the units is rejected, and the alternative hypothesis that there is causality is accepted. The findings indicate that trade openness affects food security at the 1 percent significance level. Income inequality affects the food security at the 1 percent significance level. Trade openness and income inequality are important factors causing food security.

Conclusion

The findings generally show that income inequality and trade openness are the causes of food security. Income inequality and international trade carried out over the period 2001-2021 for 19 middle and low-income country economies contribute positively or negatively to hunger and undernourishment in these countries and therefore to food security. The results show that policies to reduce income inequality and free trade should be implemented in a way that favors the poorest segments of society. Structural factors such as conflict, climate change and extreme climate events, economic slowdown and contraction, and high and persistent inequality behind the recent increases in hunger, food insecurity, and undernourishment should be addressed. Ensuring food security in these countries depends on ensuring justice in income distribution. With the decrease in income inequality, it will be possible to ensure food security in this direction by increasing the access of these countries to food by benefiting from international trade. Increasing trade can be an important tool to ensure food consumption (i.e. food availability, access, use, and stability). However, in order to reduce income inequality in these countries, it is essential to support equal distribution of resources. Improving tax systems by implementing fiscal reforms can reduce inequality through public expenditures.

Ekonomi, Politika & Finans Araştırmaları Dergisi, 2025, 10(1): 252-268
Journal of Research in Economics, Politics & Finance, 2025, 10(1): 252-268
Araştırma Makalesi / Research Article, https://doi.org/10.30784/epfad.1575919

YEŞİL İNOVASYON, TİCARET AÇIKLIĞI VE ÇEVRESEL BOZULMA: G-7 ÜLKELERİ ÜZERİNE BİR İNCELEME

Green Innovation, Trade Openness and Environmental Degradation: A Study on G-7 Countries

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Anahtar Kelimeler:
Yeşil İnovasyon,
Ticaret Açıklığı,
Çevresel Bozulma

JEL Kodları:
F18, O44, Q55

Öz

Çevresel bozulma; insan faaliyetleri ve doğal süreçler sonucunda doğal çevrenin bozulması, doğal kaynakların tükenmesi ve ekolojik dengenin bozulması anlamına gelmektedir. Bu durum da çevresel sürdürülebilirliği tehdit etmektedir. Çevresel zararı azaltan teknolojilerin ve uygulamaların geliştirilmesi ve uygulanmasını ifade eden yeşil inovasyon, küresel ölçekte çevresel sorunlar için etkin bir araç olarak değerlendirilmektedir. Gelişmiş ülkelerde çevresel bozulma ile mücadeleye daha fazla kaynak ayrılması durumunda yeşil inovasyon kavramı daha da önemli hale gelmektedir. Aynı zamanda, uluslararası ticaretin önündeki engellerin kaldırılması veya azaltılmasını ifade eden ticaret açıklığı ise büyümeyle birlikte verimlilik ve rekabet gücünü artırarak ekonomileri dönüştürmüştür. Ancak, ticaretin serbestleşmesinin çevresel etkisi, özellikle CO_2 emisyonlarıyla ilgili olarak, önemli bir tartışma konusudur. Bu bağlamda çalışmanın temel amacı, 1995-2020 dönemi için G-7 ülkelerinde yeşil inovasyon ve ticaret açıklığının çevresel bozulma üzerindeki etkisinin AMG (Augmented Mean Group) tahmincisiyle incelenmesidir. Elde edilen ampirik bulgular, yeşil inovasyonun ve ticaret açıklığının çevresel bozulma üzerinde negatif bir etkisinin olduğunu ortaya koymuştur.

Keywords:
Green Innovation,
Trade Openness,
Environmental Degradation

JEL Codes:
F18, O44, Q55

Abstract

Environmental degradation refers to the deterioration of the natural environment, depletion of natural resources, and disruption of ecological balance as a result of human activities and natural processes. This situation also threatens environmental sustainability. Green innovation, which refers to the development and implementation of technologies and practices that reduce environmental harm, is considered an effective tool for addressing global environmental challenges. As developed countries allocate more resources to combat environmental degradation, the concept of green innovation becomes even more important. At the same time, trade openness, which refers to the removal or reduction of barriers to international trade, has transformed economies by increasing productivity and competitiveness along with growth. However, the environmental impact of trade liberalization, particularly concerning CO_2 emissions, is a topic of significant debate. In this context, the main aim of this study is to examine the impact of green innovation and trade openness on environmental degradation in G-7 countries for the period 1995-2020 by using AMG (Augmented Mean Group) estimator. The empirical findings reveal that green innovation and trade openness have a negative effect on environmental degradation.

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Makale Geliş Tarihi (Received Date): 30.10.2024 Makale Kabul Tarihi (Accepted Date): 10.02.2025

1. Giriş

Çevresel bozulma, yüzyıllardır süregelen bir olgu olmakla birlikte, özellikle 18. yüzyıl sonlarında gerçekleşen Sanayi Devrimi ile ivme kazanmıştır. İnsan faaliyetleri uzun zamandır çevre üzerinde etkili olsa da bozulmanın boyutu ve şiddeti son yüzyıllarda belirgin şekilde artmıştır. Doğal kaynakların tükenmesi, çölleşme, kuraklık, arazi bozulması, tatlı su kaynaklarının azalması ve biyolojik çeşitliliğin kaybı gibi çevresel sorunlar, insanlığın karşılaştığı zorlukları derinleştirmekte ve durumun kötüleşmesine yol açmaktadır (UN, 2015).

Çevresel bozulma, doğal kaynakların tükenmesi, biyoçeşitliliğin kaybı ve ekosistemlerin kötüleşmesiyle ele alınan çağımızın en acil çözüm bekleyen sorunlarından birisidir. Bu bağlamda, çevresel sorunların azaltılmasına yönelik politikaların belirlenmesi, uygulanması ve sürekliliği küresel bir gereklilik olarak dikkat çekmektedir. Dolayısıyla, sürdürülebilirliği teşvik etmek ve çevresel sorunları hafifletmek için son teknolojilerin geliştirilmesi ve kaynak verimliliğinin artırılması öncelikli hale gelmiştir (Shan ve Shao, 2024). Bu bakış açısı doğrultusunda, çevresel bozulmayı etkileyen faktörlerin neler olduğunun belirlenmesi küresel eylem planlarının oluşturulması açısından kritik bir rol üstlenmektedir. Çevresel bozulmayı ele alan teorik çalışmalar kadar çevresel bozulmayı etkileyen faktörlere yönelik ampirik çalışmaların sayısı da giderek artmaktadır.

Küresel düzeyde çevre sorunları ile mücadele edilirken yeşil ekonomi, sürdürülebilir kalkınmayı teşvik eden dönüştürücü bir yaklaşım olarak ortaya çıkmıştır. Bir başka deyişle yeşil ekonomi, kalkınma ve büyüme konusunda düşünce yapısındaki değişimi ifade etmektedir. Bu yaklaşım, insanların yaşamlarını ve çevreyi iyileştirirken çevresel ve ekonomik sürdürülebilirliği de teşvik etmektedir (Zhang vd., 2022). Yeşil inovasyon, teknolojik öncülük yaparak sürdürülebilirliği artırmakta, kaynak kullanımını optimize etmekte ve çevresel kirliliği azaltmaktadır. Ayrıca, işletme düzeyinde sanayi yapısının iyileştirilmesini ve kaynak tahsisinin optimizasyonunu destekleyerek, genel operasyonel gelişim için kritik bir rol oynamaktadır (Shan ve Shao, 2024).

Ticari açıklık, bu paradigmada önemli bir rol oynamaktadır. Çevre dostu teknolojilerin ve sürdürülebilir uygulamaların sınırlar arasında değişimini kolaylaştırmaktadır. 1980'li yıllardan itibaren birçok ülke dışa açık ekonomi politikaları uygulamaya başlamıştır. 1990'lı yıllarla birlikte, ticaretin hızla artan açıklığı ve giderek kötüleşen çevre sorunlarıyla birlikte, ticari açıklığın CO_2 emisyonlarındaki rolünü araştıran ve gittikçe genişleyen bir literatür ortaya çıkmıştır. Ayrıca, son yıllarda gözlemlenen hızlı ekonomik büyüme, dünya genelinde yaşam kalitesini önemli ölçüde artırmakla birlikte, bazı maliyetler olmadan gerçekleşmemiştir. Ekonomik gelişimin ana motorları olarak yenilenemeyen kaynaklara olan bağımlılık, bu kaynakların tükenme riskiyle birlikte CO_2 emisyonlarının birikmesi yoluyla iklim değişikliğini de artırmıştır. Dolayısıyla, ekonomik büyümenin çevresel etkilerini ele almak, dünya genelinde politika yapıcılar ve paydaşlar için öncelikli bir endişe haline gelmiştir (Liu ve Kang, 2024).

Çevresel bozulmanın etkileri daha belirgin hale geldikçe, bu krizin temel nedenlerini ele almak için küresel iş birliğine acil ihtiyaç duyulmaktadır. Çevre üzerindeki insan baskılarını azaltmaya yönelik sürdürülebilir kalkınma stratejileri, koruma çabaları ve politika reformları, bu eğilimi tersine çevirmek için kritik öneme sahiptir. Bu bağlamda, küresel olarak ortak eylem planları uygulanmaya başlanmıştır. Bunlardan biri 1997 yılında kabul edilen ve 2005 yılında yürürlüğe giren Kyoto Protokolü'dür. Kyoto Protokolü, Sanayi Ülkeleri ve geçiş ekonomilerini, belirlenen bireysel hedeflere uygun olarak sera gazı emisyonlarını sınırlama ve azaltma

taahhütleriyle Birleşmiş Milletler İklim Değişikliği Çerçeve Sözleşmesi'ni uygulamaya geçirmektedir (UNFCCC, 2020). Gelişmiş ülkelerin, 150 yılı aşkın sanayi faaliyetinin sonucunda atmosferdeki mevcut yüksek sera gazı emisyon seviyelerinin başlıca sorumlusu olduğunu kabul eden Protokol, "ortak ama farklılaştırılmış sorumluluklar" ilkesi gereği, gelişmiş ülkelere daha fazla yükümlülük getirmektedir (Poulopoulos, 2016).

İklim değişikliği, küresel ısınma ve çevre kirliliği, insanlığın karşı karşıya olduğu önemli zorluklardandır. Bu sorunların özellikle G-7 ülkeleri gibi gelişmiş ülkelerde daha çok hissedilmesi, bu ülkelerin sanayi ve ticaret alanlarında öncü konumlarından kaynaklanmaktadır. G-7 ülkelerinin tarihsel olarak sera gazı emisyonlarındaki yüksek payı, çevresel sorunlarla başa çıkma konusundaki sorumluluklarını artırmaktadır. ABD hariç G-7 ülkeleri, Kyoto Protokolü'ne taraftır. Ayrıca, 2015 yılında imzalanan Paris İklim Anlaşması sonrasında, G-7 ülkeleri çevresel sürdürülebilirliği desteklemek ve yeşil, düşük karbonlu bir toplum oluşturmak için önemli adımlar atmışlardır. Ancak, bu çabalara rağmen, CO_2 emisyonlarını azaltma konusunda henüz tam anlamıyla başarılı olamamışlardır (Li ve Haneklaus, 2022). Bu girişimlere rağmen bu ülkelerde ekonomik gelişimin beraberinde getirdiği çevresel maliyetler yeterince incelenmemiştir. İlgili literatürde, yeşil yenilik ve ticaret açıklığının çevresel bozulma üzerindeki etkisini ele alan çalışma sayısı nispi olarak daha azdır (bkz. Shahbaz vd., 2017; Li ve Haneklaus, 2022; Olanrewaju vd., 2022; Sharif vd., 2022; You vd., 2022; Adebayo ve Ozkan, 2024; Jahanger vd., 2024). Bu çalışmalardan You vd. (2022) ve Olanrewaju vd. (2022) çalışmaları yeşil inovasyon ve ticaret açıklığının çevresel bozulma üzerindeki etkisini birlikte ele almıştır. Diğer çalışmalarda sadece yeşil inovasyonun çevresel bozulma üzerindeki etkisi ya da ticaret açıklığının çevresel bozulma üzerindeki etkisi incelenmiştir. Bu çalışmalardan yeşil inovasyon ve ticari açıklığın eş zamanlı etkilerine odaklanan bilgimiz dahilindeki tek çalışma Olanrewaju vd. (2022) tarafından hazırlanmıştır. Mevcut çalışma, bu çalışmadan yöntem açısından farklılaşmaktadır. Bu bağlamda çalışmanın amacı, dünyanın en gelişmiş ve sanayileşmiş ilk on ülkesi arasında yer alan G-7 ülkelerinde, yeşil inovasyon ve ticaret açıklığının çevresel bozulma üzerindeki etkisinin 1995-2020 dönemi için incelenmesidir. Bu çalışma, literatüre iki önemli katkı sağlamayı hedeflemektedir. İlk olarak, G-7 ülkelerinde yeşil inovasyonun ve ticaret açıklığının çevresel bozulmayı hafifletme potansiyelini ampirik olarak ortaya koymaktadır. İkinci olarak 1995-2020 dönemine odaklanarak, yeşil inovasyon ve ticaret açıklığının çevresel etkilerine dair güncel ve kapsamlı bir bakış sunmaktadır. Bu bağlamda, elde edilen bulguların, çevre politikalarının tasarımında ve sürdürülebilir kalkınma stratejilerinin oluşturulmasında rehberlik etmesi beklenmektedir.

2. Teorik Çerçeve

Yeşil inovasyon ve ticaret açıklığının çevresel bozulma üzerindeki etkileri ampirik olarak kanıtlanmıştır ve bu faktörlerin çevresel bozulmayı çeşitli mekanizmalar aracılığıyla etkilediği görülmektedir. Yeşil inovasyon, teknolojik öncülük yaparak sürdürülebilirliği artırmakta, kaynak kullanımını optimize etmekte ve çevresel bozulmayı azaltmaktadır. Ayrıca, firma düzeyinde endüstriyel yapıların iyileştirilmesi ve kaynak tahsisinin optimize edilmesine katkıda bulunmaktadır. Bu durum da hem firma düzeyinde hem de makro düzeyde çevresel iyileşme için kritik bir öneme sahiptir. Yeşil yeniliğin karbon emisyonları üzerindeki etkisi özellikle çevresel kirliliğe neden olan sanayilerde önemli bir düzeydedir. Dolayısıyla düşük karbonlu ürünlerin ve yeşil teknolojilerin benimsenmesi emisyonları azaltabilmektedir (Shan ve Shao, 2024). İnovasyon

teorisi, firmaların çevresel düzenleme yoğunluğunun etkisiyle çevre dostu teknolojik yeniliklere daha fazla yatırım yapma eğiliminde olduğunu öne sürmektedir. Çevre politika ve düzenlemeleri güçlendiğinde, şirketlerin karbon azaltımı ve çevresel etkiyi azaltma maliyetleri artmaktadır. Sonuç olarak şirketler, yenilik yoluyla karbon emisyonlarını azaltmak için daha optimal ve maliyet etkin yöntemler benimsemeye yönelmektedir (Li vd., 2023).

Ticaretin çevre üzerindeki etkisi karmaşık bir dinamiğe sahiptir. Ticaret hacmindeki artışın neden olduğu ekonomik büyüme (ölçek etkisi) sonucunda çevre kalitesi düşebilir. Bir başka deyişle, başta ihracat olmak üzere ticaret hacminin artmasıyla ekonominin büyüklüğü artırmaktadır. Dolayısıyla çevre kalitesi kirliliği artıran ölçek etkisi yoluyla düşebilmektedir. Ancak ticaret, çevresel kaliteyi teknik etki ve/veya kompozisyon etkisi aracılığıyla artırabilir. Teknik etki, ticaretin artmasıyla birlikte gelir düzeyinin yükselmesi ve buna bağlı olarak çevre düzenlemelerinin ve denetimlerinin sıkılaşmasını ifade etmektedir. Kompozisyon etkisi ise bir ülkenin üretim yapısındaki değişikliklerden kaynaklanmaktadır. Bir ülkede kirlilik yoğun malların üretimi, uluslararası ticaret yoluyla bir ülkedeki çevresel kirliliğin azalmasına neden olurken, başka ülkelerde kirliliği artırmasına yol açabilir. Kompozisyon etkisi, yer değiştirme hipotezi ve kirlilik cenneti hipotezine dayandırılmaktadır (Liddle, 2001; Dinda, 2004; Pham ve Nguyen, 2024). Kirlilik cenneti hipotezi, özellikle yüksek kirlilik yaratan sektörlerde faaliyet gösteren çok uluslu şirketlerin, çevre standartlarının zayıf olduğu ülkelere taşındığını öne sürmektedir. Diğer bir ifadeyle, çevresel düzenlemelerin zayıf olduğu ülkelerin kirlilik yoğun üretim yapan firmalar için daha cazip hale gelmesidir (Smarzynska ve Wei, 2001). Yer değiştirme hipotezi, ticaretin serbestleşmesinin, gelişmiş ülkelerdeki sıkı çevre düzenlemeleri nedeniyle kirlilik yoğun endüstrilerin gelişmekte olan ülkelerde daha hızlı büyümesine yol açacağını öngörmektedir (Liddle, 2001).

3. Literatür İncelemesi

Literatürde ticaret açıklığının ve yeşil inovasyonun çevresel bozulma üzerindeki etkilerini inceleyen pek çok çalışma bulunmaktadır. Söz konusu bu çalışmalar; kullanılan yöntem, incelenen dönem, incelenen ülke grubu ve literatüre katkıları bakımından ayrışmaktadır. Ticaret açıklığı ile çevresel bozulma arasındaki literatür incelendiğinde bir konsensüsün olmadığı, bazı çalışmalarda ticaret açıklığının çevresel bozulmayı artırdığı bazı çalışmalarda ise azalttığı görülmektedir. Yeşil inovasyon ile çevresel bozulma arasındaki literatürde ise genellikle yeşil inovasyonun karbondioksit emisyonunu azalttığı görülmektedir. Literatür incelemesi başlığında ilk olarak çevresel bozulma ile ticaret açıklığı ilişkisi, ikinci olarak yeşil inovasyon ile çevresel bozulma ilişkisi, son olarak da ticaret açıklığının ve yeşil inovasyonun çevresel bozulma üzerindeki etkileri incelenmiştir.

Ticaret açıklığının çevresel bozulma üzerindeki etkisine ilişkin ampirik literatürde bir görüş birliği bulunmamaktadır. Bu çalışmalardan bir kısmında ticaret açıklığının çevresel bozulmayı artırdığı bulgusuna erişilmiştir. Farhani ve Öztürk (2015) 1971-2012 yılları arasında Tunus için CO_2 emisyonu ile ticaret açıklığı ilişkisini ARDL yöntemiyle incelemişlerdir. Ticaret açıklığındaki %1'lik artışın karbon emisyonunu %0,418 oranında artırdığı sonucuna ulaşmışlardır. Li ve Haneklaus (2022) 1979-2019 yılları arasında G-7 ülkeleri için CO_2 emisyonu ile ticaret açıklığı ilişkisini ARDL yöntemiyle incelemişlerdir. Uzun dönemde ticaret açıklığındaki %1'lik artışın CO_2 emisyonlarını %0,27 oranında artırdığı sonucuna ulaşmışlardır. Suhrab vd. (2023) 1985-2018 yılları arasında Pakistan için kentleşme ve ticaret açıklığının CO_2

emisyonları üzerindeki etkilerini sabit etkiler yöntemiyle incelemişlerdir. Kentleşme ve ticaret açıklığın CO_2 emisyonunu artırdığı sonucuna ulaşmışlardır. Lv ve Xu (2019) 1992-2012 yılları arasında orta gelirli 55 ülke için CO_2 emisyonu ile ticaret açıklığı ilişkisini PMG yöntemiyle incelemişlerdir. Ticaret açıklığının kısa dönemde CO_2 emisyonlarını azalttığı fakat uzun dönemde CO_2 emisyonlarını artırdığı sonucuna ulaşmışlardır.

İlgili literatürdeki çalışmaların bir kısmı ise ticaret açıklığının çevresel bozulmayı azalttığı bulgusunu elde etmiştir. Ali vd. (2016) 1971-2011 yılları arasında Nijerya için CO_2 emisyonu ile ticaret açıklığı ilişkisini ARDL yöntemiyle incelemişlerdir. Ticaret açıklığındaki %1'lik artışın CO_2 emisyonlarını %0,3 oranında azalttığı sonucuna ulaşmışlardır. Zhang vd. (2017) 1971-2013 yılları arasında NICS-10 ülkeleri için CO_2 emisyonu ile ticaret açıklığı ilişkisini FMOLS yöntemiyle incelemişlerdir. Ticaret açıklığındaki %1'lik artışın CO_2 emisyonlarını %0,20 azalttığı sonucuna ulaşmışlardır. Zafar vd. (2019) 1990-2015 yılları arasında 18 gelişmekte olan ülke için CO_2 emisyonu ile ticaret açıklığı ilişkisini CUP-FM yöntemiyle incelemişlerdir. Ticaret açıklığındaki %1'lik artışın CO_2 emisyonlarını %0,064 oranında azalttığı sonucuna ulaşmışlardır. Shahbaz vd. (2017) ise 1980-2014 yılları arasında 105 yüksek, orta ve düşük gelirli ülke için CO_2 emisyonları ile ticaret açıklığı ilişkisini FMOLS yöntemiyle incelemişlerdir. Gerek toplam panel düzeyinde gerekse de yüksek, orta ve düşük gelirli ülkelerde CO_2 emisyonu ile ticaret açıklığı arasında ters U şeklinde bir ilişki olduğu sonucuna ulaşmışlardır.

Yeşil inovasyon ve çevresel bozulma arasındaki ilişkiyi inceleyen çalışmaların büyük bir kısmında, yeşil inovasyonun çevresel bozulmayı azalttığı bulgusuna erişilmiştir. Meirun vd. (2021) 1990-2018 yılları arasında Singapur için yeşil teknolojik inovasyon ve CO_2 emisyonu ilişkisini BARDL yöntemiyle incelemişlerdir. Yeşil teknolojik inovasyon ile CO_2 emisyonları arasında negatif bir ilişki olduğu sonucuna ulaşmışlardır. Sharif vd. (2022) 1995-2019 yılları arasında G-7 ülkeleri için yeşil teknolojik inovasyon ile CO_2 emisyonları arasındaki ilişkiyi CS-ARDL yöntemiyle incelemişlerdir. Yeşil teknolojik inovasyon ile CO_2 emisyonu arasında negatif ilişki olduğu sonucuna ulaşmışlardır. Ma vd. (2023) 1995-2021 yılları arasında BRICST ülkeleri için yeşil inovasyonun çevresel bozulma üzerindeki etkilerini Driscoll Kray, FMOLS, DOLS ve momentler yöntemiyle incelemişlerdir. Dört farklı yöntemde de yeşil inovasyonla çevresel bozulma arasında negatif bir ilişki olduğu sonucuna ulaşmışlardır. Geng vd. (2023) 1992-2021 yılları arasında BRICS ülkeleri için yeşil inovasyonun çevresel bozulma üzerindeki etkilerini AMG yöntemiyle incelemişlerdir. Yeşil inovasyondaki %1'lik artışın çevresel bozulmayı %0,042 azalttığı sonucuna ulaşmışlardır. Adebayo ve Ozkan (2024) 1985-2020 yılları arasında ABD'de eko-inovasyonun çevresel bozulma üzerindeki etkilerini Wavelet Quantile Regression yöntemiyle incelemişlerdir. Tüm kantil ve dönemlerde eko-inovasyon ile çevresel bozulma arasında negatif bir ilişki olduğu sonucuna ulaşmışlardır. Jahanger vd. (2024) 1994-2020 yılları arasında G-7 ülkelerinde yeşil inovasyonun ekolojik ayak izi üzerindeki etkilerini Quantile Regression, FMOLS ve Driscoll Kraay yöntemiyle incelemişlerdir. FMOLS yöntemine göre yeşil inovasyondaki %1'lik artış çevresel bozulmayı %0,5303 oranında, Driscoll Kraay yöntemine göre yeşil inovasyondaki %1'lik artış çevresel bozulmayı%0,518 oranında azaltmıştır. Ayrıca Quantile Regression yöntemine göre de tüm kantillerde yeşil inovasyonla çevresel bozulma arasında negatif bir ilişki olduğu sonucuna ulaşmışlardır. Ampirik literatürde yeşil inovasyonun çevresel bozulma üzerinde azaltıcı etkisi olduğu yaygın görüşünün aksine farklı bulgular elde eden çalışmalar da bulunmaktadır. Albaker vd. (2023) 1990-2021 yılları arasında MENA ülkeleri için yeşil inovasyon ile CO_2 arasında ilişkiyi Driscoll-Kraay yöntemiyle incelemişlerdir. Yeşil inovasyonun CO_2 emisyonunu artırdığı sonucuna ulaşmışlardır. Chen vd. (2023) 2007-2019

yılları arasında Çin'in 30 ilinde yeşil teknolojik inovasyonun CO_2 emisyonu üzerindeki etkilerini SDM yöntemiyle incelemişlerdir. Yeşil teknolojik inovasyonla CO_2 emisyonu arasında ters U ilişkisinin olduğu sonucuna ulaşmışlardır.

İlgili literatürde yeşil inovasyonun ve ticaret açıklığının çevresel bozulma üzerindeki etkisini birlikte alan çalışmalar da bulunmaktadır. Bu çalışmalar genellikle gelişmekte olan ülke örnekleminde ele alınmıştır. You vd. (2022) 1990-2018 yılları arasında ABD için çevreyle ilgili teknoloji geliştirmede uluslararası iş birliklerinin CO_2 emisyonları üzerine etkilerini FMOLS ve DOLS yöntemleriyle incelemişlerdir. Çevresel inovasyonun CO_2 emisyonlarını azalttığı ancak ticari açıklığın CO_2 emisyonlarını artırdığı sonucuna ulaşmışlardır. Wen vd. (2022) 1990-2014 yılları arasında gelişmekte olan 5 Güney Asya ülkesi için yeşil inovasyon, ticaret açıklığı ve çevre kalitesi ilişkisini FMOLS ve DOLS yöntemiyle incelemişlerdir. Yeşil inovasyon ve ticaret açıklığının CO_2 emisyonunu negatif etkilediği sonucuna ulaşmışlardır. Meng vd. (2022) 1995-2020 yılları arasında BRICST ülkelerinde yeşil inovasyon ve ticaret çeşitlendirmesinin CO_2 emisyonları üzerindeki etkisini CS-ARDL yöntemiyle incelemişlerdir. Yeşil inovasyon ve ticaret çeşitlendirmesi ile CO_2 emisyonları arasında negatif bir ilişki olduğu sonucuna ulaşmışlardır. Olanrewaju vd. (2022) 1990-2019 yılları arasında G-7 ülkeleri için eko-inovasyon ve ticaret açıklığının CO_2 emisyonları üzerindeki etkilerini FMOLS ve DOLS yöntemleriyle incelemişlerdir. Eko-inovasyon ile CO_2 arasında negatif, ticaret açıklığı ile CO_2 emisyonları arasında ise pozitif bir ilişki olduğu sonucuna ulaşmışlardır. Obobisa (2023) 1990-2019 yılları arasında 27 OECD ülkesi için eko-inovasyon, ticaret açıklığı ve CO_2 emisyonları arasındaki ilişkiyi CS-ARDL yöntemiyle incelemiştir. Eko-inovasyon ile CO_2 emisyonları arasında negatif ve istatistikî olarak anlamlı, ticaret açıklığı ile CO_2 emisyonları arasında ise pozitif ve istatistikî olarak anlamsız bir ilişki olduğu sonucuna ulaşmıştır. Chien vd. (2023) 2006-2020 yılları arasında ASEAN ülkelerinde eko-inovasyon, ticaret açıklığı ve sera gazı (CO_2) ilişkisini CS-ARDL yöntemiyle incelemişlerdir. Eko-inovasyon ile ticaret açıklığının sera gazlarıyla negatif ilişkili olduğu sonucuna ulaşmışlardır. Ozkan vd. (2023) 1990-2018 yılları arasında Çin'de yeşil inovasyonun ve ticaret açıklığının çevresel bozulma üzerindeki etkilerini DARDLS yöntemiyle incelemişlerdir. Yeşil teknolojik inovasyon uzun dönemde çevresel bozulmayı azaltırken, ticaret açıklığının hem kısa hem de uzun dönemde çevresel bozulmayı artırdığı sonucuna ulaşmışlardır. Radmehr vd. (2024) 1995-2018 yılları arasında seçilmiş 20 AB ülkesi için yeşil teknoloji inovasyonunun ve ticaret açıklığının ekolojik sürdürülebilirlik üzerindeki etkilerini SAR, SEM ve SEC yöntemleriyle incelemişlerdir. Her üç yöntem içinde yeşil teknoloji inovasyonu ekolojik bozulmayı azaltırken, ticaret açıklığının ise ekolojik bozulmayı artırdığı sonucuna ulaşmışlardır.

Ampirik literatür incelendiğinde yeşil inovasyonun ve ticaret açıklığının çevresel bozulma üzerindeki etkisini ele alan çalışma sayısı nispi olarak azdır. Mevcut çalışmaların ise daha çok gelişmekte olan ülkeler örnekleminde ele alındığı dikkat çekmektedir. Bu çalışmalardan yeşil inovasyon ve ticari açıklığın çevresel bozulma üzerindeki eş zamanlı etkisini G-7 ülkeleri örnekleminde ele alan sadece Olanrewaju vd. (2022) bulunmaktadır. Olanrewaju vd. (2022), yatay kesit bağımlılığı ve heterojenlik problemlerini dikkate almayan bir analiz tekniğiyle konuyu ele almıştır. Pesaran (2006), panel veri çalışmalarında yatay kesit bağımlılığının test edilmesinin önemine vurgu yapmış ve bu bağımlılığın göz ardı edilmesinin tutarsız sonuçlar üretebileceğini belirtmiştir. Ayrıca, eğim parametrelerinin panel birimleri arasında değişmesine izin verilmeyen homojen panel tahmin tekniklerini kullanan önceki çalışmalardan farklı olarak, bu çalışma heterojen panel zaman serileri tekniğini kullanmaktadır. Bu haliyle mevcut çalışma literatüre yöntemsel bir farklılık getirmeyi hedeflemektedir.

4. Model ve Veri Seti

Bu çalışmanın amacı, 1995-2020 yılları arasında yeşil inovasyon ve ticaret açıklığın CO_2 emisyonları üzerindeki etkilerinin incelenmesidir. Çalışmada karşılaşılan temel kısıt analiz dönemi ile ilgilidir. Verilerin temininde yaşanan problem nedeniyle analiz dönemi 1995-2020 olarak sınırlanmıştır. Çalışmada literatürle uyumlu olarak bağımlı çevresel bozulma (CO_2) yeşil inovasyonun (inv), ticaret açıklığının (to), ekonomik büyümenin (y) ve kentleşmenin (urb) bir fonksiyonu olarak tanımlanmıştır (bkz. Liu vd., 2021; Meng vd.; 2022; You vd., 2022; Wen vd., 2022; Acheampong ve Opoku, 2023; Chien vd., 2023; Obobisa, 2023; Ozkan vd., 2023; Liu vd., 2024; Radmehr vd., 2024; Singh vd., 2024). Çevresel bozulma fonksiyonu Denklem 1'de, Denklem 1'deki fonksiyonun panel veri formatında cebirsel gösterimi ise Denklem 2'de gösterilmiştir:

$$CO_2 = f(inv, to, y, urb) \quad (1)$$

$$lnCO_{2it} = \beta_1 inv_{it} + \beta_2 to_{it} + \beta_3 lny_{it} + \beta_4 urb_{it} + \varepsilon_{it} \quad (2)$$

Tablo 1. Değişkenlere İlişkin Bilgiler

Değişken	Açıklama	Kaynak
Çevresel Bozulma (CO_2)	CO_2 emisyonu (kt)	World Bank
Yeşil İnovasyon (inv)	Yeşil inovasyon (Çevreyle ilgili teknolojiler %)	OECD Stat
Ticaret Açıklığı (to)	Ticaret Açıklığı (ihracat+ ithalat) / GSYH	World Bank
Kentleşme (urb)	Kentleşme (Şehir nüfusu %)	World Bank
Ekonomik Büyüme (y)	Reel GSYH (2015 sabit Amerikan Doları fiyatlarıyla)	World Bank

Tablo 1'de çalışmada kullanılan değişkenlere ilişkin açıklamalar ve veri kaynakları gösterilmiştir. Tablo 2'de değişkenlere ilişkin tanımlayıcı istatistik değerleri yer almaktadır. Tablo 2'ye göre toplam gözlem sayısı 182 olup en yüksek ortalama ve minimum değer kentleşme değişkenine, en yüksek standart sapma ve maksimum değer ticaret açıklığı değişkenine ve en düşük ortalama ve minimum değer yeşil inovasyon değişkenine aittir.

Tablo 2. Tanımlayıcı İstatistikler

Değişken	Gözlem	Ortalama	Standart sapma	Minimum	Maksimum
$lnCO_2$	182	13.55802	0.8844454	12.49558	15.56919
inv	182	10.31533	2.854438	5.13	16.23
to	182	48.57902	17.39826	17.50571	92.59323
lny	182	28.76626	0.7519879	27.5851	30.63356
urb	182	78.55945	5.669972	66.922	91.782

5. Metodoloji ve Bulgular

5.1. Yatay Kesit Bağımlılığı

Yatay kesit bağımlılığı testi, yapılacak analizlerin tutarlılığı açısından büyük önem arz etmektedir. Öyle ki serilerde yatay kesit bağımlılığının olup olmamasına göre birim kök analizleri farklılık göstermektedir. Çalışmamızda zaman boyutu yatay kesit boyutundan büyük olduğu için Breusch-Pagan (1980) LM Testi kullanılmıştır. Yatay kesit bağımlılığının test edilmesi için kurulan hipotezler şu şekildedir:

H_0: Yatay kesit bağımlılığı yoktur

H_1: Yatay kesit bağımlılığı vardır

Breusch-Pagan (1980) LM Testine ilişkin analiz sonuçları Tablo 3'de gösterilmiştir. Tablo 3'e göre beş değişken için de H_0 temel hipotezi %1 anlamlılık düzeyinde reddedilmiş olup serilerde yatay kesit bağımlılığının olduğu sonucuna ulaşılmıştır.

Tablo 3. Yatay Kesit Bağımlılığı Sonuçları

Breusch-Pagan LM Testi	
$\ln CO_2$	274.718***
to	435.014***
inv	483.111***
lny	424.934***
urb	485.901***

Not: *** %1 anlamlılık düzeyini göstermektedir.

5.2. Birim Kök Testi

Durağan olmayan veriler kullanıldığında regresyon analizinin tutarsız olacağı ve sahte regresyon sorunu ortaya çıkabileceği için sistemdeki değişkenlerin durağanlığının test edilmesi gerekmektedir (Topcu ve Aras, 2017). Yatay kesit bağımlılığının tespit edilmesi nedeniyle bu sınama ikinci nesil birim kök testlerinin kullanılması ile gerçekleştirilmelidir. Tablo 4'de CADF birim kök analiz sonuçları yer almaktadır.

Tablo 4. CADF Birim Kök Testi Sonuçları

Değişkenler	**CADF**
$\ln CO_2$	-2.954**
to	-1.649
$\Delta$to	-3.809***
inv	-2.824*
lny	-2.586
Δlny	-3.443***
urb	-3.564***

Not: *Gecikme uzunluğu 1 olarak belirlenmiştir

** Δ simgesi değişkenlerin birinci farkını göstermektedir

***, **, * sırasıyla %1, %5 ve %10 anlamlılık düzeylerini temsil etmektedir.

Tablo 4'te CADF birim kök testine ilişkin sabitli trendli sonuçlar gösterilmiştir. Bu sonuçlara göre kentleşme, CO_2 ve yeşil inovasyon değişkenlerinin sırasıyla %1, %5 ve %10 anlamlılık düzeyinde durağan oldukları görülmektedir. Ticaret açıklığı ve GSYH değişkenleri ise birinci farklarında ve %1 anlamlılık seviyesinde durağandırlar.

5.3. AMG Testi

Uzun dönem katsayılarının tahmin edilmesi için Eberhardt ve Bond (2009), Eberhardt ve Teal (2010) ve Bond ve Eberhardt (2013) tarafından geliştirilen Genişletilmiş Ortalama Grup (AMG-Augmented Mean Group Estimator) yöntemi kullanılmıştır. AMG yönteminin en önemli özelliği, heterojenliği ve yatay kesit bağımlılığını dikkate almasıdır. Verilerin özellikleri dikkate

alındığında, AMG yönteminin alternatiflerine kıyasla araştırma sorusunu cevaplamakta güçlü ampirik sonuçlar üreteceği düşünülmektedir. Tablo 5'de AMG tahmin sonuçları gösterilmiştir.

Tablo 5. AMG Testi Sonuçları

Değişkenler	AMG
to	-0.0052**
inv	-0.0144**
lny	0.551***
urb	-0.0605*

Not: ***, **, * sırasıyla %1, %5 ve %10 anlamlılık düzeylerini temsil etmektedir.

Tablo 5'e göre ticaret açıklığı, yeşil inovasyon ve kentleşme, CO_2 emisyonu üzerinde negatif bir etkiye sahipken, GSYH ise CO_2 pozitif etkilemektedir. Ticaret açıklığı, yeşil inovasyon ve kentleşmedeki 1 birimlik artış CO_2 emisyonlarını sırasıyla %0,52, %1,44 ve %6,05 oranında azaltmaktadır. Bunun yanında, GSYH'deki %1'lik artış ise CO_2 emisyonlarını %0,551 oranında artırmaktadır.

6. Bulguların Değerlendirmesi ve Politika Çıkarımları

Yeşil inovasyon ve çevresel bozulma arasında negatif yönlü bir ilişki tespit edilmiştir. Bu bulgu, yeşil inovasyonun, sürdürülebilirliği artırarak kaynak kullanımını optimize etmesi ve çevresel bozulmayı azaltması ile açıklanabilir (Shan ve Shao, 2024).

Ticaret açıklığı ile çevresel bozulma arasında negatif yönlü bir ilişki tespit edilmiştir. Bu bulgu, ticaretin çevresel bozulma üzerindeki teknik ve kompozisyon etkileri aracılığıyla açıklanabilir. Kompozisyon etkisine göre, özellikle, çevre düzenlemeleri nispeten zayıf olan yoksul ülkeler kirli malların üretiminde uzmanlaşırken, çevre politikaları sıkı olan zengin ülkeler temiz malların üretiminde uzmanlaşmaktadır (Le vd., 2016). Teknik etkiye göre ise, ticaretin artırdığı gelirle birlikte, kirlilik politikaları sıkılaştırılır ve bu da kirliliği azaltan yenilikleri/yatırımları teşvik eder (Liddle, 2001). Bu perspektiften ele alındığında, gelişmiş ülke örneklemlerimden oluşan G-7 ülkelerinde ticaret açıklığının çevresel bozulmayı iyileştirmesi teorik olarak tutarlıdır.

Ekonomik büyüme ve çevresel bozulma arasında pozitif yönlü bir ilişki olduğu bulgusuna erişilmiştir. Bu bulgu, ekonomik büyümenin çevre üzerindeki ölçek etkisi aracılığıyla açıklanabilir. Ekonominin yapısında veya teknolojisinde bir değişiklik olmadığı durumda, ekonominin ölçeğindeki saf büyüme, kirlilik ve diğer çevresel etkilerde artışa yol açmaktadır. Buna ölçek etkisi denilmektedir. Ekonomik kalkınma ile çevresel kalite arasında çelişen hedefler olduğu yönündeki geleneksel görüş, yalnızca ölçek etkisini yansıtmaktadır. (Stern, 2004; Acheampong ve Opoku, 2023). Bu etki, ekonomik faaliyetler arttıkça, üretim ve tüketime dayalı süreçlerin büyümesinin doğal kaynakları daha fazla tüketmesine, atıkların ve kirletici gazların daha fazla üretilmesine yol açabileceğini ifade etmektedir. Çevresel kaynaklar, üretim sürecinde önemli bir girdi olarak hizmet etmektedir. Bu nedenle, ekonomik büyümeyi artırmak, bu çevresel kaynakların yoğun bir şekilde tüketilmesini gerektirmektedir. Ayrıca üretim süreci sırasında çevreyi bozan atıklar ve sera gazı emisyonları gibi birçok yan ürün üretilmektedir (Acheampong ve Opoku, 2023).

Kentleşme ve çevresel bozulma arasında negatif yönlü bir ilişki tespit edilmiştir. Bu bulgu çeşitli kanallar aracılığıyla açıklanabilir. Kentleşme, genellikle kırsal nüfusun şehirlere ve kasabalara göç etmesi ve buralarda yoğunlaşması şeklinde gerçekleşmektedir. Yüksek nüfus yoğunluğuna sahip şehirler, kamu altyapısının sağlanmasında ölçek ekonomileri yaratmaktadır. Bu durum da enerji tüketimini ve kirlilik emisyonlarını azaltabilir. Nüfusun mekânsal yoğunlaşması, bilgi, teknoloji ve yeniliklerin paylaşımını artırarak sosyal ilişkileri güçlendirmektedir. Bu durum, işletmelerin ekolojik yenilik yapma verimliliğini yükseltmektedir. Ayrıca kentleşme, yeşil teknolojilerin geliştirilmesi ve uygulanması yoluyla çevre kirliliği kontrolünde aktif bir katkı sağlamaktadır. Teknolojik yeniliklerin yayılma etkisi, yerel işletmeler ve çevredeki işletmeler için çevre kirliliğini önleme maliyetini azaltabilmekte ve böylece kirlilik emisyonlarını düşürebilmektedir (Liao vd., 2021; Shen vd., 2022; Zhang ve Cai, 2022).

Elde edilen bulgular doğrultusunda G-7 ülkelerinde çevresel bozulmanın iyileştirilmesi için politika çıkarımları olarak yeşil inovasyon girişimleri önceliklendirilmelidir. Ayrıca, yeni teknolojilerin ve bunlarla ilgili altyapının etkinliğini artırmak için çalışmalar yapılmalıdır (Geng vd., 2023). G-7 ülkelerinde, yeşil teknolojilerin ve uygulamaların benimsenmesini, tercihli ticaret anlaşmaları gibi ticaret teşvikleri yoluyla yeşil yatırımlar için finansal destek sağlayarak teşvik edebilir. Ayrıca yüksek gelirli ülkelerle iş birliği yaparak ortak emisyon azaltım hedefleri geliştirebilir ve karbon fiyatlandırma mekanizmalarının uygulanmasını destekleyebilir. Yeşil yatırımları teşvik etmek ve çevre dostu teknolojilerin benimsenmesini sağlamak, ekonomik büyümeyi artırırken çevresel zararı azaltır. Bu, çevre dostu teknolojiler oluşturma ve yenilik yapma motivasyonunu artırmak için yeşil teknolojilere yönelik araştırma ve geliştirme için hükümet harcamalarını artırarak yapılabilir (Ssekibaala vd., 2022). G-7 ülkelerinde etkin çevre politikaları ve uygulamaları yoluyla firmaların çevre dostu üretim yöntemlerine yönelmesi sağlanarak çevre üzerinde yarattıkları baskı azaltılabilir. Yeşil yeniliği teşvik etmek için en etkili politikalar arasında; emisyon ticareti sistemleri, emisyonları sınırlandıran ve yenilenebilir enerji üreticilerine minimum fiyat garantisi sağlayan besleme tarifeleri, araştırma ve geliştirme için sübvansiyonlar gibi devlet harcamaları yer almaktadır (Hasna vd., 2023).

Ticaret açıklığı, çevre dostu teknolojilerin ve sürdürülebilir uygulamaların sınırlar arasında değişimini kolaylaştırmaktadır. İş birliği ve bilgi paylaşımını artırarak yapılacak ticaret, ulusların daha yeşil ekonomilere geçişine yardımcı olabilir ve çevresel sürdürülebilirlik ile ekonomik refahın bir arada ilerlemesini sağlayabilir. Bu bağlamda, G-7 ülkelerinde ticari açıklığı destekleyici politikalar çeşitli aktarım mekanizmaları aracılığıyla çevresel bozulmanın etkilerini telafi edebilir. Ekonomik büyüme politikaları çevresel bozulmayı azaltıcı politika araçları ile desteklenebilir. Üretim artışı ile ortaya çıkan ekonomik büyüme sürecinde, üretimin çevre dostu üretim yöntemleri ile temiz enerji kaynakları kullanımının sağlanması teşvik edilebilir. Kentleşme politikalarının, yeşil alanların artırılması, yenilenebilir enerji kaynaklarının kullanılması, sürdürülebilir ulaşım sistemleri ve akıllı şehir uygulamaları gibi çevresel bozulmayı azaltıcı uygulamaları içermesi önerilebilir.

7. Sonuç

Karbondioksit emisyonları, günümüzde insanlığın karşı karşıya olduğu en kritik sorunlardan biri olarak görülmektedir. CO_2 salınımına neden olan insan faaliyetleri, ekolojik tahribat, küresel ısınma, iklim değişikliği ve çevre kirliliği gibi ciddi çevresel sorunlara yol açmaktadır (Li ve Haneklaus, 2022). Başka bir ifadeyle, karbondioksit emisyonlarının sürekli

artışı, küresel ısınmanın hızlanması ve aşırı hava olaylarının sıklıkla görülmesi gibi çeşitli çevresel problemlerin temel nedenlerinden biri haline gelmiştir (Cai vd., 2021). Çevresel kalite pek çok değişkenden etkilenirken bu değişkenler içerisinde ticaret açıklığı ve yeşil inovasyon öne çıkmaktadır. Ticaret açıklığıyla birlikte ülkelerin dış ticaret hacimleri değişmekte bu durum da üretim yapısıyla beraber CO_2 emisyonlarını etkilemektedir. Yeşil inovasyon ise çevresel kalite üzerinde büyük rol oynamaktadır. Özellikle gelişmiş ülkeler yeşil inovasyonu özendirmek için ciddi kaynak ve teşvik politikası izlemektedir. Literatürde ticaret açıklığıyla CO_2 emisyonları arasındaki ilişkinin sonuçları üzerine bir görüş birliğinin olmadığı ve ele alınan ülke gruplarına göre farklı sonuçların ortaya çıktığı görülmektedir. Bunun yanında yeşil inovasyon ise genellikle CO_2 emisyonlarını negatif etkilemektedir.

Bu çalışmada, 1995-2020 yılları arasında ticaret açıklığı ve yeşil inovasyonun CO_2 emisyonları üzerindeki etkileri AMG yöntemiyle incelenmiştir. İlk olarak, yatay kesit bağımlılığının tespit edilebilmesi için LM testi uygulanmış olup serilerin yatay kesit bağımlılığı gösterdiği görülmüştür. Yatay kesit bağımlılığı bulunduğu için ikinci nesil birim kök testlerinden CADF testi ile serilerin durağanlık durumu incelenmiştir. Devamında hem yatay kesit bağımlılığının bulunması hem de bazı değişkenlerin seviyesinde bazılarının ise birinci farklarında durağan olması sebebiyle AMG yöntemiyle katsayı tahmini yapılmıştır. AMG testi sonuçlarına göre, ticaret açıklığındaki bir birimlik artış CO_2 emisyonlarını %0,52 azaltmaktadır. Bu bulgu, Ali vd. (2016), Zhang vd. (2017), Zafar vd. (2019) çalışmalarının bulgularıyla uyumludur. Yeşil inovasyondaki bir birimlik artışın CO_2 emisyonlarını %1.44 azalttığı tespit edilmiştir. Bu bulgu, Meirun vd. (2021), Sharif vd. (2022), Ma vd. (2023), Geng vd. (2023), Albaker vd. (2023), Chen vd. (2023), Adebayo ve Ozkan (2024) ve Jahanger vd. (2024) çalışmalarının bulgularıyla paralellik göstermektedir. Kentleşmedeki bir birimlik artışın CO_2 emisyonlarını %6,05 oranında azalttığı sonuçlarına ulaşılmıştır. Bunun yanında GSYH'nin ise CO_2 emisyonlarını pozitif etkilediği ve GSYH'deki %1'lik artışın CO_2 emisyonlarını %0,551 oranında artırdığı görülmüştür.

İleride bu konuda çalışma yapacak araştırmacılara, G-7 ülkelerinin ticaret ortakları ile olan çevresel inovasyon seviyelerinin karşılıklı etkilerinin incelenmesi önerilebilir. Bununla birlikte, çevresel bozulmayı etkileyen faktörler incelenirken bölgesel analizler yapılabilir.

Araştırma ve Yayın Etiği Beyanı
Etik kurul izni ve/veya yasal/özel izin alınmasına gerek olmayan bu çalışmada araştırma ve yayın etiğine uyulmuştur.

Araştırmacıların Katkı Oranı Beyanı
Yazar, makalenin tamamına yalnız kendisinin katkı sağlamış olduğunu beyan eder.

Araştırmacıların Çıkar Çatışması Beyanı
Bu çalışmada herhangi bir potansiyel çıkar çatışması bulunmamaktadır.

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GREEN INNOVATION, TRADE OPENNESS AND ENVIRONMENTAL DEGRADATION: A STUDY ON G-7 COUNTRIES

EXTENDED SUMMARY

Aim

Climate change, global warming, and environmental pollution are among the significant challenges faced by humanity. These issues are particularly more pronounced in developed countries like the G-7 due to their leading roles in industrial and trade sectors. The historically high share of G-7 countries in greenhouse gas emissions increases their responsibility in addressing environmental problems. Except for the United States, the G-7 countries are parties to the Kyoto Protocol. Additionally, following the signing of the Paris Climate Agreement in 2015, the G-7 countries have taken significant steps to support environmental sustainability and create a green, low-carbon society. However, despite these efforts, they have not yet achieved full success in reducing CO_2 emissions (Li and Haneklaus, 2022). Despite these initiatives, the environmental costs brought about by economic development in these countries have not been sufficiently examined. In the relevant literature, studies addressing the impact of green innovation and trade openness on environmental degradation are relatively limited (see Shahbaz et al., 2017; Li and Haneklaus, 2022; Sharif et al., 2022; Olanrewaju et al., 2022; You et al., 2022; Adebayo and Ozkan, 2024; Jahanger et al., 2024). Among these studies, to the best of our knowledge, the only one focusing on the simultaneous effects of green innovation and trade openness is by Olanrewaju et al. (2022). The current study differentiates itself from this work in terms of methodology. In this context, the aim of this study is to examine the impact of green innovation and trade openness on environmental degradation in G-7 countries, which are among the world's most developed and industrialized nations, for the period 1995–2020. This study aims to contribute to the literature in two significant ways. First, it empirically reveals the potential of green innovation and trade openness to mitigate environmental degradation in G-7 countries.

Literature

There are many studies in the literature. Studies examining the effects of trade openness and green innovation on CO_2 emissions studies differ in terms of the method used, both the period and the country group examined, and their contributions to the literature. When the literature on the relationship between trade openness and CO_2 emissions is analyzed, it is observed that there is no consensus and that trade openness increases carbon dioxide emissions in some studies and decreases it in others. In the literature on green innovation and carbon dioxide emissions, it is generally observed that green innovation reduces carbon dioxide emissions. In the literature review, we first examined the relationship between CO_2 emissions and trade openness, then we focused on the relationship between green innovation and CO_2 emissions, and finally, we reviewed the effects of trade openness and green innovation on CO_2 emissions.

When the empirical literature is examined, the number of studies addressing the impact of green innovation and trade openness on environmental degradation is relatively limited. It is noteworthy that the existing studies are predominantly conducted on samples from developing

countries. Among these studies, only Olanrewaju et al. (2022) examine the simultaneous impact of green innovation and trade openness on environmental degradation within the sample of G7 countries. However, Olanrewaju et al. (2022) employ an analytical technique that does not account for cross-sectional dependence and heterogeneity problems. Pesaran (2006) emphasizes the importance of testing for cross-sectional dependence in panel data studies and notes that ignoring this dependence may produce inconsistent results. Moreover, unlike previous studies that use homogeneous panel estimation techniques where slope parameters are not allowed to vary across panel units, the current study employs a heterogeneous panel time series technique. In this way, the present study aims to introduce a methodological difference to the literature.

Methodology

First, the LM test was applied to detect cross-sectional dependence. Then, the stationarity of the series was examined using the CADF test, one of the second-generation unit root tests. Finally, the coefficient estimation was carried out using the AMG method.

Findings

The LM test results show that the series exhibited cross-sectional dependence. The CADF test results indicate that some variables were stationary in their levels while some variables were stationary in the first difference. According to the results of the AMG test, a one-unit increase in trade openness reduces CO_2 emissions by 0.52%, while a one-unit increase in green innovation decreases CO_2 emissions by 1.44%. Additionally, a one-unit increase in urbanization reduces CO_2 emissions by 6.05%. On the other hand, GDP has a positive impact on CO_2 emissions, with a 1% increase in GDP leading to a 0.551% rise in CO_2 emissions.

Conclusion

In this study, the effects of trade openness and green innovation on CO_2 emissions over the period 1995-2020 were analyzed using the AMG method. According to the AMG test results, a one-unit increase in trade openness reduces CO_2 emissions by 0.52%. This finding aligns with the results of studies by Ali, Law, and Zannah (2016); Zhang, Liu, and Bae (2017); and Zafar et al. (2019). It was found that a one-unit increase in green innovation reduces CO_2 emissions by 1.44%. This result is consistent with findings from studies by Meirun et al. (2021); Sharif et al. (2022); Ma et al. (2023); Geng et al. (2023); Albaker et al. (2023); Chen et al. (2023); Adebayo and Ozkan (2024); and Jahanger et al. (2024). Additionally, a one-unit increase in urbanization was found to reduce CO_2 emissions by 6.05%. On the other hand, GDP was observed to have a positive impact on CO_2 emissions, with a 1% increase in GDP leading to a 0.551% increase in CO_2 emissions.

Future researchers are recommended to examine the mutual effects of environmental innovation levels between G7 countries and their trade partners. Additionally, regional analyses could be conducted when investigating factors affecting environmental degradation.

Ekonomi, Politika & Finans Araştırmaları Dergisi, 2025, 10(1): 269-302
Journal of Research in Economics, Politics & Finance, 2025, 10(1): 269-302
Araştırma Makalesi / Research Article, https://doi.org/10.30784/epfad.1591963

KORUYUCU SAĞLIK HİZMETLERİ İŞ GÜCÜ VERİMLİLİĞİNİ ARTIRIR MI? BOOTSTRAP PANEL GRANGER NEDENSELLİK TESTİNE DAYALI EKONOMETRİK BİR ANALİZ

Do Preventive Healthcare Services Increase Labor Productivity? An Econometric Analysis Based on Bootstrap Panel Causality Test

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Anahtar Kelimeler:
Koruyucu Sağlık Hizmetleri,
İş gücü Verimliliği,
Bootstrap Panel Granger Nedensellik Analizi

JEL Kodları:
I15, J11, E23

Öz

Başta bireylerin, ardından da toplumun genel sağlığını ilgilendiren ve tehdit eden sorunların çeşitlenmesi, büyümesi ve etkilediği alanların genişlemesi koruyucu sağlık hizmetlerinin önemini daha da artırmıştır. Bunun yanında diğer sektörler üzerinde yarattığı pozitif dışsallıklarla, koruyucu sağlık hizmetleri adından sıklıkla söz ettirmektedir. Bu kapsamda araştırmalara konu olan koruyucu sağlık hizmetlerinin dışsallıklarından biri de iş gücü verimliliği üzerine olan etkileridir. Bu çalışmada Kónya'nın (2006) bootstrap panel Granger nedensellik testi kullanılarak koruyucu sağlık hizmetlerinin iş gücü verimliliğini artırıp artırmadığı analiz edilmektedir. Bunun için de örneklem olarak seçilmiş beş Avrupa ülkesinin (Danimarka, Fransa, Lüksemburg, Hollanda ve Norveç) 1995-2019 dönemine ilişkin yıllık veri seti kullanılmıştır. Yapılan ekonometrik analizde Danimarka, Fransa ve Hollanda'da koruyucu sağlık hizmetlerine yönelik harcamalar ile iş gücü verimliliği arasında çift yönlü bir Granger nedensellik ilişkisi tespit edilmiştir. Norveç ve Lüksemburg açısından bu ilişkinin koruyucu sağlık hizmetlerine yönelik harcamalardan iş gücü verimliliğine doğru tek yönlü olduğu sonucuna ulaşılmıştır. Bunun yanında ekonometrik bulgular koruyucu sağlık hizmetlerine yönelik harcamalardaki bir birimlik artışın, iş gücü verimliliğinde %1 istatistiksel anlamlılık düzeyinde yaklaşık %0,78 ile %0,96 arasında değişen bantta bir artışa neden olduğunu ortaya koymaktadır.

Keywords:
Preventive Healthcare Services,
Labor Productivity,
Bootstrap Panel Granger Causality Test

JEL Codes:
I15, J11, E23

Abstract

The diversification, expansion, and widening impact of issues threatening individual and social health have highlighted the growing importance of preventive healthcare services. These services are often noted for their positive externalities on other sectors. This study uses Kónya's (2006) bootstrap panel Granger causality test to examine whether preventive healthcare services boost labor productivity. Annual data from five European countries (Denmark, France, Luxembourg, the Netherlands, and Norway) from 1995 to 2019 are used for this purpose. The econometric analysis reveals a bidirectional Granger causality relationship between expenditures on preventive healthcare services and labor productivity in Denmark, France, and the Netherlands. In Norway and Luxembourg, the relationship is unidirectional, from expenditure on preventive healthcare services to labor productivity. Furthermore, the findings show that a one-unit increase in expenditure on preventive healthcare services leads to a rise in labor productivity in the range of approximately 0.78% to 0.96% at the 1% statistical significance level.

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Makale Geliş Tarihi (Received Date): 28.11.2024 Makale Kabul Tarihi (Accepted Date): 01.02.2025

1. Giriş

Yaklaşık yarım asrı aşkın bir süredir akademisyenler ekonomik büyümenin nasıl artırılacağı konusuna kafa yormaktadırlar. Çoğunlukla beşerî sermaye üzerine odaklanan bu araştırmalar, 1980'lerin ortalarından itibaren içsel büyüme modelleriyle birlikte ivme kazanmaya başlamıştır. Söz konusu akademik araştırmalar bu büyüme modelleriyle, beşerî sermayenin bir başka ifadeyle insana yatırımın iki temel bileşeni olan eğitim ve sağlığın toplumdaki yapısal değişim ve ekonomik dönüşümde başat rol oynadığını ortaya koymuştur. Nitekim kamu maliyesi literatüründe de insana yatırım, "kalkınma carileri" veya "yatırım carileri" olarak ifade edilmektedir. Bunları diğer cari harcamalardan (kamu tüketim harcamalarından) farklı kılan şey, faydalarının yapıldıkları yılla sınırlı kalmayıp uzun yıllara sirayet etmesi ile birlikte büyüme üzerinde olumlu bir artışı ortaya çıkarma potansiyelleridir (Şen vd., 2018). Bu sebeple ülkeler eğitim ve sağlık harcamalarına yoğunlaşmış ancak bu harcamaları bir bütün olarak ele almak yerine harcama alt türlerine dair farklı yaklaşımlar benimseyerek en fazla çıktıya sebep olacak harcama kalemlerini dikkate almışlardır. Son dönemde yaşanan COVID-19 salgının neden olduğu ciddi gelir kaybıyla birlikte bu iki harcama türü kıyaslandığında sağlık harcamalarının daha fazla ön plana çıktığı görülmektedir.

Esas olarak devletin sağlık hizmeti sunması ve dolayısıyla buna yönelik harcamalar yapması bir zorunluluk olmanın yanında aynı zamanda bir gelişmişlik göstergesidir. Bir başka anlatımla bir ülke ne kadar gelişmiş ise, sağlık hizmetleri için ayırdığı bütçe de o denli büyük olacaktır denilebilir. Bunun altında yatan temel sebep sağlıklı bireyin sağlıklı toplum; sağlıklı toplumun ise güçlü beşerî sermaye anlamına geldiği gerçeğidir. Ülkelerin iktisaden gelişmeleri de vatandaşlarının sağlığına gereken derecede önem vermesine bağlıdır. Çünkü beşerî sermaye, iş gücü kabiliyetinin, yeteneğinin ve bilgisinin ekonomik değerini yansıtır. O halde sağlıklı bireyler genel olarak daha fazla verimlilik potansiyeline sahip olduğu için, bir ülkede sağlık hizmetleri yoluyla bireylerin daha sağlıklı olması, o ülkenin sahip olduğu beşerî sermaye niteliğinin artmasına katkıda bulunacaktır. Bu durum ise söz konusu ülkeyi ekonomik anlamda daha güçlü kılacaktır.

Beşerî sermayeyi artırmak için daha sağlıklı bir topluma ulaşma isteği aynı zamanda ülkelerdeki sağlık sisteminin birtakım özelliklere sahip olmasını da gerektirir. Bunun için sağlık hizmetlerinin başta herkes için erişilebilir, eşit ve kapsayıcı olmasının yanı sıra sistemin talep edilen tıbbi mal ve hizmeti karşılaması, sürdürülebilir ve entegre sağlık politikalarının oluşturulmasına açık olması gereklidir. Özetle, bu sistem vasıtasıyla bir yandan her birey ihtiyaç duyduğu ve talep ettiği sağlık hizmetine etkili ve hızlı bir şekilde ulaşabilmeli diğer yandan ise devlet bunun arzını yine hızlı ve etkin bir şekilde sağlayabilmelidir. Ancak devletin sunmuş olduğu sağlık hizmetleri yalnızca talepler ve ihtiyaçlar doğrultusunda şekillenmemektedir. Söz konusu sağlık hizmetleri toplumun genel sağlığını korumak, riski ve riske maruziyeti en aza indirmek, olası epidemik ve pandemik faktörleri engellemek gibi toplumunun tamamına yönelik "koruyucu" sağlık hizmetlerini de içermelidir.

Koruyucu sağlık hizmetleri devlete, daha hızlı ve daha kaliteli sağlık hizmeti sunumu, kaynakların daha acil ve gerekli yerlere aktarılması, ekonomik açıdan iş gücü verimliliğinin artırılması, hastalıkların ve tıbbi sorunların büyümeden engellenmesi olmak üzere zamansal, mekânsal, yönetişimsel, nicel ve nitel iyileşmeler gibi bir dizi fayda sağlar. Bu nedenledir ki, sağlık hizmetlerinin sağladığı dışsal faydalar ekonomik açıdan oldukça önemlidir. Ancak bu hizmetlere dair hedeflerin bu kadar çok yönlü olması, aynı zamanda söz konusu hedeflere ulaşmak için detaylı bir stratejik planlamayı da gerektirir. Bu planlama, toplumun ihtiyaçlarına yönelik çok yönlü analizler ile uzun vadeli politikaları içerir. Bu bağlamda toplum sağlığına yönelik risk faktörleri tespit edilir

ve bu risklere karşı proaktif önlemler alınır. Bu amaçla, halk sağlığı eğitim programları, aşı kampanyaları, periyodik sağlık taramaları ve çevresel sağlık önlemleri gibi çeşitli uygulamalar devreye sokulur. Doğal olarak yapılacak bu planlamalarda çeşitli problemlerle de karşılaşılması olasıdır. Örneğin hem kısa hem de uzun vadeli planlamalarda anne ve çocuk sağlığı, aşılama, sağlıklı yaşam davranışı kazandırma eğitimleri gibi koruyucu sağlık hizmetlerinin sağladığı faydanın etkileri anlık olarak ortaya çıkabilmektedir. Buna karşın, fizik tedavi ve rehabilitasyon hizmeti alan bireylerin toplumsal entegrasyonu ve çevreleri ile uyum sağlamalarında ortaya çıkacak fayda ancak uzun dönemde kendini gösterebilir. Diğer taraftan sağlığına kavuşan bireylerin koruyucu sağlık hizmetleri vasıtasıyla elde ettikleri bireysel kazanımlarının yanı sıra iş gücüne katılımları ile ülke ekonomisine sağladıkları katkının ölçümü de oldukça karmaşık olabilir. Özellikle tedavi edilen bireylerin dışsallık yaratan mesleklerde çalışmaları, bu karmaşıklığı daha da artırabilir.

Bütün bunlara ilaveten koruyucu sağlık hizmetlerinin sunduğu faydaların fiyat mekanizması yoluyla doğru şekilde ölçülememesi de başka bir zorluk olarak ortaya çıkabilir. Toplumda görülen hastalıkların sıklığı ve bu hastalıkların tedavi edilmesi için gereken kaynakların uzun vadeli maliyetlerinin planlanması da ülkeler için önemli bir sorundur. Bu tarz problemler için bir dizi önlem alınması temel bir gereklilik olarak ortaya çıkar. Örneğin stratejik planlarda uzun vadeli maliyetler, genellikle yapılacak olan fayda-maliyet analizleri ile ekonomik anlamda etkin bir şekilde yönetilmeye çalışılır. Bunun yanı sıra bu planlarda sağlık harcamaları bir bütün olarak ele alınmak yerine harcamanın alt türlerine dair farklı yaklaşımlar benimsenerek en fazla çıktıya sebep olacak harcama kalemlerine yoğunlaşılır ve bu durumda ortaya "verimlilik" unsuru çıkar.

Verimlilik, belli bir üretim ile bu üretimin gerçekleştirilmesini sağlayan girdi arasındaki oransal ilişkiyi ortaya koyan iktisadi bir kavramdır. Başka bir ifadeyle verimlilik, iktisat literatüründe yaygın olarak çıktı miktarının girdi miktarına oranı ile ölçülür. Verimlilik unsuru olarak iş gücünün dikkate alınması durumunda iş gücü verimliliğinden, sermayenin dikkate alınması durumunda ise sermaye verimliliğinden bahsedilebilir. Verimlilik hem ekonomik büyüme hem de rekabet gücü açısından hayati derecede önemlidir ve bir ülkenin ekonomik performansının değerlendirmesinde kullanılan temel istatistiki bilgilerin başında gelir.

İş gücü ve sermaye verimliliğinde meydana gelecek bir artışın ekonominin toplam çıktı düzeyinde de bir artışa neden olacağı genel kabul gören bir husustur. Bir ülkenin üretim faktörlerinin herhangi birinde, birkaçında veya hepsinde meydana gelecek bir nitelik artışının, o ülkenin toplam çıktı düzeyinde de aynı yönde bir artışa neden olacağı; bir başka ifadeyle, ekonomik büyümeyi tetikleyeceği öncül bir varsayımdır (Ünsal, 2020). Şu hâlde verimlilik artışı ülkeler için arzu edilen bir durumdur. Verimlilik artışı, daha yüksek ekonomik büyüme ve daha fazla istihdam, kısacası daha fazla refah artışı demektir. İş gücü ve sermaye üretim açısından elzem olsa da bu iki girdiden iş gücü, üretim sürecinde özel bir öneme haizdir. Çünkü sermayeyi çıktıya çevirecek yegâne unsur iş gücü arzı ve onun niteliğidir. Bu durumda iş gücü, üretimi artırma bakımından sermayeden daha büyük önem taşımaktadır denilebilir. Bu kapsamda çalışma açısından önem arz eden unsur iş gücü verimliliği olacaktır.

İş gücü verimliliği, bir birim emek kullanılarak kaç birim üretim yapıldığını ölçen iktisadi bir kavramdır. Bir başka anlatımla birim iş gücü başına elde edilen çıktı miktarı bize verimliliği vermektedir. Genel olarak da toplam çıktı miktarının toplam iş gücü girdisine oranlanması suretiyle hesaplanır. İş gücü verimliliği, bir ekonominin mevcut insan kaynağından etkin olarak ne ölçüde faydalanabildiği konusunda da fikir verir. İş gücü verimliliğindeki bir artış, ülke ekonomileri için her şeyden önce daha yüksek oranlı büyüme demektir. Çünkü iş gücü verimliliğindeki artış, aynı

miktardaki emekle daha fazla çıktı elde edilmesi; bu da büyümenin artması demektir. Yine, iş gücü verimliliğindeki artış, ülkenin ulusal rekabet gücünde artış anlamına gelmektedir. Daha yüksek iş gücüne sahip ülkeler aynı miktardaki iş gücü ile daha düşük maliyetli mal ve hizmet üretebilme imkânına sahip olurlar. Bu durum o ülkelere uluslararası piyasalarda daha rekabetçi olabilme fırsatı sunar.

Dahası, iş gücü verimliliğinin artması ücret artışlarına olanak sağlayacak ve dolayısıyla işçilerin yaşam standartlarının iyileşmesine ortam hazırlayacaktır. Öte yandan iş gücü verimliliğinin artması yatırımcılara da cezbedici bir ortam sağlayacaktır. Bu da yatırım potansiyelinin artmasına ve böylelikle de iktisadi kalkınmanın teşvikine katkıda bulunacaktır. Buna ek olarak yapılan çalışmalar göstermektedir ki teknolojik ilerlemeler ve inovasyon iş gücü verimliliğinin artmasının arkasında yatan temel itici güçtür. Bu da ekonomik kalkınmayı tetikleyici bir başka faktördür. Özetle, iş gücü verimliliği hem bir ülkenin refahı hem de o ülkenin uluslararası rekabet gücü açısından anahtar role sahip bir ekonomik göstergedir. Dolayısıyla iş gücü verimliliğin artması, ülkelerin refahının artması açısından büyük önem taşımaktadır.

Bu genel kabulden hareketle iş gücü verimliliğini artırmaya ilişkin olarak konuyu farklı yönleriyle ele alan oldukça fazla sayıda çalışma kaleme alınmıştır (Bu konudaki çok sayıdaki çalışma arasında özellikle ayrıntılı bilgi için bkz. Constantinescu vd., 2019; Hernæs vd., 2023). Ancak iş gücü verimliliği üzerine yapılan çalışmaları kapsayan literatür detaylı incelendiğinde, akademik araştırmaların ekseriyetinin verimliliği yalnızca beşerî sermaye perspektifinden ele aldığı görülmektedir (Ayrıntılı bilgi için bkz. Corvers, 1997; Van Lottum ve Zanden, 2014; Máté, 2015; Gul vd., 2022). Bunun yanında söz konusu literatürde iş gücü verimliliği üzerindeki etkisinin daha güçlü olacağına inanılan ve sağlık harcamalarının alt bileşenlerinden biri olan koruyucu sağlık hizmetlerine yönelik harcamalar ile diğer temel etkenleri bir arada analiz eden bir çalışmaya rastlanmamıştır. Aynı zamanda bu konu literatürde farklı ekonometrik analizlere tabi tutulsa da yatay kesit bağımlılığını ve heterojenliği dikkate alan nedensellik analizlerine konu olmamıştır. Bu nedenle söz konusu eksikliklerden motive olarak hazırlanan bu çalışma ile mevcut ekonometrik literatüre katkıda bulunulması amaçlanmaktadır.

Çalışmada öncelikle koruyucu sağlık hizmetlerinin yanı sıra iş gücü verimliliği üzerinde güçlü etkisi olduğunu düşünülen ---ki bu hususta literatürde de aynı yönde ve şekilde bir kanaat mevcuttur--- üç değişkenin [(Ayrıntılı bilgi için bkz. Harris, 1999), (beşerî sermaye, yatırım harcamaları ve ekonominin dışa açıklık derecesi)] Granger nedensellik ilişkileri tek tek ele alınacaktır. İkinci olarak, analizde Granger nedensellik ilişkisinin tespiti için Kónya'nın (2006) bootstrap panel Granger nedensellik testinden istifade edilecektir. Bu yöntemin muadillerine göre üstünlüğü, analize dâhil edilen ülkeler arasındaki yatay kesit bağımlılığını ve heterojenliği dikkate alması ve kesitler için farklı gecikme uzunluklarına imkân vermesidir. Son olarak çalışmada 1995-2019 dönemi için veri kısıtının olmadığı benzer büyüme ve kalkınma düzeylerinden müteşekkil olan ve aynı zamanda hem AB (Avrupa Birliği) hem de OECD (Ekonomik İşbirliği ve Kalkınma Örgütü) üyesi olan beş Avrupa ülkesi (Danimarka, Fransa, Lüksemburg, Hollanda ve Norveç) örneklem olarak alınacaktır.

Beş bölümden oluşan çalışmanın ikinci bölümünde teorik arka plan ve ekonometrik literatür irdelenirken, üçüncü bölümünde veri seti ve araştırma yöntemi ele alınmaktadır. Çalışmanın dördüncü bölümünde de ekonometrik analiz ve bulgulara yer verilmektedir. Son bölümde ise sonucuna yer verilmektedir.

2. Teorik Arka Plan ve Ekonometrik Literatür

Koruyucu sağlık hizmetleri ile iş gücü verimliliği arasındaki ilişkiye odaklanarak hazırlanan çalışmanın bu bölümünde konunun teorik arka planı ve ilgili ekonometrik literatür incelenmiştir.

2.1. Teorik Arka Plan

Sağlık hizmetlerine yönelik talep, daha ziyade bir sağlık sorunu ortaya çıktığında söz konusu olmaktadır. Ancak burada önemli olan sağlık sorunu daha ortaya çıkmadan ya da ilerlemeden önlem alınabilmesidir. Çünkü çoğu zaman söz konusu sağlık problemi ortaya çıktıktan sonra o problemi çözmenin maliyeti, problem için önlem alma maliyetinden daha yüksek olabilmektedir. Bu kapsamda karşımıza koruyucu sağlık hizmetleri ve bu hizmetlere yönelik harcamalar çıkmaktadır. Koruyucu sağlık hizmetleri, başta toplumun genel sağlığına yönelik olmak üzere hastalık, yaralanma ve diğer kişisel sağlık problemlerini engellemek maksadıyla yapılan aktivite ve faaliyetlere dönük hizmetlerdir. Bu hizmetler de aşılamadan, düzenli genel sağlık taramalarına (check-up), görüntüleme ve sağlıklı yaşam koçluğuna ve bireysel sağlık eğitimine kadar bir dizi hizmeti içermektedir. Amaç, yukarıda belirtildiği gibi sağlık sorunlarını ciddi bir hal almadan ve/veya aşırı maliyetli bir hale gelmeden önce teşhis etmek ve gerekli önleyici tedbirleri almaktır.

Koruyucu sağlık hizmetleri, DSÖ'nün (Dünya Dağlık Örgütü) tıbbi sistematik sınıflandırma yaptığı ilk çalışmasında "koruyucu prosedürler" başlığı ile kendine yer bulmuştur (WHO, 1978). OECD'nin sağlık sektöründe politikacılara yardımcı olmak ve uluslararası düzeyde veri teminini kolaylaştırmak için dizayn ettiği sağlık hesapları sisteminde ise "koruma ve sağlık hizmetleri" başlığı altında yer alan hizmetlerin, sağlıklı olmanın teşvik edilmesi ve bu fikrin yaygınlaştırılmasına yönelik tedbirler ile hastalıkların önlenmesine ilişkin olarak devlet tarafından sağlanan genel halk sağlığı faaliyetlerini içeren hizmetler olduğu ifadesine yer verilmektedir. Sağlık sorunlarını iyileştiren tedavi edici hizmetlerden farklı olarak, nüfusun sağlık durumunun iyileştirilmesinin amaçlandığı bu hizmetlerin kapsamına; "anne-çocuk sağlığı; aile planlaması ve danışmanlığı, okul sağlık hizmetleri, bulaşıcı olan ve olmayan hastalıkların önlenmesi, mesleki sağlık bakımı ve diğer tüm çeşitli kamu sağlığı hizmetleri" girmektedir (OECD, 2000: 132). Yine OECD'nin 2011 yılında yayımladığı çalışmada koruyucu sağlık hizmetleri; "genel sağlık standartlarını veya sağlık sisteminin etkinliğini ve verimliliğini, tüm kullanıcılara aynı anda fayda sağlayacak şekilde iyileştirmeyi amaçlayan yönetişim ve idari hizmetlerin yanı sıra belirli hastalık kontrol programlarının izlenmesi ve değerlendirilmesi gibi tüm sağlık sistemi veya alt bileşenleri üzerindeki müdahalelerle bağlantılı olan hizmetler" olarak tarif edilmektedir (OECD, 2011: 73). Bunun yanında koruyucu sağlık hizmetleri fonksiyonel sınıflandırmada kendi içerisinde; bağışıklama programları, sağlıklı durum izleme programları, erken hastalık tespit programları, epidemiyolojik risk ve hastalık programları ile afet ve acil durum müdahale programları olmak üzere altı kısma ayrılmıştır (OECD, 2011). Bu programlar ise birincil, ikincil ve üçüncül koruma olmak üzere stratejik bakımdan kategorize edilmiştir. Bu kapsamda birincil koruma; hastalık daha ortaya çıkmadan tüm nüfusu hedefleyen önleyici tedbirler alınmasını konu alan spesifik sağlık önlemlerini ve hizmetlerini içermektedir. Aşılama, sağlıksız yaşam tarzının değiştirilmesi, risk unsurlarının ortadan kaldırılması, riske maruz kalmanın önüne geçilmesi bunun tipik örnekleri arasında yer almaktadır. İkincil koruma ise, sağlık sorunları ve şikâyetler baş gösterdikten sonra kan testleri, taramalar, laboratuvar ve görüntüleme teknikleri ile risk altındaki nüfusta vakaların erken tespit edilmesi ve tedavinin geciktirilmeden yapılması sürecindeki hizmetleri içerir. Üçüncül koruma da ise tanısı konunmuş sağlık probleminin

daha da kötüleşmesini önlemek ve oluşacak komplikasyonları engelleme, tedaviyi izleme amacı güden hizmetler karşımıza çıkmaktadır (OECD, 2011).

İş gücü verimliliği penceresinden bakıldığında sağlık hizmetlerinde ilk akla gelen koruyucu sağlık hizmetleri ve bu kapsamda yapılan harcamalar olmaktadır. Çünkü koruyucu sağlık önlemleri kapsamında bireyin sağlıklı kalması ve sağlığını koruyabilmesi mümkün hale geldiğinden hastalanması, sakatlanması ve potansiyel ölüm riski minimize edilebilmektedir. Böylelikle de potansiyel sağlık sorunlarının gerçek sorunlara dönüşmeden engellenebilmesi mümkün olmaktadır. Dolayısıyla bireylerin sağlığı konusunda sürpriz yaşama ihtimali azalmaktadır. Ayrıca sağlık sorununun ortaya çıkmadan önlenmesi zaman ve para tasarrufu anlamına da gelmektedir. Şöyle ki, önceden tedbir alınması nedeniyle pahalı muayene ve/veya hastanede yatışa gereksinim azalacaktır.

Bireyin sağlıklı olması ve hayatının büyük bölümünde sağlıklı kalabilmesi başta bireysel isteği/çabası olmak üzere; genetik ve çevresel faktörlere göre şekillenmektedir. Koruyucu sağlık hizmetleri de bu noktada bireyin sağlık durumunu destekleme ve koruma işlevi sunmaktadır. Böylelikle bireyin daha kaliteli bir hayat yaşamasına imkân sunulmaktadır ki bu da gündelik yaşamıyla sınırlı kalmamakta doğrudan iş hayatını da etkilemektedir. Çünkü en nihayetinde sağlıklı birey sağlıklı çalışan anlamına gelmektedir. Örneğin bel ve boyunda ortaya çıkan eklem/kas ağrıları hemen hemen herkeste ortaya çıkabilecek sağlık sorunlarından birkaçıdır. Otururken bile yapılabilecek basit fiziksel aktivitelerle güçlendirilebilecek bu bölgelerde, ortaya çıkması muhtemel ya da çıkan sorunlar için önlem alınmadığı takdirde ağrılar şiddetlenecek, kol ve bacak gibi başka uzuvları da etkileyecek, sonunda ameliyata ya da ömür boyu fiziksel kısıtlarla ve ilaçlarla yaşamayı gerektirecektir. Bu süreç hem maddi hem zaman hem de fizyolojik olarak oldukça zahmetli ve yıpratıcıdır. Yine karbonhidrat ağırlıklı beslenen bireylerde yemek sonrası ani kan şekeri yükselmesine bağlı uyku hali, halsizlik, ağırlık hissi, hızlı acıkma uzun vadede ise diyabet riski gibi problemler doğacaktır. Gerek sağlıklı işçilerin sağlığını korumaları için gerekse diyabetli işçilerin sağlık sorunlarının nüksetmemesi için iş yerindeki yemek planını/mönüsünü değiştirecek basit tedbirlerle bu problemlerin ortadan kalkması mümkündür. Dolayısıyla sağlık problemlerini ve neden olacağı sorunları iş hayatından bağımsız değerlendirmek mümkün değildir. Bu sağlık problemlerinden etkilenecek ilk unsur işteki verim ve üretkenlik olacaktır. İnsanların gündelik hayatının çok büyük bir bölümünün iş ortamında geçtiği hesaba katıldığında, basit ama kronik rahatsızlıkların dahi verimlilik düşüşündeki etkileri yüksek olmaktadır. Böylesi kronik rahatsızlığı bulunan bireyler masa başı işlerde dahi çalışsalar yeterince verimli olamamaktadır.

Koruyucu sağlık hizmetlerinde nitel-nicel iyileşmelerin yaşanması hiç kuşkusuz bu alana yapılacak harcamalarla doğrudan ilgilidir. Diğer bir anlatımla koruyucu sağlık hizmetlerine ne kadar önem verildiğini bu alana yönelik harcamalar göstermektedir. Bu kapsamda koruyucu sağlık hizmetlerine yatırım yapmak demek sağlıklı bireylere ve topluma ve bir bakıma daha sağlıklı bir iş gücüne sahip olmak demektir. Koruyucu sağlık hizmetleriyle işe gelmeme, işi aksatma yahut işteki verimin ya da çalışma saatlerinin düşmesi gibi problemlerin önüne geçileceğinden, işteki verimlilik ve üretkenlik de artmış olacaktır. Tersi durumda da işe gelmemeler artacak, sağlık sorunları olduğu halde çalışan veya çalışmak zorunda kalanlar da daha düşük verimlilik sergiliyor olacaklardır. Bunun yanında, sağlık sorunları nedeniyle işe gel(e)meyen işçilerin neden olacağı kaybı telafi etmek isteyen işverenlerin, işe gelenlerden fazla mesai ve fazla iş talep etmesi söz konusu olabilmektedir. Bu durum uzun vadede ek ücret taleplerine, iş tatminin kaybolmasına, işten ayrılmalara uzanan sonuçlar doğurabilmektedir. Kısacası koruyucu sağlık hizmetleri, kişilerin etkin bir biçimde çalışmasına mâni olan kronik hastalıkları ve sakatlıkları azaltmak suretiyle de iş gücü verimliliğini

uzun dönemde pozitif yönde etkileme potansiyeline sahiptir. Bununla birlikte sağlık hizmetlerine ayrılan kaynakların etkin kullanılmasını sağlayarak, daha az kaynak tahsis edilmesi sonucu ortaya çıkan kaynak tasarrufunun, iş gücü verimliliğinde artış sağlayacak eğitim, teknoloji ve benzerine aktarılması için fırsat sunacaktır.

Görüleceği üzere koruyucu sağlık hizmetleri ile iş gücü verimliliği arasında sıkı bir nedensellik ilişkisinin olması; çalışanı, işvereni, üretkenliği, ekonomiyi ve dolayısıyla ülkeyi içine alan oldukça önemli katkılar sunmaktadır. Bu nedenle ülkeler bu hizmetlere oldukça önem vermektedirler. Örneğin, üst-orta gelirli ülkelerde devlet tarafından finanse edilen temel sağlık harcamaları içerisinde tedavi edici hizmetler ve sağlık sistemi yönetim harcamalarından sonra üçüncü büyük harcama kalemi olarak koruyucu sağlık hizmetleri göze çarpmaktadır (WHO, 2021a). Yine koruyucu sağlık hizmetlerine yönelik harcamaların toplam sağlık harcamaları içindeki payının, COVID-19 pandemi döneminde neredeyse tüm ülkelerde arttığı tespit edilmiştir (WHO, 2023). Söz konusu pandemi dönemi boyunca ülkelerin üretim zincirleri bozulmuş, çalışanların sağlık durumlarında oluşan problemler veya bu tarz problemlerin oluşma ihtimali sebebiyle günlerce süren karantinalar uygulanmış, çalışma saatleri olması gerekenin çok altına çekilmiş ve sonuç olarak ülkelerin GSYİH'sinde ciddi azalmalarla birlikte bu ülkelerde farklı makroekonomik sorunlarla karşılaşılmıştır. Örneğin dünyada sağlık harcamalarına en yüksek harcamayı yapan (OECD, 2023a) ve aynı zamanda örneklem ülkelerimizden biri olan Hollanda'da koruyucu sağlık hizmetlerine yönelik harcamalar için ayrılan ve 2019'da %3.3 olan bu pay, COVID-19 pandemisinde daha da yükselerek 2020'de %4.7'ye çıkmıştır. Fransa'da da pandemi sırasında koruyucu sağlık hizmetlerine yönelik harcamaların, toplam sağlık harcamaları içindeki payı 2021'de %5'i aşmıştır (OECD, 2023b). Zaman içinde krizin etkisinin yavaş yavaş azalmasıyla devletler yaşadıkları bu deneyimden yola çıkarak durumu hem çalışanlar hem de beşerî sermaye açısından ele almaya başlamışlardır. Pandemi ile birlikte sağlık sistemlerinin dayanıklılığının ve evrensel sağlık güvencesinin sağlanması gerekliliği gündeme gelmiş ve buna ilişkin politikalar hazırlanmaya başlamıştır (Ayrıntılı bilgi için bkz. WHO, 2021b, 2022). İş gücü verimliliğinde kaybı önlemek için böyle bir sağlık krizi döneminde çalışamayacak duruma gelebilecek işçi sayısını azaltmak için koruyucu sağlık hizmetlerine daha fazla önem verilmesi konusunda hemfikir olmuşlardır.

2.2. Ekonometrik Literatür

Eğitim ve sağlığın ---daha genel bir ifadeyle beşerî sermayenin--- ekonomik büyüme ve kalkınma üzerindeki rolü içsel büyüme modellerinin ön plana çıktığı 1980 sonrası süreçte sıklıkla tartışılmaya başlanmıştır. İçsel büyüme modelleri bağlamında Romer (1986), Lucas (1988) ve Barro (1991) gibi önde gelen ABD'li akademik iktisatçılar beşerî sermayenin ekonomik büyüme ve kalkınmadaki rolü üzerine odaklanan çalışmalar yapmışlardır. Örneğin Lucas'a (1988) göre beşerî sermaye, pozitif dışsallıkları olan kümülatif bir değişken olup, ekonomik büyümenin arkasındaki temel itici güçtür. Çünkü sağlıklı aynı zamanda eğitim düzeyi yüksek kalifiye bireyler, iş hayatında hem daha verimli hem de daha üretken olabilirler (Şen vd., 2018). Bir başka deyişle iyi eğitim almış kalifiye ve aynı zamanda sağlıkları yerinde olan bireylerin iş başında geçirdiği gün sayısı arttığında iş gücü verimliliğinin üretime ve sonrasında ekonomiye katkısı pozitif yönde olacaktır. Bunun yanında sağlıklı olmayan bireyin eğitimli olsa bile iş gücü kaybına neden olabileceği son dönem yaşanan pandemi ile yeniden kanıtlanmıştır. Bu nedenle yaşanılan bu deneyimden de yola çıkarak koruyucu sağlık hizmetlerine yönelik harcamalardaki bir artışın iş gücü verimliliğini ve dolayısıyla

ekonomik büyümeyi artıracağı öngörülmektedir (Edington ve Burton, 2003; Burton vd., 2005, 2006; Goetzel ve Ozminkowski, 2008; Loeppke, 2008).

ABD üzerine yapılan bir araştırmada kronik hastalıkların ABD'de sağlık bakım maliyetleri üzerindeki en büyük etken olduğu tespit edilmiş, aynı çalışmada bunun ekonomik üretkenlikte ortaya çıkardığı kaybın neredeyse 4 trilyon dolara yaklaştığına dikkat çekilmiştir (Waters ve Graf, 2018). Diğer taraftan Street ve Lacey'in (2019) iş yerinde sağlığın korunması ve geliştirilmesi kapsamında Avusturya'da bir madencilik şirketinde yaptıkları çalışmada, mevcut sağlık riskleri ve sağlık koşullarının 30 milyon doları aşan üretkenlik kaybına neden olduğunu ve bu maliyetin %70'den fazlasının önlenebilir sağlık riskleri nedeniyle ortaya çıktığını tespit etmişlerdir. Bu kapsamda koruyucu sağlık hizmetlerinden faydalanmak suretiyle çalışan sağlığında, üretkenlikte, güvenlik sorunlarında ve kurumsal kârda önemli iyileşmeler sağlanacağı dile getirilmiştir. Kang vd. (2021), ABD'de 2010-2013 dönemini ve 1.112 yerel bölgeyi kapsayan çalışmalarında diyabet için koruyucu sağlık hizmetlerinin, hasta sonuçlarını iyileştirme ve bakım maliyetlerini azaltma noktasında kritik öneme sahip olduğu bulgusuna ulaşmışlardır. Bazı araştırmalarda da hastalıklar nedeniyle işe gelememenin üretkenlikte ortaya çıkardığı maliyetlerin, tıbbi maliyetlere nazaran ortalama iki ya da üç kat daha fazla olduğu ortaya konmuştur (Edington ve Burton, 2003; Loeppke vd., 2003, 2007; Loeppke ve Hymel, 2008). Wang vd. (2016), OLS yöntemini kullanarak 1975-2013 dönem için ABD'de koruyucu sağlık hizmetlerine yönelik harcamalar ile ekonomik performans arasındaki etkileşimi analiz etmiş ve söz konusu harcamalara daha fazla kaynak tahsis edilmesinin, daha iyi bir ekonomik performansa ve refaha ulaşılmasına imkân sağladığı bulgusuna ulaşmışlardır. Görüldüğü üzere bahsi geçen çalışmanın bulguları da koruyucu sağlık hizmetlerine yönelik harcamalar ile iş gücü verimliliği arasındaki yakın ilişkiyi teyit eder niteliktedir.

Bunun yanında konuyu spesifik olarak koruyucu sağlık hizmetleriyle sınırlandırmadan daha geniş perspektiften ele alan bazı çalışmalar da mevcuttur. Bu çalışmaların daha ziyade sağlık harcamalarına ve bu harcamaların verimlilik üzerindeki etkisine odaklandığı görülmektedir. Örneğin, 44 Asya ülkesi için 1980-2017 dönemini dikkate alan Koyuncu ve Ünver (2019), sağlık harcamalarının verimlilik üzerine etkisini araştırmış ve söz konusu harcamalardan verimliliğe doğru pozitif yönlü ve istatistiksel olarak anlamlı bir ilişki olduğu bulgusuna ulaşmışlardır. 2003-2014 dönemi için sağlık harcamaları ve ekonomik performans arasındaki ilişkiyi ABD için araştıran Raghupathi ve Raghupathi (2020) ise sağlık harcamaları ile iş gücü verimliliği arasında güçlü bir pozitif korelasyon tespit etmiştir. Yine, ASEAN+3 (Güneydoğu Asya Ülkeleri Birliği) ülkeleri için 2008-2009 dönemi verilerini kullanarak sağlık harcamalarının verimlilik üzerine etkisini çeşitli panel eşik regresyon modelleri ile inceleyen Osathanunkul vd. (2023), sağlık harcamalarının verimliliği etkili bir şekilde artırdığı bulgusuna ulaşmıştır. Seçilmiş 15 Batı Afrika ülkesi için 1980'den 2022'ye kadar olan dönemi çoklu regresyon analizi ile inceleyen Osim vd. (2024) ise sağlık harcamalarının kısa dönemde iş gücü verimliliğini olumlu etkilerken uzun dönemde bu etkinin tersine döndüğünü vurgulamaktadır.

Günümüzde koruyucu sağlık hizmetleri yanında nakliye ve makineye yapılan yatırımlar ile iş gücü verimliliği arasında da sıkı bir ilişki olduğu varsayılmaktadır. Bu nedenle daha modern ekipmanlar ve etkin nakliye altyapısı, üretim süreçlerini hızlandırır ve maliyetleri düşürür görüşü yaygındır. İş gücünün teknolojiye uyumu ile süreçlerin yeniden düzenlenmesinin de bu artışı desteklediği savunulur. Bu iddiayı Choudhry (2009) tarafından 45 ülke için 1980-2005 dönem için yapılan bir çalışma da desteklemektedir. Söz konusu çalışmanın bulgularına göre, özellikle eğitimle birlikte bilgi ve iletişim yatırımının iş gücü verimliliğini artırmaktadır. Gera vd. (1999) tarafından

Kanada üzerine yapılan çalışma da aşağı yukarı benzer bulguları ortaya koymakta ve bilgi teknolojilerine yapılan yatırımın iş gücü verimliliğini pozitif yönde etkilediğini göstermektedir.

Aynı şekilde dışa açıklık derecesi ile iş gücü verimliliği arasında da bir bağlantı kurulabileceği literatürde sıkılıkla tartışılmaktadır. Kacou vd. (2022) tarafından 61 gelişmekte olan ülke için 1999-2018 dönemini esas alarak yapılan çalışma da dışa açıklığın iş gücü verimliliği üzerinde olumlu etki yarattığı ortaya konmuştur. Çoklu regresyon modeli ile 22 yıllık bir süreci OECD ülkeleri için inceleyen Mallick (2013) ise aynı şekilde küreselleşmenin iş gücü verimliliği üzerinde pozitif ve anlamlı etkisi olduğunu tespit etmiştir.

3. Veri Seti ve Araştırma Yöntemi

Çalışmanın bu bölümünde Avrupa'nın en gelişmiş ve kişi başına düşen geliri yüksek olan seçilmiş beş ülkesi için koruyucu sağlık hizmetlerinin iş gücü verimliliğine etkisi tahmin edilmektedir. Bahsi geçen verimlilikte etkisi olabileceği varsayılan faktörlerden dışa açıklık derecesi, yatırım harcamaları ve beşerî sermaye indeksi gibi değişkenler de yapılacak nedensellik testlerine dâhil edilecektir. Böylece bütün değişkenlerle iş gücü verimliliği arasındaki nedenselliğin yönü panel veri analizi ile tespit edilmeye çalışılacaktır. Bu amaçla öncelikle analizde kullanılacak değişkenler hakkında bilgi verilecek, akabinde de kullanılacak araştırma yöntemi ve buna bağlı yapılacak testlerin teori ve varsayımlarından bahsedilecektir.

3.1. Veri Seti

Bir ekonometrik analizde modeli oluşturan değişkenlerin rakamlarla ifade edilebilir hale getirilebilmesi büyük önem taşımaktadır. Bunun için de literatürde üç farklı veri seti türünden istifade edilmektedir: i) Yatay kesit verileri, ii) Zaman serisi verileri ve iii) Panel veriler. Zaman serileri ve yatay kesit serilerinden farklı olarak panel verilerin özellikle heterojenliği dikkate alması, daha fazla bilgiyi barındırarak çoklu gözlemi mümkün kılması (Hsiao, 2003), gözlem sayısına bağlı olarak tahminlerin güvenilirliğini artırması, çoklu bağlantı problemi ile karşılaşma ihtimalini azaltması, daha karmaşık modelleri oluşturmaya olanak sağlayarak bu modellerin test edilmesini kolaylaştırması (Baltagi, 2005), kısa zaman serileri ya da yetersiz veri durumunda bile ekonometrik analize imkân vermesi, ihmal edilmiş değişkenlerden kaynaklanan sapmaları ortadan kaldırması (Pindyck ve Rubinfeld, 1998) yönüyle analizlerde son derece başarılı olduğu kabul edilmektedir. Bu çalışmada, sıralanan söz konusu üstünlükleri nedeniyle panel veri seti yöntemi tercih edilmiştir.

Analizde koruyucu sağlık hizmetlerine yönelik harcamalar, OECD tarafından geliştirilen ve kamu harcamalarının fonksiyonel sınıflandırması (The Classification of Functions of Government,) olarak bilinen COFOG (bkz. Manuel on sources and methods for compiling COFOG statistics (EU, 2019)) sistemini baz alarak veri setine dâhil edilecektir. OECD'nin veri tabanlarında söz konusu harcamalar, COFOG'un sağlık harcamaları altındaki ikinci kırılımından (Orijinali, "Second-level COFOG- Expenditures on Public Health Services" şeklindedir) biri olarak raporlanmaktadır.

Genel olarak, on farklı kamu harcamasından oluşan ve birinci düzey kırılım olarak adlandırılan COFOG sınıflandırmasına ait verilere farklı ülkeler bazında ulaşmak nispeten daha kolay iken, ikinci kırılım olarak adlandırılan ve bu on harcamanın her birini alt kırılımlara ayıran sınıflandırma verilerine ulaşmak nispeten daha zordur. Bunun temel nedeni, ülkelerin farklı makro

raporlama teknikleri kullanmayı tercih etmeleri ve bu konuda ülkeler arasında bir standardizasyonun mevcut olmamasıdır. Bu nedenle COFOG'un ikinci düzey kırılım verilerini eksiksiz olarak temin etmeleri, ekonomik yapılarının birbirine benzerlik göstermeleri, sağlık hizmetlerine verdikleri önem ve sağlık harcamalarına ayırdıkları pay (OECD, 2023a) ile kişi başına düşen sağlık harcamaları (OECD, 2023c) bağlamında benzerlikleri dolayısıyla analizde Danimarka, Fransa, Lüksemburg, Hollanda ve Norveç'ten müteşekkil beş ülke seçilmiştir. Bu ülkelerden ilk dördünün AB üyesi ülke olduğunu, Norveç'in ise AB üyesi olmayan ancak Avrupa Ekonomik Alanı'na dahil bir ülke olması hasebiyle AB içinde serbest ticaret ve ekonomik entegrasyon avantajlarından faydalandığını ancak AB'nin politika oluşturma sürecine doğrudan katılamadığını burada vurgulamakta fayda vardır.

Öte yandan kamu harcamalarının COFOG'a göre tanzim edilmesine ilk kez 1995 yılında başlandığı için ekonometrik analizimizin başlangıç dönemi olarak 1995 yılı dikkate alınmaktadır. Veri setine ilişin burada belirtilmesi gereken bir diğer önemli husus da 2020 yılının ilk çeyreğinde küresel bir sağlık sorunu haline gelen COVID-19 pandemi gerçeği ve bunun etkisiyle ister istemez kamu sağlık harcamalarında ciddi bir sıçramanın yaşanmasıdır. Bu durumun veri setinde bir farklılaşmaya neden olacağı ve bunun da ekonometrik bulgularda yanıltıcı ve hatta saptırıcı sonuçları ortaya çıkaracağı ihtimaline karşı 2019 sonrası veriler çalışmaya dâhil edilmemiştir. Analizlerde kullanılan değişkenlerin açıklamaları ve veri kaynaklarına dair bilgiler ile değişkenlere ait tanımlayıcı istatistikler sırasıyla Tablo 1 ve 2'de özetlenmiştir.

Tablo 1. Değişkenler ve Veri Kaynakları

Değişken Notasyonu	Açılımı	Değişkenin Açıklaması ve Ölçümü	Kaynak
LnİşgüçVer	İş gücü verimliliği	Saat başı üretilen Reel GSYİH*	OECD
KorSağHiz	Koruyucu sağlık hizmetleri	COFOG 07.4** Koruyucu sağlık hizmetlerine yönelik harcamalar -GSYİH içinde % payı	IMF
LnYatırımHar	Yatırım harcamaları	Makine ve nakliye için yapılan harcamalar-İmalattaki katma değer yüzdesi (%)	WB
LnDışaAç	Dışa açıklık derecesi	Dış ticaret hacminin GSYİH içindeki payı*** (%)	WB
BeşSer	Beşerî sermaye indeksi	Eğitim süresine ve eğitim getirisine dayalı insan sermayesi indeksi	PWT 10.00

Not: GSYİH: Gayri Safi Yurtiçi Hasıla; OECD: Ekonomik İşbirliği ve Kalkınma Örgütü; IMF: Uluslararası Para Fonu; WB: Dünya Bankası; PWT: Penn Dünya Tablosu. *ABD Doları olarak **Orijinali: COFOG 07.4. Expenditure on Public Health Services ***Mal ve hizmet ihracatı ile ithalatı toplamı.

Modelde kullanılan değişkenlere ait açıklamalar ve bu değişkenlerin elde edildiği veri kaynakları Tablo 1'de özetlenmiştir. Söz konusu tablodan görüleceği üzere analize dâhil edilen bazı değişkenlerin doğal logaritmaları alınmıştır. Bunun sebebi ekonometrik analizde logaritmik dönüşümün, orijinal verilerde çarpıklık, değişen varyans veya geniş bir değer aralığı gibi belirli özelliklerin varlığında verinin ölçeğini ayarlamak için en uygun yöntem olmasıdır. Buradaki amaç özellikle veri dağıtımıyla ilgili belirli varsayımlara dayanan istatistiksel modellerle çalışırken, verileri analiz için daha uygun ve yorumlanabilir hale getirmektir.

Tablo 2. Tanımlayıcı İstatistikler

Değişken	Ortalama	Medyan	Maksimum	Minimum	Standart Sapma	Gözlem Sayısı
İş Gücü Verimliliği	4.271162	4.210899	4.651513	3.953876	0.192035	125
Koruyucu Sağlık Hizmetleri	0.134570	0.131541	0.291580	0.014433	0.065006	125
Yatırım Harcamaları	3.010885	3.183145	3.634674	0.482252	0.583413	125
Dışa Açıklık Derecesi	4.653859	4.544358	3.776115	3.776115	0.588720	125
Beşerî Sermaye İndeksi	3.251376	3.272473	2.800899	2.800889	0.232325	125

3.2. Araştırma Yöntemi

İş gücü verimliliği ile bağlantılı dört farklı değişken arasındaki nedensellik ilişkisinin ele alındığı ekonometrik analizde sırasıyla homojenlik testi, yatay kesit bağımlılığı testi ve panel nedensellik testine yer verilmektedir.

3.2.1. Homojenlik Testi

Ekonometrik tahmin modelinde heterojenliğin olup olmadığını tespit edebilmek için Pesaran-Yamagata'nın (2008) Delta testinden faydalanılmıştır. Delta ya da Delta Tilde testi olarak adlandırdıkları homojenlik testini büyük örneklem için önerirken, Düzeltilmiş Delta Tilde (Orijinali, "Delta Tilde Adjusted" şeklindedir) testini ise küçük örneklem için hazırlamışlardır. Bu testlerin varsayımları incelendiğinde temelde Delta ve $Delta_{adj}$ testi T ve N için bir sınırlama koymamaktadır. Bir başka anlatımla, hem T > N hem de N > T durumlarında dengeli ve dengesiz panellerde bu testlerin kullanılabilmesi mümkün olup her ikisi de (1) test istatistiğine dayanarak hesaplanabilmektedir (Pesaran ve Yamagata, 2008).

$$\Delta = \sqrt{N}\left(\frac{N^{-1}\,\hat{S} - k}{\sqrt{2k}}\right) \quad (1)$$

Testin boş ve alternatif hipotezleri ise aşağıdaki gibidir:

H_0: ßi=ß Yatay kesitler boyunca eğim parametreleri homojendir.

H_1: ß ≠ ß$_j$ Yatay kesitler boyunca eğim parametreleri heterojendir.

Yapılacak test sonucunda ortaya çıkan olasılık değeri 0.05'ten küçük olduğunda, %5 istatistiksel anlamlılık düzeyinde H_0 hipotezi reddedilir ve paneli oluşturan yatay kesitlerin heterojen olduğu sonucuna ulaşılır.

3.2.2. Yatay Kesit Bağımlılığı Testi

Ekonometri literatüründe yatay kesit bağımlılığını analiz etmede kullanılan farklı testler mevcuttur. Ancak ekonometrik bir analizde bu testlerden hangisinin kullanılacağına karar verilirken oluşturulan panel veri setinin yatay kesit boyutu olan "N" değeri ile zaman boyutu olan "T" değerine bakılarak karar verilmektedir. Bunun yanında, serilerin homojen veya heterojen olma durumu da test seçiminde göz önünde bulundurulan bir diğer husustur. Bu çalışmada panele dâhil edilen ülkeler (Danimarka, Fransa, Lüksemburg, Hollanda ve Norveç) için N = 5, 1995-2019

döneme ilişkin yıllık veri seti kullanıldığı için T = 25'tir. Bu durumda analizde T > N olduğu için özellikle bu varsayım üzerine kurgulanmış testler tercih edilmiştir.

3.2.2.1. Lagrange Çarpanı (LM) Testi

Breusch ve Pagan (1980) geliştirdikleri Lagrange Çarpanı (LM) testi ile ekonometrik analizlere yeni bir bakış açısı kazandırmışlardır. Hem homojen hem de heterojen paneller için kullanılabilmesi mümkün olan bu test için (2)'deki klasik panel veri modeli dikkate alınmaktadır.

$$y_{\mathrm{it}} = \alpha_{\mathrm{i}} + \beta_i' x_{it} + \mathrm{u}_{\mathrm{it}}, i = 1, 2, \ldots, N;\ t = 1, 2, \ldots, T \qquad (2)$$

Bu panel veri modelinde i, modelin yatay kesit boyutunu; t, zaman serisi boyutunu; β, eğim parametresini; x, bağımsız değişkenini; y bağımlı değişkenini; α, sabit terimini; u da hata terimini göstermektedir. Bahse konu panel veri modelinden hareketle, Breusch ve Pagan (1980) eşitlik (3)'de sunulan LM test istatistiğini geliştirmişlerdir. Burada önemle belirtelim ki, Pesaran'ın (2004) da dikkat çektiği gibi, bu test istatistiği yalnızca T > N durumu için önerilmekte olup N > T durumunda ise kullanımı mümkün olmamaktadır.

$$\mathrm{LM} = \mathrm{T} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} T_i \, \hat{\rho}^2{}_{ij} \qquad (3)$$

(3) ile gösterilen eşitlikte $\rho^{\wedge 2}_{ij}$ ile gösterilen değer, i ve j artıklarının korelasyon katsayısı olarak tanımlanmıştır. Birim boyutu yani N sabit, T sonsuz olduğu durumda LM testi N(N-1)/2 serbestlik derecesinde asimptotik x^2 dağılımı göstermedir. Testin boş ve alternatif hipotezleri ise aşağıdaki gibi belirlenecektir.

H_0: Yatay kesitler arasında yatay kesit bağımlılığı yoktur.

H_1: Yatay kesitler arasında yatay kesit bağımlılığı vardır.

LM testi sonucunda ortaya çıkan olasılık değeri 0.05'ten küçük olduğunda, %5 istatistiksel anlamlılık düzeyinde, H_0 hipotezi reddedilmekte ve buradan hareketle de paneli oluşturan yatay kesitler arasında yatay kesit bağımlılığı olduğu sonucuna ulaşılmaktadır.

3.2.2.2. Ölçeklendirilmiş Lagrange Çarpanı (CDLM) Testi

Bir panelin zaman boyutu, yatay kesit boyutundan büyük (T > N) ise geleneksel zaman serisi teknikleri uygulanabilir. Böyle bir testin en basit örneği Breusch ve Pagan tarafından öne sürülen LM testidir ve bu test bahsedildiği gibi yalnızca T > N durumunda kullanılabilmektedir. Bu testin eksikliği olan N > T durumunda uygulanamaması durumu, standart teknikler dışında yeni yöntemlere başvurmayı gerekli kılmıştır (Pesaran, 2004). Bu eksiklikten yola çıkan Pesaran hem homojen hem de heterojen panellerde kullanılabilen yeni iki farklı test önermiştir. Bunlardan ilki (Orijinali, "Scaled Version of CD_{LM}" şeklindedir) CD_{LM} olarak ana makalede anılan ölçeklendirilmiş CD_{LM} testidir (Pesaran, 2004). Test, (4)'de gösterildiği gibi LM testinin standardize edilmiş bir türevinden geliştirilmiş olup (Demir, 2019) hem T > N hem de N > T durumunda kullanılabilmektedir.

$$\mathrm{CD_{LM}} = \sqrt{\frac{2T}{N(N-1)}} \sum_{\mathrm{i}=1}^{N-1} \sum_{J=i+1}^{N} \left(T\hat{\rho}_{ij}^{2} - 1\right) \tag{4}$$

Pesaran'a (2004) göre bu test, N büyük ve T küçük olduğunda (N>T) önemli ölçüde boyut bozulması sergileme eğilimindedir ve bu durum ekonometrik uygulamalarda çok sık karşılaşılan bir husustur. Bozulmanın temel nedeni, sınırlı bir T için $E(T\hat{\rho}_{ij}^{2})$ değerinin doğru bir şekilde sıfıra yakınsamamış olması gerçeğidir ve N büyük olduğunda LM istatistiğinin yanlış merkezlenmesinin muhtemel olmasıdır. Bu da N arttıkça daha da kötüleşen boyut bozulmalarına neden olacaktır.

3.2.2.3. Yatay Kesit Bağımlılığı (CD) Testi

Breusch-Pagan'ın (1980) LM testi ile Pesaran'ın (2004) ölçeklendirilmiş $\mathrm{CD_{LM}}$ testindeki boyuta bağlı ortaya çıkan bozulmalar Pesaran'ın (2004) makalesinde kesitler arası korelasyon katsayılarının ($\hat{\rho}ij$) ortalamasına dayanan ve (5) ile istatistiği gösterilen ikinci bir test önermesine sebep olmuştur. Bu test hem T > N hem de N > T durumundaki panellerde oldukça güçlüdür. Pesaran'a göre testte CD'nin ortalamasının T > k + 1 ve N sabit olduğunda tam olarak sıfıra eşit olduğu açıktır; bu nedenle test küçük örneklemde de başarılı olacaktır. Bu durum Monte Carlo simülasyonları ile de desteklenmiştir (Pesaran, 2004).

$$\mathrm{CD} = \sqrt{\frac{2T}{N(N-1)}} \left(\sum_{i=1}^{N-1} \sum_{J=i+1}^{N} \hat{\rho} ij\right) \tag{5}$$

Testin hipotezlerine gelince boş ve alternatif hipotezler şu şekilde olacaktır:

H_0: Seriler arasında yatay kesit bağımlılığı yoktur.

H_1: Seriler arasında yatay kesit bağımlılığı vardır.

Yapılacak test sonucunda ortaya çıkan olasılık değeri 0.05'ten küçük olduğunda, %5 istatistiksel anlamlılık düzeyinde, H_0 hipotezi reddedilir ve paneli oluşturan yatay kesitler arasında yatay kesit bağımlılığı olduğu sonucuna ulaşılır.

3.2.2.4. Düzeltilmiş Lagrange Çarpanı (LM-Adjusted) Testi

Pesaran, Ullah ve Yamagata (2008) yaptıkları çalışmalarda Breusch-Pagan LM ve Pesaran CD testlerinde çeşitli sapmalar olduğunu tespit etmişlerdir. Yazarlar, özellikle Pesaran (2004), CD testinin grup ortalamasının ikili korelasyonlarının sıfır olduğu, ancak bireysel ikili korelasyonlarının sıfır olmadığı belirli durumlarda yatay kesit bağımlılığını ölçmede güçsüz kaldığını belirlemişlerdir. Bu sapmayı ortadan kaldırmak için test istatistiğine varyansı ve ortalamayı eklemişler ve (6) ile gösterilen test istatistiğini türetmişlerdir. Test bu düzeltmeler sonucunda sapması düzeltilmiş LM testi ismini almıştır. Söz konusu $\mathrm{LM_{adj}}$ testi genel olarak T > N durumunda özellikle heterojen panel verilerde etkilidir (Pesaran vd., 2008).

$$LM_{adj} = \sqrt{\frac{2}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{J=i+1}^{N} \frac{(\mathrm{T}-\mathrm{k})\rho\hat{}^{2}ij - \mu Tij}{\upsilon \mathrm{Tij}} \tag{6}$$

Testin boş ve alternatif hipotezleri şu şekildedir:

H_0: Yatay kesit bağımlılığı yoktur.

H_1: Yatay kesit bağımlılığı vardır.

Yapılacak test sonucunda ortaya çıkan olasılık değeri 0.05'ten küçük olduğunda, %5 istatistiksel anlamlılık düzeyinde, H_0 hipotezi reddedilir ve paneli oluşturan yatay kesitler arasında bağımlılık olduğu sonucuna ulaşılır.

3.2.3. Bootstrap Panel Granger Nedensellik Testi

Çalışmanın nedensellik testi bölümünde, Kónya (2006) tarafından önerilen ve alternatif ekonometrik yöntemlere göre üç önemli üstünlüğü barındıran bootstrap panel Granger nedensellik testi kullanılacaktır. Bu üstünlüklerden birincisi, gecikme uzunluğuna dayalı bu testin diğer testlerin ön koşulu olan birim kök testi ile eş bütünleşme testine ihtiyaç duymamaktadır. Bir başka ifadeyle testi uygulamak için değişkenlerin durağanlığına bakılmasına gerek yoktur. Ayrıca bu test, eş bütünleşme testleri genel anlamda değişkenler arası uzun dönemli ilişkileri tahmin etmede düşük güce sahip olduğu ve aynı veriler için farklı testler farklı eş bütünleşme neticeleri verdiği (Kónya, 2006) için yapılan söz konusu eş bütünleşme testi sonunda ortaya çıkabilecek sapmalı sonuçları ortadan kaldırmaktadır. İkinci üstünlüğü, yatay kesit bağımlılığını dikkate alan Görünürde SUR (İlişkisiz Regresyon, Orijinali, "Seemingly Unrelated Regression" şeklindedir) tahmin yöntemini kullanmasıdır (Kar vd., 2011). Son olarak söz konusu test, yatay kesitlere özgü bootstrap kritik değerleri ile Wald testini dayanak alarak her bir yatay kesit için ayrı ayrı sonuç üretebilmektedir (Menyah vd., 2014).

Kónya'nın (2006) bootstrap panel Granger nedensellik testine dayanılarak bu çalışmada kullanılacak değişkenler için eşitlik (7)'den (11)'e kadar gösterilen beş farklı istatistik değer ile hesaplama yapılacak ve nedenselliğin yönü tahmin edilecektir.

$$\begin{aligned}\text{LnİşgüçVer}_{1,t} &= \alpha_{1,1} + \sum_{l=1}^{p1} \beta_{1,1,l}\, \text{LnİşgüçVer}_{1,t-1} + \sum_{l=1}^{p1} \delta_{1,1,l}\, \text{KorSağHiz}_{1,t-1} \\ &+ \sum_{l=1}^{p1} \theta_{1,1,l}\, \text{LnYatırımHar}_{1,t-1} + \sum_{l=1}^{p1} \gamma_{1,1,l}\, \text{LnDışaAç}_{1,t-1} \\ &+ \sum_{l=1}^{p1} \omega_{1,1,l}\, \text{BeşSer}_{1,t-1} + \varepsilon_{1,1,t} \\ \text{LnİşgüçVer}_{N,t} &= \alpha_{i,N} + \sum_{l=1}^{p1} \beta_{1,N,l}\, \text{LnİşgüçVer}_{N,t-1} + \sum_{l=1}^{p1} \delta_{1,N,l}\, \text{KorSağHiz}_{N,t-1} \\ &+ \sum_{l=1}^{p1} \theta_{1,N,l}\, \text{LnYatırımHar}_{N,t-1} + \sum_{l=1}^{p1} \gamma_{1,N,l}\, \text{LnDışa Aç}_{N,t-1} \\ &+ \sum_{l=1}^{p1} \omega_{1,N,l}\, \text{BeşSer}_{N,t-1} + \varepsilon_{1,N,t}\end{aligned} \tag{7}$$

$$\begin{aligned}\text{KorSağHiz}_{1,t} = \alpha_{2,1} &+ \sum_{l=1}^{p1} \beta_{2,1,l}\, \text{LnİşgüçVer}_{1,t-1} + \sum_{l=1}^{p1} \delta_{2,1,l}\, \text{KorSağHiz}_{1,t-1} \\ &+ \sum_{l=1}^{p1} \theta_{2,1,l}\, \text{LnYatırımHar}_{1,t-1} + \sum_{l=1}^{p1} \gamma_{2,1,l}\, \text{LnDışaAç}_{1,t-1} \\ &+ \sum_{l=1}^{p1} \omega_{2,1,l}\, \text{BeşSer}_{1,t-1} + \varepsilon_{2,1,t}\end{aligned} \tag{8}$$

$$\begin{aligned}\text{KorSağHiz}_{N,t} = \alpha_{i,N} &+ \sum_{l=1}^{p1} \beta_{2,N,l}\, \text{LnİşgüçVer}_{N,t-1} + \sum_{l=1}^{p1} \delta_{2,N,l}\, \text{KorSağHiz}_{N,t-1} \\ &+ \sum_{l=1}^{p1} \theta_{2,N,l}\, \text{LnYatırımHar}_{N,t-1} + \sum_{l=1}^{p1} \gamma_{2,N,l}\, \text{LnDışa Aç}_{N,t-1} \\ &+ \sum_{l=1}^{p1} \omega_{2,N,l}\, \text{BeşSer}_{N,t-1} + \varepsilon_{2,N,t}\end{aligned}$$

$$\begin{aligned}\text{LnYatırımHar}_{1,t} &= \alpha_{3.1} + \sum_{l=1}^{p1} \beta_{3,1,l}\, \text{LnİşgüçVer}_{1,t-1} + \sum_{l=1}^{p1} \delta_{3,1,l}\, \text{KorSağHiz}_{1,t-1} \\ &+ \sum_{l=1}^{p1} \theta_{3,1,l}\, \text{LnYatırımHar}_{1,t-1} + \sum_{l=1}^{p1} \gamma_{3,1,l}\, \text{LnDışaAç}_{1,t-1} \\ &+ \sum_{l=1}^{p1} \omega_{3,1,l}\, \text{BeşSer}_{1,t-1} + \varepsilon_{3,1,t}\end{aligned} \tag{9}$$

$$\begin{aligned}\text{LnYatırımHar}_{N,t} &= \alpha_{3,N} + \sum_{l=1}^{p1} \beta_{3,N,l}\, \text{LnİşgüçVer}_{N,t-1} + \sum_{l=1}^{p1} \delta_{3,N,l}\, \text{KorSağHiz}_{N,t-1} \\ &+ \sum_{l=1}^{p1} \theta_{3,N,l}\, \text{LnYatırımHar}_{N,t-1} + \sum_{l=1}^{p1} \gamma_{3,N,l}\, \text{LnDışa Aç}_{N,t-1} \\ &+ \sum_{l=1}^{p1} \omega_{3,N,l}\, \text{BeşSer}_{N,t-1} + \varepsilon_{3,N,t}\end{aligned}$$

$$\begin{aligned}\text{LnDışaAç}_{1,t} = \alpha_{4,t} &+ \sum_{l=1}^{p1} \beta_{4,1,l}\, \text{LnİşgüçVer}_{1,t-1} + \sum_{l=1}^{p1} \delta_{4,1,l}\, \text{KorSağHiz}_{1,t-1} \\ &+ \sum_{l=1}^{p1} \theta_{4,1,l}\, \text{LnYatırımHar}_{1,t-1} + \sum_{l=1}^{p1} \gamma_{4,1,l}\, \text{LnDışaAç}_{1,t-1} \\ &+ \sum_{l=1}^{p1} \omega_{4,1,l}\, \text{BeşSer}_{1,t-1} + \varepsilon_{4,1,t}\end{aligned} \tag{10}$$

$$
\begin{aligned}
\mathrm{LnDışaAç}_{N,t} &= \alpha_{4,N} + \sum_{l=1}^{p1} \beta_{4,N,l}\, \mathrm{LnİşgüçVer}_{N,t-1} + \sum_{l=1}^{p1} \delta_{4,N,l}\, \mathrm{KorSağHiz}_{N,t-1} \\
&\quad + \sum_{l=1}^{p1} \theta_{4,N,l}\, \mathrm{LnYatırımHar}_{N,t-1} + \sum_{l=1}^{p1} \gamma_{4,N,l}\, \mathrm{LnDışa\ Aç}_{N,t-1} \\
&\quad + \sum_{l=1}^{p1} \omega_{4,N,l}\, \mathrm{BeşSer}_{N,t-1} + \varepsilon_{4,N,t} \\
\mathrm{BeşSer}_{1,t} &= \alpha_{5,t} + \sum_{l=1}^{p1} \beta_{5,1,l}\, \mathrm{LnİşgüçVer}_{1,t-1} + \sum_{l=1}^{p1} \delta_{5,1,l}\, \mathrm{KorSağHiz}_{1,t-1} \\
&\quad + \sum_{l=1}^{p1} \theta_{5,1,l}\, \mathrm{LnYatırımHar}_{1,t-1} + \sum_{l=1}^{p1} \gamma_{5,1,l}\, \mathrm{LnDışaAç}_{1,t-1} \\
&\quad + \sum_{l=1}^{p1} \omega_{5,1,l}\, \mathrm{BeşSer}_{1,t-1} + \varepsilon_{5,1,t} \\
\mathrm{BeşSer}_{N,t} &= \alpha_{5,N} + \sum_{l=1}^{p1} \beta_{5,N,l}\, \mathrm{LnİşgüçVer}_{N,t-1} + \sum_{l=1}^{p1} \delta_{5,N,l}\, \mathrm{KorSağHiz}_{N,t-1} \\
&\quad + \sum_{l=1}^{p1} \theta_{5,N,l}\, \mathrm{LnYatırımHar}_{N,t-1} + \sum_{l=1}^{p1} \gamma_{5,N,l}\, \mathrm{LnDışaAç}_{N,t-1} \\
&\quad + \sum_{l=1}^{p1} \omega_{5,N,l}\, \mathrm{BeşSer}_{N,t-1} + \varepsilon_{5,N,t}
\end{aligned}
\tag{11}
$$

(7)'den (11)'e kadarki eşitliklerde yer alan İşgüçVer, KorSağHiz, YatırımHar, DışaAç ve BeşSer, notasyonları ile belirtilen değişkenler daha önce de belirtildiği gibi sırasıyla iş gücü verimliliği, koruyucu sağlık hizmetlerine yönelik sağlık harcamalarını, yatırım harcamalarını, ekonominin dışa açıklık derecesini ve beşerî sermaye indeksini göstermektedir. N paneldeki ülke sayısını (i = 1, 2, 3, ..., N), t zamanı (t = 1, 2, 3, ..., T), l gecikme uzunluğunu ve $\varepsilon 1Nt$, $\varepsilon 2Nt$, $\varepsilon 3Nt$, $\varepsilon 4Nt$ ve $\varepsilon 5Nt$ ise belli bir ülke bazında ilişkilendirilebilirken, ülkeler arasında ilişkilendirilemeyen beyaz gürültü (white-noise) olduğu kabul edilen hata terimlerini göstermektedir (Kónya, 2006).

4. Ekonometrik Analiz ve Bulgular

Bu bölümde örnekleme dâhil edilen ülkelerde 1995-2019 dönemi için koruyucu sağlık hizmetlerine yönelik harcamaların iş gücü verimliliği üzerindeki etkisi söz konusu verimlilik üzerine etkili olabileceği varsayılan belirlenmiş bazı faktörler de dikkate alınarak panel veri analizi ile ortaya koyulmaya çalışılacaktır.

4.1. Homojenlik Testi

Nedensellik testine tabi tutulacak paneli oluşturan tüm değişkenler üzerindeki muhtemel zaman veya birim etki hakkında bir çıkarım yapabilmek için Pesaran-Yamagata (2008) tarafından önerilen homojenlik testi yapılmış ve test sonuçları da Tablo 3'te sunulmuştur. Tablo 3'deki

sonuçlara göre hem delta hem de $delta_{adj}$ testlerinde olasılık değerleri 0.05'ten küçüktür. Bu durumda H_0 reddedilir ve modeli oluşturan değişkenlerin eğim katsayılarının heterojen olduğu sonucuna ulaşılır.

Tablo 3. Homojenlik Testi Sonuçları

Test	Test İstatistiği	Prob Değeri
Delta	9.388	0.000
$Delta_{adj}$	10.769	0.000

4.2. Yatay Kesit Bağlamlılığı Testi

Modelde yatay kesit bağımlılığının olup olmadığı incelenirken Breusch ve Pagan (1980) LM, Pesaran (2004) CD_{LM}, Pesaran (2004) CD ve Pesaran-Ullah-Yamagata LM_{adj} testlerinden faydalanılmıştır. Modelde kullanılan değişkenlere ve modelin geneline dair yatay kesit bağımlılığı test sonuçları Tablo 4'te sunulmuştur. Tablo 4'te CD'nin tespiti için farklı yazarlar tarafından ileri sürülen test sonuçlarından elde edilen değerler incelendiğinde tüm testlerde istatistiki olarak anlamlı bir şekilde "H_0 = Yatay kesit bağımlılığı yoktur" hipotezi güçlü bir şekilde reddedilmiş hem değişken bazında hem de modelin tamamında yatay kesit bağımlılığının mevcut olduğu tespit edilmiştir.

Tablo 4. Yatay Kesit Bağımlılığı Test Sonuçları

Değişken	Breusch-Pagan (1980) LM		Pesaran (2004) Scaled LM (CD_{LM})		Pesaran (2004) CD		Pesaran-Ullah-Yamagata (2008) LM_{adj}	
	İstatistik	Prob	İstatistik	Prob	İstatistik	Prob	İstatistik	Prob
LnİşgüçVer	195.56	0.0000	41.49	0.0000	13.93	0.0000	59.37	0.0000
KorSağHiz	62.36	0.0000	11.71	0.0000	6.59	0.0000	5.547	0.0000
LnYatırımHar	77.20	0.0000	15.03	0.0000	7.008	0.0000	11.89	0.0000
LnDışaAç	132.44	0.0000	27.38	0.0000	9.37	0.0000	44.49	0.0000
BeşSer	242.95	0.0000	52.09	0.0000	15.59	0.0000	55.77	0.0000
Model için	25.57	0.0044	1.95	0.0412	4.50	0.0000	7.716	0.0000

4.3. Bootstrap Panel Granger Nedensellik Testi

Analize dâhil edilen beş ülke için yatay kesit bağımlılığı ve eğim heterojenliği farklı testlerle sınanarak tespit edildikten sonra elde edilen sonuçlar, Kónya (2006) tarafından geliştirilen bootstrap panel nedensellik testinin yapılabilmesi için uygun şartların oluştuğunu göstermektedir. Bu aşamada değişkenler için farklı ancak modelin tamamı için aynı olması gereken gecikme uzunluğunu tespit etmek gerekecektir. Uygulanacak olan bootstrap panel Granger nedensellik testi, Granger nedensellik testine dayandığı için optimal gecikme uzunluğunun seçilmesi önem arz etmektedir (Şen vd., 2018). (7)'den (11)'ye kadar olan eşitliklerde de belirtildiği gibi p1'den p5'e kadar her bir nedensellik testi için bir ile dört arası gecikme tahmine dâhil edilecektir.

İş gücü verimliliği ile koruyucu sağlık hizmetlerine yönelik sağlık harcamaları arasındaki nedensellik ilişkisine dair sonuçlar Tablo 5'te sunulmuştur. Söz konusu tablodan görüldüğü üzere Danimarka, Fransa ve Hollanda'da iş gücü verimliliğinden koruyucu sağlık hizmetlerine doğru %1 istatistiksel anlamlılık düzeyinde güçlü bir Granger nedensellik ilişkisi söz konusudur. Yine, koruyucu sağlık hizmetlerine yönelik harcamalardan iş gücü verimliliğine doğru analize dâhil edilen

tüm ülkelerde %1 istatistiksel anlamlılık düzeyinde güçlü ve pozitif bir Granger nedensellik ilişkisi mevcuttur.

Tablo 5. İş Gücü Verimliliği ile Koruyucu Sağlık Hizmetlerine Yönelik Harcamalar Arasındaki Granger Nedensellik İlişkisi

Ülke	Tahmin Edilen Katsayı	Wald Test İstatistik Değeri	Bootstrap Kritik Değerleri		
			%1	%5	%10
		H_0= İşgüçVer, KorSağHiz'nin nedeni değildir.			
Danimarka	0.12675	5.822*	0.673	0.621	0.598
Fransa	0.02843	0.497*	0.242	0.181	0.151
Lüksemburg	0.02756	0.048	0.117	0.086	0.068
Hollanda	0.11491	2.824*	0.488	0.355	0.248
Norveç	-0.00602	0.007	2.218	1.953	1.806
		H_0= KorSağHiz, İşgüçVer'in nedeni değildir.			
Danimarka	0.87846	7.742*	0.362	0.342	0.337
Fransa	0.95825	2.406*	0.523	0.517	0.515
Lüksemburg	0.77741	0.229*	0.032	0.030	0.028
Hollanda	0.95231	0.853*	0.561	0.545	0.537
Norveç	0.80651	5.898*	0.185	0.182	0.181

Not: Kullanılan veri 1995-2019 arasını kapsamakta olup, kritik değerler 500 Bootstrap replications üzerinden hesap edilmiştir. *, **, *** istatistiksel olarak sırasıyla %1, %5 ve %10 anlamlılık düzeylerinde H_0 hipotezinin reddini ifade eder. Sonuçlar, Gauss 24 paket programına dayanmaktadır. Çalışmanın veri setinin dönemsel uzunluğuna bağlı olarak söz konusu paket program, maksimum lag uzunluğunu "1" olarak tayin etmiştir. Öte yandan, bilgi kriteri olarak da Akaika bilgi kriteri (AIC) seçilmiştir.

Elde edilen ekonometrik sonuçlar, incelenen dönem bağlamında ve analize dâhil edilen beş ülke için değerlendirildiğinde koruyucu sağlık hizmetleri ile iş gücü verimliliği arasında teorik beklentilere paralel şekilde Danimarka, Fransa ve Hollanda için karşılıklı ve pozitif katsayılı bir nedensellik ilişkisinin mevcut olduğunu gösterirken aynı ilişkinin Norveç ve Lüksemburg için tek yönlü ve pozitif katsayılı olduğu tespit edilmektedir. Yine bu sonuçlar koruyucu sağlık hizmetlerine yönelik yapılan harcamaların iş gücü verimliliğini, dolayısıyla büyümeyi artırır yönde bir etki yarattığı kanısını doğrular niteliktedir.

Analiz bulgularına göre Norveç'te iş gücü verimliliğinden koruyucu sağlık hizmetlerine doğru nedenselliğin anlamsız bulunma nedeninin ülkenin yeraltı zenginliklerine bağlı güçlü finansal yapısı olduğu düşünülmektedir. Devlet bu yeraltı zenginliğine dayanarak dünyanın en büyük varlık fonunu kurmuş ve bu fonun gelirini daha çok eğitim alanında kullanmıştır. Dolayısıyla Norveç söz konusu fon sayesinde çok vasıflı iş gücü ile birlikte, yine çok güçlü bir refah sistemi ve kamu altyapısı elde etmiştir. Lüksemburg ise yatırım fonları ve varlık yönetimi konusunda lider konumu ile Avrupa'nın en büyük yatırım fonu merkezi olarak bilinmektedir. Bu liderliği kazanmasına sebep olan en önemli faktör ülkenin vergi politikalarıdır ki bu politikalarla vergi avantajları ve bu avantajları sunmak için yaptığı kapsamlı vergilendirme anlaşmaları ile hem bireysel hem de kurumsal yatırımcılar için cazip bir vergi ortamı yaratmaktadır. Böylece ülke global yatırımcılar ve şirketler için büyük bir avantaj sunmakla birlikte bu sayede ciddi oranda istihdam ve ekonomik büyüme de sağlamaktadır (KPMG, 2024). Bu ekonomik güçten beslenen Lüksemburg ve Norveç aynı zamanda etkili birer sosyal devlet kültürü sürdürmektedir. Dolayısıyla ülkelerde güçlü sosyal güvenlik ağları ve işçi hakları bulunmaktadır. Bu bulgudan hareketle, "Norveç ve Lüksemburg koruyucu sağlık hizmetlerini yalnızca iş gücü verimliliğini artırmak için değil aynı zamanda refah devleti olmanın

gerekliliklerini yerine getirmek için de yapmaktadır" şeklinde bir çıkarımda bulunmak mümkündür. Bu çıkarımdan hareketle de koruyucu sağlık hizmetlerinin yegâne sebebinin iş gücü verimliliğini sağlamak olmadığı iddia edilebilir.

Netice olarak analiz bulguları, koruyucu sağlık hizmetlerinden iş gücü verimliliğine doğru istatistiksel olarak güçlü ve yaklaşık %0,78 ile %0,96 arasında değişen bir katsayı ile nedensellik ilişkisi olduğunu ancak iş gücü verimliliğinden koruyucu sağlık hizmetlerine doğru bir nedenselliğin analize konu olan her ülkede mevcut olmadığını göstermektedir.

Tablo 6'da iş gücü verimliliği ile yatırım harcamaları arasındaki Granger nedensellik ilişkisine dair bulgular özetlenmiştir. Söz konusu tablodan görüldüğü üzere Danimarka, Fransa, Lüksemburg ve Hollanda için iş gücü verimliliğinden yatırım harcamalarına doğru yine %1 istatistiksel anlamlılık düzeyinde güçlü bir Granger nedensellik ilişkisi mevcut iken, yatırım harcamalarından iş gücü verimliliğine doğru Granger nedenselliğin yalnızca Danimarka, Fransa ve Hollanda için mevcut olduğu görülmektedir. Öte yandan bulgulara ilişkin katsayıların (Lüksemburg için iş gücü verimliliğinden yatırıma doğru olan nedensellik ilişkisi hariç) tamamı pozitiftir.

Tablo 6. İş Gücü Verimliliği ile Yatırım Harcamaları Arasındaki Granger Nedensellik İlişkisi

Ülke	Tahmin Edilen Katsayı	Wald Test İstatistik Değeri	Bootstrap Kritik Değerleri		
			%1	%5	%10
H_0= İşgüçVer, YatırımHar'ın nedeni değildir.					
Danimarka	0.76298	9.667*	0.521	0.358	0.244
Fransa	0.75679	18.814*	0.070	0.058	0.052
Lüksemburg	-2.43979	1.072*	0.359	0.272	0.232
Hollanda	0.50893	2.589*	0.363	0.284	0.255
Norveç	0.37165	1.551	1.906	1.658	1.556
H_0= YatırımHar, İşgüçVer'in nedeni değildir.					
Danimarka	0.94903	8.192*	0.732	0.711	0.697
Fransa	0.89748	5.443*	0.000	0.000	0.000
Lüksemburg	0.74676	0.149	0.892	0.876	0.868
Hollanda	0.84501	2.886*	0.005	0.004	0.004
Norveç	0.83279	0.282	0.807	0.801	0.798

Not: Kullanılan veri 1995-2019 arasını kapsamakta olup, kritik değerler 500 Bootstrap replications üzerinden hesap edilmiştir. *, **, *** istatistiksel olarak sırasıyla %1, %5 ve %10 düzeylerinde H_0 hipotezinin reddini ifade eder. Sonuçlar, Gauss 24 paket programına dayanmaktadır. Çalışmanın veri setinin dönemsel uzunluğuna bağlı olarak söz konusu paket program, maksimum lag uzunluğunu "1" olarak tayin etmiştir. Öte yandan, bilgi kriteri olarak da Akaika bilgi kriteri (AIC) seçilmiştir.

Tablo 6'dan da anlaşılacağı üzere Lüksemburg için iş gücü verimliliğinden yatırıma doğru güçlü bir nedensellik ilişkisi vardır ancak bu nedenselliğin yönü negatiftir; aynı zamanda yine bu ülkede yatırım, iş gücü verimliliğinin sebebi değildir. Bir başka anlatımla, yatırımdan iş gücü verimliliğine doğru bir nedensellik yokken iş gücü verimliliği ile yatırım arasındaki etkileşim ters yönlüdür. Beklenen, iş gücü verimliliğindeki artışın yatırımı artırması iken bunun tam tersi bir sonucun çıkma sebebi ülkenin rekabetçi ancak esnek olmayan iş gücü piyasasına sahip olması ile açıklanabilir (Ayrıntılı bilgi için bkz. Index of Economic Freedom, 2024). Bunun yanı sıra halihazırda dünyanın en açık ve en dinamik ekonomilerinden biri olan Lüksemburg'un iş gücü verimliliğindeki başarısının altında çok dilli ve vasıflı uluslararası iş gücü gösterilmektedir (Ayrıntılı bilgi için bkz. Portrait of the Luxembourg Economy, 2024). Buna rağmen ülkede son yıllarda baş

gösteren ve literatürde de sıkça tartışılan iş uyumsuzluğu (Bu husus uluslararası literatürde "skill-mismatch" olarak adlandırılmaktadır) problemi sebebiyle önemli iş alanlarında eksik istihdam bulunmaktadır. Ülkenin finansal ve yönetim alanı dâhil olmak üzere bilgi teknolojileri ve lojistik alanında uzman mühendis ve doktor ihtiyacı halen mevcuttur (European Union, 2016a). Buna rağmen ülke yatırımlarına devam ederek uluslararası iş gücü piyasasından iş gücü talep etmeye devam etmektedir. Ülkenin yatırımlarını sürdürmesinin en önemli nedeni ise yine güçlü finansal yapısı olarak karşımıza çıkmaktadır. Ülke ekonomisi büyük ölçüde bankacılık sektörüne dayalıdır ve bu sektör ülkenin brüt katma değerinin neredeyse %25'ine, mali gelirlerin yine %25'ine ve toplam istihdamın %12'sine denk gelmektedir (Ayrıntılı bilgi için bkz. Investment in Luxembourg, 2024). Lüksemburg'un bu güçlü ekonomisinin ülkeye giren yüksek sermayeli yatırım ile ilgili olduğu bilinen bir gerçektir. Ancak yüksek sermaye girişi bir ülkede iş gücü verimliliğini artırabilirken aynı zamanda söz konusu verimlilik üzerinde etkisiz de olabilir. Örneğin, finans sektöründeki yatırımların büyük bir kısmı bilgi teknolojisi veya otomasyon gibi alanlara yönelmiş olabilir. Bu da fiziksel sermaye yoğun sektörlerdeki iş gücü verimliliğine doğrudan bir etki yapamaz. Bahsedilen sebepler nedeniyle Lüksemburg için iş gücü verimliliğinden yatırımlara doğru güçlü bir nedensellik ilişkisi olsa da bu nedenselliğin katsayısının negatif olması ise yatırımdan iş gücü verimliliğine doğru bir nedenselliğin olmamasının sebepleri olarak değerlendirilmektedir.

Aynı nedensellik ilişkisi Norveç için ele alındığında değişkenler arasında her iki yönde de nedenselliğin bu ülke için anlamsız olarak bulunması yine ülkenin mevcut güçlü ekonomik yapısı ile açıklanabilir. Norveç söz konusu ekonomik gücü nedeniyle yatırımların tek sebebi olarak iş gücü verimliliğini dikkate almamaktadır. Bunun yerine, sosyal devlet anlayışını benimsemiş olmaktan kaynaklı yatırım yaparken istihdamı artırıp işçiye daha iyi çalışma koşulları sağlamaktadır. Buna dayanarak ülke yatırımlarını iş gücü verimliliğinden bağımsız bir şekilde istediği kadar artırabilme gücüne sahip olduğu için bu iki değişken arasındaki nedensellik ilişkisi anlamsız olarak bulunabilir ve Norveç'te iş gücü verimliliği ile yatırım harcamaları arasında herhangi bir nedensellik ilişkisinin ortaya çıkmaması beklenebilir.

Çalışmanın bulgularına göre iş gücü verimliliği ile yatırım harcamaları arasındaki nedensellik ilişkisi yine büyük ölçüde literatürdeki teorik beklentilere uygun olarak Norveç hariç diğer örneklem ülkelerinde çift yönlüdür. Dolayısıyla elde edilen bulgular makine ve teçhizat ile nakliyeye yapılan yatırımlar ve iş gücü verimliliği arasında pozitif ve iki taraflı bir nedensellik ilişkisi olduğunu ortaya koymaktadır.

Tablo 7 ise ekonominin dışa açıklık derecesi ile iş gücü verimliliği arasındaki Granger nedensellik ilişkisini ortaya koymaktadır. Analize dâhil edilen beş ülkede iş gücü verimliliğinden ülke ekonomilerinin dışa açıklık derecesine doğru güçlü bir Granger nedensellik ilişkisi mevcuttur. Yine aynı tabloda görüleceği üzere, Norveç dışındaki diğer dört ülkede de dışa açıklık derecesinden iş gücü verimliliğine doğru Granger nedenselliği mevcuttur. Nedenselliğin yönü analize konu ülkelerin dışa açıklık derecesinden iş gücü verimliliğine doğru pozitif yönlü iken, iş gücü verimliliğinden dışa açıklık derecesine doğru büyük ölçüde negatif yönlüdür.

Tablo 7. İş Gücü Verimliliği ile Dışa Açıklık Derecesi Arasındaki Granger Nedensellik İlişkisi

Ülke	Tahmin Edilen Katsayı	Wald Test İstatistik Değeri	Bootstrap Kritik Değerleri		
			%1	%5	%10
		H_0= İşgüçVer, DışaAç'ın nedeni değildir			
Danimarka	0.27775	1.770*	0.077	0.067	0.061
Fransa	-0.12187	0.557*	0.024	0.022	0.020
Lüksemburg	-0.35471	1.149*	1.125	0.111	0.102
Hollanda	0.17510	1.256*	0.203	0.200	0.197
Norveç	-0.13157	2.923*	1.204	1.191	1.187
		H_0= DışaAç, İşgüçVer'in nedeni değildir.			
Danimarka	1.12860	4.553*	0.427	0.405	0.395
Fransa	0.84028	3.926*	0.179	0.178	1.176
Lüksemburg	0.70435	0.182*	0.001	0.002	0.000
Hollanda	0.94703	1.508*	0.021	0.019	0.017
Norveç	0.84892	0.376	0.647	0.640	0.637

Not: Kullanılan veri 1995-2019 arasını kapsamakta olup, kritik değerler 500 Bootstrap replications üzerinden hesap edilmiştir. *, **, *** istatistiksel olarak sırasıyla %1, %5 ve %10 anlamlılık düzeylerinde H_0 hipotezinin reddini ifade eder. Sonuçlar, Gauss 24 paket programına dayanmaktadır. Çalışmanın veri setinin dönemsel uzunluğuna bağlı olarak söz konusu paket program, maksimum lag uzunluğunu "1" olarak tayin etmiştir. Öte yandan, bilgi kriteri olarak da Akaika bilgi kriteri (AIC) seçilmiştir.

Ekonomilerin dışa açıklık derecesi globalleşmeyle çok yakından ilişkilidir. Hatta öyleki ekonomilerin dışa açıklık derecesi yerine zaman zaman ekonomik globalleşme eşdeğer manada kullanılmaktadır. Bu sebeple iş gücü verimliliği ve büyüme üzerinde ülkelere özgü nedenlere bağlı olarak farklı sonuçlar doğurabilmektedir. Özellikle teknolojik gelişmelerle desteklenen dışa açıklık derecesinin artması, nitelikli iş gücüne olan talebi artırabilir. Dolayısıyla ülkede vasıflı işçi varsa iş gücü verimi artacak, bu nitelikteki işçi yoksa iş gücü verimi azalacaktır (Atkinson, 2015). Analiz sonucu göstermektedir ki, incelenen beş ülkede de iş gücü verimliliği dışa açıklığın sebebidir. Ancak bu nedenselliğin yönü Fransa, Lüksemburg ve Norveç için negatiftir. Diğer bir ifadeyle, dışa açıklık derecesinin artmasıyla bu ülkelerde iş gücü verimliliği olumsuz yönde etkilenmektedir. Norveç için bu durum değerlendirildiğinde ülkenin yeraltı zenginliğinden kaynaklı bir sonuca ulaşılabilmektedir. Dolayısıyla Norveç yeraltı kaynaklarını satmak için dış pazara entegre olurken, iş gücü verimliliği ile ilgili pozitif bir katsayı alması (bir başka ifadeyle pozitif bir ilişkide olması) akılcı bir beklenti olmayacaktır. Tablo 7'nin ikinci kısmı incelendiğinde Norveç için dışa açıklık derecesinden iş gücü verimliliğine doğru nedensellik ilişkisinin istatistiksel olarak anlamsız bulunduğu dikkat çekmektedir. Bunun nedeni olarak Norveç'in devlet varlık fonuna sahip olması gösterilebilir. Norveç doğal kaynaklarından elde ettiği geliri, kurduğu bu fona aktararak dünyanın en büyük varlık fonunu oluşturmuştur. Bu fonun anaparası hükümet tarafından kullanılamamakla birlikte fonun yatırımlarından elde edilen kazanç özellikle daha kalifiye iş gücü elde edebilmek için eğitim sistemine yönlendirilmektedir. Dolayısıyla bu fon sayesinde çok vasıflı iş gücü ile birlikte, güçlü bir refah sistemi ve kamu altyapısı elde edilmektedir (Pangean, 2020). Bu nedenle ekonominin dışa açıklık derecesi iş gücü verimliliğini etkilememekte; ancak ülke sahip olduğu eğitim altyapısını etkin kullanarak vasıflı iş gücü arzını artırarak maksimum verim almayı hedeflemektedir.

Yine yapılan analizin bulgularına Lüksemburg özelinde bakıldığında iş gücü verimliliğinin bu ülkenin dışa açıklık derecesinin nedeni olmasına karşın, bu nedenselliğe ilişkin yönün negatif olması oldukça dikkat çekicidir. Bu durumu Lüksemburg'un Norveç'e benzeyen bir özelliği ile açıklamak mümkündür. Şöyle ki Lüksemburg'un finansal gücü uluslararası yatırım ve bankacılık sektöründen geldiği için doğal olarak ülkenin dışa açıklık derecesi yüksek olacaktır. Buna karşın dışa açıklık derecesi belirgin bir şekilde yüksek iken bu yüksek dışa açıklık derecesinin iş gücü ve onun verimliliği ile ilgisi olmadığı için nedenselliğin yine negatif yönlü olması normal bir durum olarak ortaya çıkmaktadır.

Analiz bulgularına Fransa için bakıldığında ise durumun Norveç ve Lüksemburg'a göre biraz farklılık arz ettiği görülmektedir. Şöyle ki, Fransa'nın sahip olduğu iş gücü piyasası son dönemde özellikle bazı meslek gruplarında iş gücü fazlalığı, bazılarında ise iş gücü yetersizliği ile yüz yüzedir. Fransa, özellikle bilişim ve iletişim, sağlık, mühendislik, finans ve hukuk sektörü gibi alanlarda vasıflı işçi ve uzman gerektiren alanlarda iş gücü yetersizliği ile karşı karşıyadır. Ülke aynı zamanda dışa açıklık derecesi yüksek bir ülkedir (European Union, 2016b). Netice itibariyle yüksek dışa açıklık kalifiye iş gücüne talebi artıran bir unsur olarak ortaya çıkmaktadır. Fransa'nın artan kalifiye iş gücü talebini karşılayamaması, beklentilerin aksine iş gücü verimliliği ile dışa açıklık derecesi arasında ters yönlü bir ilişki olduğu sonucunu doğurmaktadır.

Tablo 8 ise iş gücü verimliliği ile beşerî sermaye arasındaki Granger nedensellik ilişkisini ortaya koymaktadır. Söz konusu tablodan da görüleceği üzere analize dâhil edilen beş ülkede iş gücü verimliliğinden beşerî sermaye doğru güçlü bir nedensellik ilişkisi mevcuttur. Yine aynı tablo, Norveç hariç dört ülke (Danimarka, Fransa, Lüksemburg ve Hollanda) için beşerî sermaye indeksinden iş gücü verimliliğine doğru yine güçlü bir nedensellik ilişkisi olduğunu göstermektedir.

Tablo 8. İş Gücü Verimliliği ile Beşerî Sermaye İndeksi Arasındaki Granger Nedensellik İlişkisi

Ülke	Tahmin Edilen Katsayı	Wald Test İstatistik Değeri	Bootstrap Kritik Değerleri		
			%1	%5	%10
		H_0= İşgüçVer, BeşSer'in nedeni değildir.			
Danimarka	-0.00999	0.100*	0.060	0.057	0.055
Fransa	0.03978	24.030*	0.031	0.029	0.028
Lüksemburg	0.08041	22.464*	0.119	0.115	0.113
Hollanda	-0.01542	32.709*	0.179	0.174	0.172
Norveç	0.07633	23.673*	1.289	1.277	1.267
		H_0= BeşSer, İşgüçVer'in nedeni değildir.			
Danimarka	0.68425	4.513*	0.172	0.163	0.157
Fransa	0.86910	1.178*	0.110	0.109	0.108
Lüksemburg	0.82382	0.445*	0.122	0.117	0.114
Hollanda	0.97826	1.164*	0.126	0.121	0.117
Norveç	0.87077	0.132	0.385	0.381	0.379

Not: Kullanılan veri 1995-2019 arasını kapsamakta olup, kritik değerler 500 Bootstrap replications üzerinden hesap edilmiştir. *, **, *** istatistiksel olarak sırasıyla %1, %5 ve %10 düzeylerinde H_0 hipotezinin reddini ifade eder. Sonuçlar, Gauss 24 paket programına dayanmaktadır. Çalışmanın veri setinin dönemsel uzunluğuna bağlı olarak söz konusu paket program, maksimum lag uzunluğunu "1" olarak tayin etmiştir. Öte yandan, bilgi kriteri olarak da Akaika bilgi kriteri (AIC) seçilmiştir.

Tablo 8 incelendiğinde elde edilen bulgular, iş gücü verimliliğinden beşerî sermayeye doğru Granger nedenselliğinin analize dâhil edilen beş ülke için de geçerli olduğunu ortaya koymakta ancak bu nedenselliğin beklenenin aksine incelemeye konu edilen ülkelerden Danimarka ve Hollanda için negatif yönlü olduğunu göstermektedir. İş gücü verimliliği ile beşerî sermaye arasındaki ilişki incelendiğinde teorik beklentiden farklı olarak bazı ülkeler için Granger nedenselliğinin yönünün negatif olması çeşitli nedenlere bağlanabilir. Her şeyden önce son yıllarda ilgili ülke verilerine bakıldığında, hükümetlerin büyümenin temel itici gücü olarak gördükleri eğitime bütçelerinden daha büyük bir pay ayırmaya başladıkları ve bunun sonucunda çalışanların eğitiminde önemli ölçüde artış sağladıkları görülmektedir. Örneğin, halihazırdaki AB üyesi ülkelerde 2009 yılında 20-64 yaş aralığındaki yükseköğretim mezunu bireylerin oranı %28,1 iken, bu oran 2023 yılında %38,8'e ulaşmıştır (Eurostat, 2023). Bu konuda AB'nin öncelikli hedeflerinden biri, 2030 yılına kadar 25-34 yaş aralığındaki bireylerin %45'inin yükseköğretim eğitimi almalarını sağlamaktır (European Commission, 2021: 95).

Ancak böyle bir durumun neredeyse yarım asır önce Freeman (1976) tarafından da dikkat çekildiği gibi iş uyumsuzluğu olgusunu ortaya çıkarma ihtimali söz konusu olabilecektir (İş uyumsuzluğu iki ayrı sorundan kaynaklanmaktadır. Bunlardan birincisi işçiye işin gereğinden fazla eğitim vermek iken diğeri ise söz konusu işçiye işin gereğinin altında eğitim vermektir. Literatür ilkini iş gereğinin üzerinde eğitim (overeducation) olarak adlandırırken ikincisini ise iş gereğinin altında eğitim (undereducation) olarak tanımlamaktadır (Cedefop, 2010)). Bu olgu, çalışanların sahip olduğu eğitim düzeyi ile işinin gerektirdiği eğitim seviyesi arasındaki uyumsuzluğa işaret etmektedir. İşin gerektirdiğinin üzerinde alınan eğitim, AB'nin özellikle ileri düzey sanayileşmiş ülkeleri için son yıllarda daha da belirgin bir hal almıştır. Söz konusu durum, daha ziyade eğitim düzeyi yüksek iş gücü arzındaki artışla birlikte eğitimli bireyler arasında daha düşük maaş, kariyer gelişiminde kısıtlama ve dolayısıyla iş tatmininde bir düşüş şeklinde kendini göstermektedir. Tüm bunlar da ortaya çıkardığı psikolojik etki ile çalışanların verimliliklerinde ve dolayısıyla genel işgücü verimliliğinde azalışı beraberinde getirmektedir (Giuliano vd., 2024).

Danimarka, Avrupa ülkeleri arasında eğitime yaptığı yatırımlarla adından sıkça bahsedilen bir ülkedir. Danimarka hükümeti söz konusu eğitim yatırımlarını yalnızca kendi vatandaşlarına yönelik değil aynı zamanda ülkedeki göçmenleri de kapsayacak şekilde yapmaktadır. Bunun sonucunda ülkede iş gereğinin üzerinde eğitim olgusu ortaya çıkmakta ve bu seviyede eğitim almış bireylerin iş gücü verimliliğini tam anlamıyla kullanamadıkları ve niteliklerine uygun işlerde çalışamadıkları için olması gerekenin altında bir gelirle çalışmak zorunda kalmaktadırlar (Nielsen, 2011). Dolayısıyla Danimarka için beşerî sermaye ile iş gücü verimliliği arasında pozitif yönlü bir nedensellik ilişkisi mevcuttur ancak işin gerektirdiğinden fazla eğitimle donanmak bu iki değişken arasındaki ilişkinin negatif yönlü olması sonucunu doğurmaktadır. Aynı hususa Hollanda özelinde bakıldığında ise sorunun Danimarka ile hemen hemen benzer nitelik taşıdığı; bu ülkede işin gereğinden fazla alınan eğitimin getirisinin pozitif olduğu ancak gerekli eğitimin getirisinden daha düşük olduğu dikkat çekmektedir (Hartog vd., 1999). Sonuç olarak iş gücü verimliliği beşerî sermayenin nedeni olmakla birlikte bireylerin işin gerektirdiğinin üzerinde eğitimle donanması durumunda söz konusu değişkenler arasındaki nedenselliğin yönü negatif olabilecektir.

Diğer taraftan elde edilen bulgular, literatürde de beklenildiği gibi analize dâhil edilen Norveç hariç diğer dört ülkede beşerî sermayenin iş gücü verimliliğinin sebebi ve pozitif yönlü olduğu sonucunu vurgulamaktadır. Norveç'in katsayısının anlamsız çıkma nedeni, ülke ekonomisinin büyük ölçüde petrol ve doğal gaz sektörüne dayanması olabilir. Bu sektörler, iş gücü verimliliğini

büyük ölçüde etkileyebilir ancak aynı zamanda beşerî sermayenin söz konusu verimlilik üzerindeki etkisini de gölgeleyebilir (Sachs ve Warner, 1995). Doğal kaynaklara dayalı bir ekonomi, diğer sektörlerdeki beşerî sermaye gelişimini ikinci plana atabilir. Buna ek olarak Norveç, dünyanın en yüksek refah seviyelerinden birine sahiptir ve ülkenin güçlü bir sosyal güvenlik sistemi bulunmaktadır (OECD, 2024). Bu durum bireylerin iş gücü verimliliği üzerindeki kişisel motivasyonlarını azaltabilir. Dahası Norveç, genel olarak vatandaşlarına yüksek kalitede eğitim sunar ancak eğitimin iş gücü verimliliği üzerindeki doğrudan etkisi, Norveç gibi gelişmiş ülkelerde, zaten yüksek olan ortalama eğitim seviyesi nedeniyle daha az belirgin olabilir. Bir başka anlatımla eğitimden kaynaklı marjinal kazançlar, diğer ülkelerdeki kadar belirgin olmayabilir. Eğitimin yanı sıra Norveç'teki iş gücü piyasası düzenlemeleri, çalışanların haklarını ve refahını koruma amacı güder. Bu düzenlemeler, iş gücü verimliliğini doğrudan artırmaktan ziyade, iş gücü memnuniyetini ve sosyal dengeyi hedefler. Bu durum beşerî sermayenin verimlilik üzerindeki etkisini azaltabilir. Ayrıca Norveç, ileri teknoloji ve otomasyonun yaygın olduğu bir ülkedir. Yüksek teknoloji ve otomasyon, iş gücü verimliliğini büyük ölçüde etkileyebilir ve beşerî sermayenin etkisini minimize edebilir. Bir başka anlatımla teknolojik yatırımların verimlilik üzerindeki etkisi, beşerî sermayenin etkisinin önüne geçebilir. Bahsedilen bu sebepler beşerî sermaye indeksinden iş gücü verimliliğine doğru olan nedensellik ilişkisinin anlamsız çıkmasına neden olabilecektir.

Çalışmanın bu bölümüne kadar yapılan ekonometrik analizin bulguları detaylı bir şekilde incelenmiş olup, her bir ülke için literatürde beklenmeyen sonuçlara ilişkin gerekçeler sıralanmıştır. Söz konusu bulguların daha açık ve toplu bir şekilde sunulması amacıyla değişkenler arasındaki Granger nedensellik ilişkisinin yönüne ve bu ilişkilerin katsayılarına Tablo 9'da ayrıntılı olarak yer verilmiştir.

Tablo 9. Bootstrap Panel Granger Nedensellik Test Sonuçları

Ülke	Nedenselliğin Yönü	Granger Nedenselliğinin Yönü		
Lüksemburg ve Norveç	Anlamlı ve pozitif /Tek yönlü	KorSağHiz	⇨	İşgüçVer
Danimarka-Fransa-Hollanda	Anlamlı ve pozitif/ Çift yönlü	İşgüçVer	⇔	KorSağHiz
Lüksemburg	Anlamsız ve pozitif	İşgüçVer		KorSağHiz
Norveç	Anlamsız ve negatif	İşgüçVer		KorSağHiz
Lüksemburg	Anlamlı ve negatif	İşgüçVer	⇨	YatırımHar
Danimarka-Fransa-Hollanda	Anlamlı ve pozitif	YatırımHar	⇔	İşgüçVer
Lüksemburg	Anlamsız ve pozitif	YatırımHar		İşgüçVer
Norveç	Anlamsız ve pozitif	İşgüçVer		YatırımHar
Norveç	Anlamsız ve pozitif	YatırımHar		İşgüçVer
Norveç	Anlamlı ve negatif	İşgüçVer	⇨	DışaAç
Danimarka- Hollanda	Anlamlı ve pozitif	İşgüçVer	⇔	DışaAç
Fransa ve Lüksemburg	Anlamlı (İşgüçVer-DışaAç negatif / DışaAç-İşgüçVer pozitif katsayılı)	İşgüçVer	⇔	DışaAç
Norveç	Anlamsız ve pozitif	DışaAç		İşgüçVer
Norveç	Anlamlı ve pozitif	İşgüçVer	⇨	BeşSer
Norveç	Anlamsız ve pozitif	BeşSer		İşgüçVer
Danimarka- Hollanda	Anlamlı (İşgüçVer-BeşSer negatif/ BeşSer-İşgüçVer pozitif katsayılı)	BeşSer	⇔	İşgüçVer
Fransa-Lüksemburg	Anlamlı ve pozitif	BeşSer	⇔	İşgüçVer

Not: İşgüçVer, KorSağHiz, YatırımHar, DışaAç ve BeşSer sırasıyla iş gücü verimliliği, koruyucu sağlık hizmetlerine yönelik sağlık harcamaları, yatırım harcamaları, dışa açıklık derecesi ve beşerî sermaye indeksini temsil etmekte olup, oklar nedenselliğin yönünü göstermektedir.

Koruyucu sağlık hizmetleri ile iş gücü verimliliği arasındaki Granger nedensellik ilişkisi Lüksemburg ve Norveç için tek yönlü iken, geri kalan üç ülke (Danimarka, Fransa ve Hollanda) için bu ilişki çift yönlüdür. Elde ettiğimiz bulgular tüm bu ülkeler için %1 istatistiksel anlamlılık düzeyinde güçlü bir Granger nedensellik ilişkisi ortaya koymaktadır. Buna göre koruyucu sağlık hizmetlerine yönelik harcamalardaki bir birimlik bir artış, Lüksemburg ve Norveç'te işgücü verimliliğinde yaklaşık %0,78-%0,81 bandında bir artışa neden olmaktadır ve bulgular bu ülkeler için koruyucu sağlık hizmetlerine yönelik harcamaların iş gücü verimliliğini artırdığı kanısını doğrulamaktadır. Aynı ilişki Danimarka, Fransa ve Hollanda'da çift yönlü olup koruyucu sağlık hizmetleri, iş gücü verimliliğini; "iş gücü verimliliği de koruyucu sağlık hizmetlerini olumlu yönde etkilemektedir" sonucuna ulaşmaktadır. Sonuç olarak analize dâhil edilen tüm ülkeler dikkate alındığında koruyucu sağlık hizmetlerindeki bir birimlik bir artış, iş gücü verimliliğinde yaklaşık %0,81-%0,96 aralığında bir artışa sebep olmaktadır.

Yatırım harcamaları ile iş gücü verimliliği arasındaki Granger nedenselliğine gelince, Norveç için söz konusu değişkenler arasında çift yönlü veya tek yönlü bir ilişki tespit edilemezken; Lüksemburg için yalnızca iş gücü verimliliğinden yatırım harcamalarına doğru tek yönlü negatif bir nedensellik ilişkisi tespit edilmiştir. Danimarka, Fransa ve Hollanda için ise bu nedensellik ilişkisi çift yönlü ve pozitiftir. İstatistiksel olarak anlamlı olan katsayılar ise değişkenler arası her iki yön de dikkate alındığında yaklaşık olarak %-2,44 ile %0,95 arasında değişmektedir.

Ekonominin dışa açıklık derecesi ile iş gücü verimliliği arasında Danimarka, Fransa, Lüksemburg ve Hollanda için iki taraflı Granger nedensellik ilişkisi mevcuttur. Ancak bahse konu ilişkinin iş gücü verimliliğinden ekonominin dışa açıklığına doğru Danimarka ve Hollanda için pozitif, Fransa ve Lüksemburg için negatif katsayı aldığı; diğer taraftan bahsi geçen dört ülke için ekonominin dışa açıklığından iş gücü verimliliğine doğru nedenselliğin ise pozitif katsayılı olduğu tespit edilmiştir. Norveç için ise nedensellik ilişkisi, iş gücü verimliliğinden ekonominin dışa açıklığına doğrudur. Ancak ilişki tek yönlü ve negatiftir. Bahsedilen istatistiksel olarak anlamlı katsayılar değişkenler arası her iki yön de dikkate alındığında yaklaşık olarak %-0,35 ile %1,12 bandında değişmektedir.

Beşerî sermaye için aynı nedensellik ilişkisi incelendiğinde Norveç'te nedenselliğin iş gücü verimliliğinden beşerî sermayeye doğru ve pozitif yönlü olduğu, kalan dört ülkede (Danimarka, Fransa, Lüksemburg ve Hollanda) bu nedenselliğin iki taraflı olduğu görülmektedir. Ancak bu çift yönlü nedensellik ilişkisi Danimarka ve Hollanda için nedenselliğin katsayılarının iş gücü verimliliğinden beşerî sermayeye doğru negatif olduğu Fransa ve Lüksemburg için aynı katsayıların pozitif olduğu anlaşılmıştır. Diğer taraftan beşerî sermayeden iş gücü verimliliğine doğru pozitif yönlü bir Granger nedensellik ilişkisi söz konusudur. İstatistiksel olarak anlamlı olan katsayılar, değişkenler arası her iki yön de dikkate alındığında yaklaşık olarak %-0,1 ile %0,98 arasında değişmektedir.

5. Sonuç

Bu çalışmada beş gelişmiş Avrupa ülkesi özelinde (Danimarka, Fransa, Lüksemburg, Hollanda ve Norveç) 1995-2019 verilerini kullanarak koruyucu sağlık hizmetleri ile iş gücü verimliliği arasındaki Granger nedensellik ilişkisini analiz edilmiştir. Söz konusu analizde Kónya'nın (2006) ülkeler arası yatay kesit bağımlılığına ve heterojenliğe duyarlı bootstrap panel Granger nedensellik testi kullanılmıştır.

Burada önemle belirtmek gerekir ki çalışmamız üç temel kısıtla karşı karşıyadır. Bunlardan ilki modelin zaman boyutu olarak ortaya çıkmıştır. Kamu giderlerinin OECD tarafından geliştirilen COFOG kırılımına göre raporlanmasına 1995 yılında başlanmış olması, ekonometrik analizde kullanılan veri setinin uzunluğu 25 yılla sınırlı tutmuştur. Bu nedenle daha uzun dönemli olan bir veri setiyle çalışılamamıştır. Çalışmada karşılaşılan bir diğer önemli kısıt da analize dâhil edilen ülke sayısının yalnızca beş ülke ile sınırlı tutulabilmesidir. Bunun temel nedeni ise analize dâhil edilebilme potansiyeli bulunan diğer ülkelere dair harmonik data bulunmaması ve bu ülkelerin COFOG kırılımını kullanmamalarıdır. Sonuncu kısıt ise tahmin modeline dâhil edilen beşerî sermaye indeksi değişkenine ilişkindir. Beşerî sermaye indeksinin aslında beşerî sermayenin tüm unsurlarını dikkate alması gerekirken bu indeksin söz konusu sermayenin yalnızca bir unsuru olan eğitim düzeyini dikkate almasıdır (Bkz. Schultz (2003), Feenstra vd. (2015), Lee ve Lee (2016), Máté vd. (2016)). Sonuç olarak sonraki çalışmalarda daha uzun bir veri seti ile birlikte daha fazla ülke üzerinden konunun araştırılması literatüre değerli bir katkı sağlayabilir.

Analiz sonuçları, analize dâhil edilen ülkeler bazında koruyucu sağlık hizmetleri ile iş gücü verimliliği arasında çift yönlü, pozitif ve istatistiksel olarak anlamlı bir Granger nedensellik ilişkisi olduğunu ortaya koymaktadır. Söz konusu ekonometrik bulguların yanı sıra araştırma, özellikle ekonomik gücü yüksek olan refah devletlerinde koruyucu sağlık hizmetlerinin miktarını belirlemede göz önünde bulundurulan tek unsurun iş gücü verimliliğini artırmak olmadığına; ülkelerin toplum bireylerine sundukları sağlık hizmetlerinin kalitesini artırmak suretiyle refah devleti olmanın gerekliliklerini yerine getirmek amacı güderek de bu harcamaları gereğinden fazla yaptığına dair kanıtlar sunmaktadır. Bu kanıtlardan yola çıkarak bazı ülkeler için koruyucu sağlık hizmetlerinin miktarına karşın elde edilen iş gücü verimliliği arasında nedensellik ilişkisi beklenenden daha zayıf çıkabilir sonucuna ulaşılmaktadır. Dahası bu gibi ülkelerde eğitime çok fazla yatırım yapılarak iş gücünün diğer ülkelere göre daha vasıflı hale getirilmesi iş gücü verimliliğini koruyucu sağlık harcamalarından daha fazla etkilemiş olabilir. Bu durumda iş gücü verimliliği üzerinde koruyucu sağlık harcamalarının etkisi eğitime göre daha zayıf olabilir sonucuna varılmaktadır.

Ekonometrik analize dayalı bulgular, koruyucu sağlık hizmetlerindeki bir birimlik bir artışın iş gücü verimliliğinde yaklaşık %0,78 ile %0,96 arasında değişen bir bantta artışa neden olduğunu ortaya koymaktadır. Görüldüğü üzere, koruyucu sağlık hizmetlerine yönelik harcamalar iş gücü verimliliğini pozitif yönde etkilemektedir. Şu hâlde iddia edilebilir ki sağlık hizmetlerinin koruyucu harcamalarına gereken önemin verilmesi iş gücü verimliliğini artıracaktır. Artan iş gücü verimliliği de ekonomik büyüme ve ülkenin rekabet gücüne pozitif katkıda bulunacaktır. Bu da refah seviyesini yükseltecektir.

Çalışmanın bulguları, koruyucu sağlık hizmetlerinin iş gücü verimliliği açısından hayati derecede önemli olduğunu da ortaya koymaktadır. Her şeyden önce bu harcamalar, çalışanların işteki devamsızlığını azaltarak, iş başında geçirilen süreyi artıracaktır. Şöyle ki, çalışanların uzun dönemde sağlık sorunları ile yüz yüze kalma riski koruyucu sağlık hizmetleri sayesinde düşeceğinden, işte devamlılık sağlanacak ve iş gücü verimliliği artmış olacaktır. İkincisi, bu harcamalar sayesinde sağlıklı kalabilen insanlar hem daha enerjik olacaklar hem de işlerine daha iyi motive olabileceklerdir. Bu da onların daha verimli olabilmeleri anlamına gelecektir. Yine, koruyucu sağlık hizmetleri ileride daha maliyetli olma riski yüksek olan kronik hastalıklara karşı önceden tedbir alınmasına imkân sağlayarak genel manada hem çalışanların hem de işverenin sağlık giderlerini azaltacak ve böylelikle de kaynakların daha etkin dağıtımına fırsat verecektir.

Sonuç olarak iş gücünün fiziksel ve zihinsel sağlığına yatırım yapmak, uzun vadede ülkelerin rekabet gücünü, gelirini ve bu iki unsurun sürdürülebilirliğini artıracaktır.

Koruyucu sağlık hizmetlerinin iş gücü verimliliği üzerindeki etkisini artırmayı hedefleyen politika yapıcılar bireylere koruyucu sağlık hizmetleri konusunda eğitim imkânları sağlayarak hem hane halkı toplam gelirinin hem de ülke gelirinin artmasına katkıda bulunabilmeleri pekâlâ mümkündür. Şöyle ki, sağlıklı insan daha uzun süre iş başında kalacağından, işten uzaklaşma kaynaklı maaş kesintisi ile karşılaşmayacak; fazla mesai ve üretilen üründen/verilen hizmetten promosyan/prim alma gibi araçlarla ek gelir elde edebilecektir. Bu da hane halkı geliri üzerinde olumlu bir etki yaratacaktır. Bunun için iş yeri temelli, özellikle meslek hastalıklarını önlemeye yönelik, sağlık programlarının uygulanmasına, bu yönde eğitim için görsel ve yazılı basının kullanılmasına, aile hekimlerine sahada daha aktif rol verilmesine, e-devlet aracılığıyla bireylere çevrim içi kısa eğitim ve bilgi videoları sunulmasına, sağlık harcamalarının zamanında ve sağlık hizmetinin yeterli kalitede temini için özel sağlık sigortalarının teşvik edilmesine öncelik verilebilir. Hatta sağlık sigortaları için çeşitli vergi indirimleri uygulanarak bu kapsamdaki çalışan sayısının artırılması da pekâlâ mümkündür. Şöyle ki, sağlığı ile alakalı olumsuz belirtiler yaşayan bir çalışan, özel sağlık sigortası kapsamında değilse, kamu hastanelerindeki yoğunluk ve gecikmeler nedeniyle hemen hastaneye gitmeyi tercih etmeyecek ya şikayetlerin kendiliğinden geçmesini ya da daha da artmasını bekleyecektir. Kamu hastanelerine göre özel hastaneler gerek hizmetin sunum hızı gerek etkinliği açısından daha hızlı hizmet verdiğinden, çalışan eğer özel sağlık sigortası kapsamında ise, şikâyetleri başlar başlamaz sağlık hizmetlerinden faydalanma yoluna gidecektir. Dahası çalışanlara sunulan sağlık sigortaları ücretsiz check-up da içerdiği için kişi genel anlamda bir kontrolden belli aralıklarla geçmektedir. Bu da hastalıkların erken teşhisi konusunda oldukça etkili olacaktır.

Burada özellikle belirtmek gerekir ki politika yapıcılar bahsedilen girişimlerde bulunmadan önce öncelikle mevcut koruyucu sağlık hizmetlerinin etkinliğini daha da artırılabilmek amacıyla düzenli ve güvenilir bir veri tabanının oluşmasını sağlamalıdır. Bu kapsamda aile hekimliklerini ziyaret eden bireylerin yaş, kilo, şeker, tansiyon ve varsa kronik rahatsızlıkları gibi konulara ilişkin verileri toplanmalı ve belirli aralıklarla Sağlık Bakanlığı'nda yetkili mercilere bu konular hakkında bilgi verilmelidir. Bu tür uygulamaların zaman içinde toplumun temel sağlık problemlerinin ortaya konulması ile birlikte devletin daha etkin ve spesifik politika geliştirmesine olanak sağlaması da çok muhtemeldir. Öte yandan koruyucu sağlık hizmetlerine bu hizmetlerin maliyetleri açısından bakıldığında söz konusu hizmetlerin özellikle alternatif tıp kapsamında olanlarının tedavi edici hizmetlere göre çok daha düşük maliyetli olduğu görülmektedir. Bu nedenle koruyucu sağlık hizmetleri kapsamında hacamat, sülük, fizik tedavi, kaplıca, tuz mağaraları gibi alternatif tedavi yöntemlerinden de istifade edilmesi etkili bir politika seçeneği olabilir. Bu noktada bilhassa sertifikalı eğitimlerin ve tamamlayıcı tıp merkezlerinin yaygınlaşmasına yönelik politikaların da gündeme alınması tartışılmalıdır.

Araştırma ve Yayın Etiği Beyanı
Etik kurul izni ve/veya yasal/özel izin alınmasına gerek olmayan bu çalışmada araştırma ve yayın etiğine uyulmuştur.

Araştırmacıların Katkı Oranı Beyanı
Yazarlar makaleye eşit oranda katkı sağlamış olduklarını beyan eder.

Araştırmacıların Çıkar Çatışması Beyanı
Bu çalışmada herhangi bir potansiyel çıkar çatışması bulunmamaktadır.

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DO PREVENTIVE HEALTHCARE SERVICES INCREASE LABOR PRODUCTIVITY? AN ECONOMETRIC ANALYSIS BASED ON BOOTSTRAP PANEL CAUSALITY TEST

EXTENDED SUMMARY

Purpose of the Study

This study aims to analyze in detail the impact of preventive healthcare services on labor productivity. Labor productivity plays a key role in terms of both the welfare and the international competitiveness of a country. Therefore, an increase in labor productivity is, in a sense, an increase in the welfare of that country. This study investigates whether there is a Granger causality relationship between spending on preventive healthcare services, which is thought to have a strong effect on labor productivity, and labor productivity. Although the relationship between the two variables has been subjected to various econometric analyses in the existing literature, to the best of our knowledge, no causality analysis has been conducted that takes into account horizontal cross-sectional dependence and heterogeneity has not been carried out up to now. This study aims to fill this gap and thus contribute to the literature.

Literature Review

Labor productivity is an economic concept that measures the amount of output produced per unit of labor. In other words, it represents the output produced per unit of labor input. Labor productivity also provides information on how effectively an economy uses its existing human resources. An increase in labor productivity means, first and foremost, higher economic growth rates for countries. This is because higher productivity allows more output to be produced with the same amount of labor, thereby driving economic expansion. In addition, an improvement in labor productivity increases a country's competitiveness. Countries with higher productivity can produce goods and services at lower costs with the same amount of labor, giving them a competitive edge in international markets. Moreover, higher labor productivity paves the way for wage growth, thereby improving workers' living standards. It also creates a more attractive environment for investors, who can increase investment potential and, in turn, promote economic development.

Building on this generally accepted notion, numerous studies have been conducted to explore ways of improving labor productivity. However, a detailed review of the literature on labor productivity shows that the majority of academic research approaches productivity primarily from the perspective of human capital. In particular, there is a lack of studies analyzing preventive healthcare expenditures---one of the subcomponents of health expenditures---together with other key factors that are believed to have a more significant impact on labor productivity. Furthermore, while the topic has been subjected to various econometric analyses, the existing literature has largely overlooked causality analyses that take into account cross-sectional dependence and heterogeneity. Motivated by these gaps, this study aims to contribute to the existing econometric literature by addressing these shortcomings.

Methodology

The study estimates the impact of preventive healthcare services on labor productivity for five selected European countries that are among the most developed and have the highest levels of per capita income. Variables such as the degree of trade openness, investment spending, and the human capital index, which are hypothesized to influence productivity, are also included in the causality tests. This approach aims to determine the direction of causality between all variables and labor productivity through panel data analysis. The method used is Kónya's (1996) bootstrap panel Granger causality test, which is known for its ability to account for both cross-sectional dependences.

Findings

The results based on econometric analysis show that a one-unit increase in preventive healthcare services leads to an increase in labor productivity, ranging from about 0.78% to 0.96%. As observed, spending on preventive healthcare services has a positive impact on labor productivity. It can therefore be argued that putting the necessary emphasis on spending on preventive healthcare will increase labor productivity.

Result

The results of the study show that preventive healthcare services are important for labor productivity. First and foremost, this expenditure will reduce employee absenteeism, thereby increasing the time spent at work. Specifically, as the risk of facing long-term health problems decreases due to preventive healthcare services, employees will maintain a higher level of job continuity, leading to increased labor productivity. Second, individuals who remain healthy as a result of these expenditures will not only be more energetic but also more motivated in their work, resulting in higher productivity. In addition, preventive healthcare services help to reduce the risk of chronic diseases, which are likely to be more costly in the future, by enabling early intervention. This will reduce healthcare costs for both employees and employers, allowing for a more efficient allocation of resources. In conclusion, investing in the physical and mental health of the workforce will improve a country's competitiveness, income, and the sustainability of both in the long term.

Policymakers can contribute to the increases in both total household income and national income by providing individuals with educational opportunities to learn about preventive healthcare services. To this end, priority can be given to the implementation of workplace health programs, particularly those aimed at the prevention of occupational diseases, and to the promotion of private health insurance through tax deductions to ensure the provision of adequate quality healthcare services. Establishing a regular and reliable database will make it possible to identify fundamental public health issues and thus facilitate the development of effective and specific policies. Furthermore, when healthcare services are considered from a cost perspective, it is clear that alternative medicine approaches are significantly more cost-effective than curative treatments. Therefore, policies aimed at expanding certified training programs and complementary medicine centers should also be considered.

Ekonomi, Politika and Finans Araştırmaları Dergisi, 2025, 10(1): 303-331
Journal of Research in Economics, Politics and Finance, 2025, 10(1): 303-331
Araştırma Makalesi / Research Article, https://doi.org/10.30784/epfad.1595233

RİSK ŞOKLARI VE TÜRKİYE'DEKİ FİNANSAL VARLIKLAR ARASINDAKİ YAYILIM ETKİSİNİN TVP-VAR DAYALI WAVELET UYUM ANALİZİ İLE İNCELENMESİ*

Analysis of the Spillover Effect between Risk Shocks and Financial Assets in Turkey Using TVP-VAR-Based Wavelet Coherence Analysis

Aslan AYDOĞDU**

Öz

Bu çalışmanın amacı, risk şokları ile Türkiye'de finansal varlıklar arasındaki yayılım etkisinin TVP-VAR genişletilmiş ortak bağlantılılık yaklaşımına dayalı wavelet uyum analizi ile incelemektir. Bu amaç doğrultusunda, BIST100 Endeksi, Brent ham petrol, USD/TRY, altın ons, Bitcoin ve Volatilite Endeksi (VIX) değişkenleri kullanılmıştır. 08.11.2017-08.09.2024 dönemini kapsayan günlük veri seti tercih edilmiştir. TVP-VAR genişletilmiş ortak bağlantılılık yaklaşımı, wavelet uyum analizi ve Hatemi-j (2012) asimetrik nedensellik analizi kullanılmıştır. Analiz sonuçlarına göre piyasalar arasındaki dinamik yayılmaların dalgalanma dönemlerinde önemli ölçüde arttığı tespit edilmiştir. Buna göre BIST100 getirisi ve altın ons getirisi volatiliteyi net şok yayan değişkenler olarak belirlenmiş; dolar, Bitcoin ve Brent petrol ise volatiliteyi net şok alan değişkenler olarak tespit edilmiştir. Bitcoin ve Brent petrol, doların BIST100'den meydana gelen değişimlerden etkilendiği görülmüştür. VIX'in Toplam Bağlantı Endeksi (TCI) üzerindeki etkisi 2020 ve 2022-2023 yılları arasında pozitif ve karşılıklı olup orta ve uzun vadede yoğunlaşmaktadır. VIX ile TCI volatilitesi arasında çift yönlü; VIX ile Bitcoin ve BIST100 hariç altın ons ve Brent petrol net yayılma volatilitesi arasında tek yönlü nedensellik ilişkisi bulgusuna ulaşılmıştır. Bu bulguların wavelet uyum analizi ile tutarlı olduğu sonucuna varılmıştır.

Anahtar Kelimeler: Wavelet Uyum Analizi, Volatilite Yayılımı, Pay Senedi Piyasaları, TVP-VAR, Bitcoin

JEL Kodları: G01, G15, G32

Abstract

This study uses wavelet coherence analysis based on the TVP-VAR extended joint approach to examine the spillover effect between risk shocks and financial assets in Turkey. For this purpose, the BIST100 Index, Brent crude oil, USD/TRY, gold ounce, Bitcoin, and Volatility Index (VIX) variables are used. The daily data set covering the period 08.11.2017-08.09.2024 is preferred. TVP-VAR extended joint approach, wavelet coherence analysis, and Hatemi-j (2012) asymmetric causality analysis were used. According to the results of the studies, dynamic spillovers between markets increase significantly during periods of volatility. Accordingly, BIST100 return and gold ounce return are determined as net shock emitters of volatility, while the dollar, Bitcoin, and Brent oil are defined as net shock receivers of volatility. Bitcoin, Brent oil, and the dollar were found to be affected by the changes in BIST100. The effect of VIX on the Total Connectivity Index (TCI) is positive and reciprocal between 2020 and 2022-2023 and intensifies in the medium and long term. A bidirectional causality relationship was found between VIX and TCI volatility, and a unidirectional causality relationship was found between VIX and gold ounce and Brent oil net spread volatility excluding Bitcoin and BIST100. It was concluded that these findings are consistent with wavelet coherence analysis.

Keywords: Wavelet Coherence Analysis, Volatility Spillovers, TVP-VAR, Stock markets, Bitcoin

JEL Codes: G01, G15, G32

* Bu çalışmanın önceki hali 27-29 Eylül 2024 tarihlerinde düzenlenen 11. Uluslararası Muhasebe ve Finans Araştırmaları Kongresi'nde *"Risk Şokları ile Türkiye'de Finansal Varlıklar Arasındaki Yayılım Etkisinin TVP-VAR Dayalı Wavelet Uyum Analizi ile Araştırılması"* başlıklı özet bildiri olarak sunulmuştur.

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Makale Geliş Tarihi (Received Date): 02.12.2024 Makale Kabul Tarihi (Accepted Date): 19.02.2025

1. Giriş

Uluslararası yatırımların hacminin ülkelerin sınırlarını aşarak dünya finans piyasalarında hızla artış gösterdiği gözlemlenmektedir. Bu süreç, ülkelerdeki yerel finans piyasalarının küresel bir boyut kazanmaya başlamasıyla paralel olarak ilerlemektedir (Hatipoğlu ve Tekin, 2017: 1). Bu bağlamda, bireysel ve kurumsal yatırımcılar, birikimlerini değerlendirirken finansal piyasalardaki risklerden korunmak ve güvenli bir ortam sağlamak amacıyla sürekli bir arayış içindedir. Finansal piyasalar arasındaki artan etkileşim, oynaklık yoluyla riske maruziyeti artırmakta; ekonomik ve siyasi krizler ise bu durumu daha da derinleştirmektedir. Örneğin, Covid-19 pandemisi ve jeopolitik riskler, finansal piyasalarda dalgalanmalara neden olmuş ve yatırımcılar üzerinde olumsuz etkiler yaratmıştır. Bu bağlamda volatilite kavramı, uluslararası yatırım kararlarında öncelikli bir unsur haline gelmiştir (Kök ve Nazlıoğlu, 2020: 246).

Bağlantılılık, günümüzde risk ölçümünde ve yönetiminde temel bir rol üstlenmektedir. Finansal ve ekonomik değişkenler arasındaki bağlantıların incelenmesi, sistemik risklerin, bulaşıcılık etkilerinin ve genel ekonomik istikrarın değerlendirilmesi açısından kritik öneme sahiptir. Bu tür analizler, sistemin belirli bir bölümünde meydana gelen şokların veya aksaklıkların diğer bileşenlere nasıl yayılabileceğini ve bu etkilerin büyüklüğünü ortaya koyarak, kapsamlı bir risk değerlendirmesi yapılmasına olanak sağlamaktadır. Böyle bir bilgi, yatırımcılar, politika yapıcılar ve finansal kurumlar için sistemik krizlere yönelik politika oluşturma ve etkili risk azaltma stratejilerini hayata geçirme noktasında temel bir kaynak teşkil etmektedir. Özellikle son yıllarda, küresel krizlere ve jeopolitik risklere verilen yanıtlar, özellikle olağanüstü olaylar sırasında bulaşıcılık riskinin analiz edilmesinin ne denli önemli olduğunu bir kez daha gözler önüne sermiştir (Shang ve Hamori, 2024: 1). Bu tür olaylar, piyasalarda aşırı oynaklık yaratarak (örneğin, olağanüstü piyasa koşulları), sistematik risklerin hem ulusal düzeyde hem de küresel ölçekte artmasına sebep olmuştur (Sharif vd., 2020; Izzeldin vd., 2023). Buna ek olarak, Ando vd. (2018) belirttiği gibi, sistematik risklerin, ortalama piyasa koşulları (medyan çeyrekler) ile karşılaştırıldığında aşırı piyasa koşulları (aşırı çeyrekler) sırasında önemli ölçüde daha yüksek olduğu gözlemlenmiştir. Bu bağlamda, aşırı çeyreklerdeki yayılma mekanizmalarının incelenmesi, medyan çeyreklerin analizine kıyasla daha büyük bir öncelik taşımaktadır. Ayrıca, Baruník ve Křehlík (2018) çalışmalarında vurguladıkları üzere, ekonomik sistemlerdeki yayılma etkilerinin kökenlerini anlamak için bağlantılılıkların frekans dinamiklerini çözümlemek kritik bir öneme sahiptir.

Finansal ve makroekonomik değişkenler arasındaki bağlantılar, küresel finansal sistemde emtia piyasaları, hisse senedi piyasaları, döviz piyasaları ve kripto para piyasaları gibi çok boyutlu göstergeler arasındaki ilişkilerin analizini giderek daha kritik bir hale getirmektedir. Çünkü finansal veya makroekonomik bir alanda ortaya çıkan olumsuz bir şok, bu bağlantılar yoluyla sistemin diğer kısımlarına yayılabilir ve bu durum sistemik istikrarı tehdit edebilir (Gkillas vd., 2019). Bu bağlamda petrol ve altın, finansal ve ekonomik göstergeler arasındaki bağlantıları anlamak için sıklıkla temsilci emtialar olarak seçilmektedir. Petrol fiyatlarındaki dalgalanmalar enerji piyasalarını, enflasyonu ve sanayi üretimini doğrudan etkilerken (Kilian, 2009; Yoshizaki ve Hamori, 2013), altın, güvenli liman özelliği taşıyan bir varlık olarak yatırımcı duyarlılığını ve ekonomik istikrarı göstermektedir (Choudhry vd., 2015; Iqbal, 2017). Ayrıca, bu emtiaların ekonomik ve jeopolitik olaylara verdiği farklı tepkiler, sistemik risklerin değerlendirilmesi açısından önemli bir içgörü sağlamaktadır. Son yıllarda, bu bağlamda kripto para birimleri de önemli bir analiz boyutu olarak öne çıkmıştır. Bitcoin gibi kripto varlıklar, dijital bir güvenli liman olarak değerlendirilmekte ve özellikle ekonomik belirsizlik dönemlerinde yatırımcılar için

alternatif bir varlık sınıfı oluşturmaktadır (Bouri vd., 2017). Bunun yanı sıra kripto para birimlerinin döviz piyasaları ve hisse senedi piyasaları ile gösterdiği dinamik ilişkiler, finansal sistemde dalgalanmaların iletimi için yeni ve özgün bir kanal sunmaktadır (Corbet vd., 2018). Kripto para birimlerinin teknolojik yeniliklere, piyasa regülasyonlarına ve uluslararası politik gerilimlere duyarlılığı, onların volatilitesini artırmakta ve finansal istikrar üzerindeki etkilerini karmaşıklaştırmaktadır. Petrol ve altın gibi geleneksel emtiaların ekonomik ve jeopolitik olaylara verdiği farklı tepkiler, sistemik risk değerlendirmeleri için önemli içgörüler sağlarken kripto para birimlerinin kendine özgü piyasa dinamikleri bu tür analizlerin kapsamını genişletmektedir. Özellikle kripto piyasalarının diğer finansal varlıklarla olan ilişkisi ve oynaklığının yüksekliği, sistemik risklerin tahmin edilmesi ve yönetilmesi açısından dikkate alınması gereken bir husus haline gelmiştir. Bu durum, kripto para piyasalarının volatilitesinin ve diğer finansal piyasalara olan etkisinin, sistemik istikrarın korunması açısından giderek daha fazla önem kazandığını göstermektedir.

Pay senedi, altın, döviz kuru, petrol ve Bitcoin piyasaları arasındaki yayılımlarla ilgili geniş çaplı araştırmalara rağmen literatürde hâlâ boşluklar bulunmaktadır. İlk olarak, mevcut çalışmaların çoğu bireysel pay senedi piyasaları ile altın, petrol, döviz kuru ve Bitcoin piyasaları arasındaki yayılımlara odaklanmıştır. Hem ulusal hem de uluslararası pay senedi piyasaları arasında, varlık büyüklüğü ve gelişmişlik derecesi açısından belirgin farklılıklar mevcuttur ve bu piyasalar arasındaki yayılımlar heterojendir. Bu nedenle, bu çalışmanın amacı, 08.11.2017-08.09.2024 tarihleri arasındaki BIST100 Endeksi, Brent ham petrol, dolar, altın ons, Bitcoin ve (VIX) piyasaları arasındaki yayılma etkilerini günlük getirilerini inceleyerek, risk şokları ve yayılma etkileri arasındaki ilişkiyi bütünsel bir bakış açısıyla ele almaktır. Çalışmada, pay senedi piyasasını temsil etmek için Borsa İstanbul (BIST100) Endeksi; altın piyasasını temsil etmek için altın ons; döviz kuru piyasasını temsil etmek için USD/TRY; petrol piyasasını temsil etmek için Brent petrol; kripto para piyasasını temsil etmek için ise Bitcoin getirileri kullanılmıştır. İkinci olarak mevcut çalışmaların çoğu piyasalar arasındaki yayılımlar ve bağlantılara odaklanmakta, yayılımları etkileyen faktörleri ölçmeyi ihmal etmektedir. Piyasalar arasındaki yayılımlar üzerindeki risk şoklarının etkisi de karmaşık bir konudur: Bazı çalışmalar, tek bir kriz olayının piyasa yayılımları üzerindeki etkisine odaklanmaktadır. Hatipoğlu ve Tekin (2017), Sarıtaş ve Nazlıoğlu (2019), Tunçel ve Gürsoy (2020) ve Özdemir Höl (2023) piyasa bağlantılarını ve nedenselliklerini incelemiş, VIX ile piyasalar arasındaki nedensellik ve bağlantılar üzerinde önemli etkiler olduğunu belirtilmiş ancak daha ayrıntılı bir analiz yapılmamıştır. Bu çalışmada, sadece risk şoklarının piyasalar arası yayılımlar üzerindeki etkisini ölçmekle kalmayıp, aynı zamanda risk şoklarının piyasalar arası yayılımlar üzerindeki ilgili rolünü hem zaman hem de frekans boyutlarında incelenmiştir. Ayrıca, piyasalar arası yayılımlardaki değişikliklerin dış riski etkileyip etkilemediğini incelenmiştir. Mevcut çalışmalarda Antonakakis vd. (2019) önerilen TVP-VAR bağlantılılık yaklaşımı kullanırken, bu çalışmada, Balcılar vd. (2021) önerilen TVP-VAR genişletilmiş ortak bağlantılılık yaklaşımı (TVP-VAR extended joint connectedness approach) ve wavelet uyum analizi kullanılmıştır.

Finansal piyasaların dinamik yapısı içinde finansal varlık sınıfları arasındaki ilişkiler, portföy çeşitlendirmesi ve risk yönetimi açısından kritik bir rol oynamaktadır. Bu ilişkiler, yatırımcıların risklerini farklı finansa varlık sınıflarına yayarak portföylerini optimize etmelerine olanak tanırken, politika yapıcılar için piyasa şoklarına karşı etkili stratejiler geliştirme fırsatı sunmaktadır. Bu yüzden zaman ve frekans uzayında volatilite yayılma etkileri, finansal sistemlerin birbirine olan bağlılığını analiz etmek sistemik risklerin anlaşılmasında ve

yönetilmesinde önemli bir çerçeve sağlamaktadır. Doğru bir analiz, olası krizlerin önceden tespit edilmesine ve daha etkin politika müdahalelerinin oluşturulmasına yardımcı olabilir. Bu bağlamda, hem yatırımcıların tek bir finansal varlık sınıfına aşırı bağımlılıktan kaçınmaları hem de politika yapıcıların piyasa bağlantılarını dikkate alarak genişletici nitelikte para ve maliye politikaları uygulamaları önem arz etmektedir. Özellikle küresel düzeyde yaşanan Covid-19 pandemisi, Rusya-Ukrayna çatışması veya İsrail-Filistin savaşı gibi olaylar, piyasa bağlantıları ve yayılma etkileri üzerinde belirgin bir etki yaratmıştır. Bu doğrultuda, çalışmada elde edilen bulguların literatüre katkı sağlaması beklenmektedir. Çalışmanın geri kalanı şu şekilde organize edilmiştir: İkinci Bölüm, araştırmanın metodolojisini detaylandırmaktadır. Üçüncü Bölüm, betimleyici istatistiklerle birlikte veri sunumunu içermektedir. Dördüncü Bölümde, ampirik analizlerin sonuçları ve sağlamlık testleri ele alınmaktadır. Son olarak, Beşinci Bölüm, politika önerileriyle makaleyi sonuçlandırmaktadır.

2. Literatür Taraması

Literatürde, Borsa İstanbul (BIST) ile küresel piyasalar arasındaki volatilite ve dinamik ilişkiler incelenmiştir. Çalışmalarda, VIX endeksi, döviz kurları, emtia fiyatları ve Bitcoin gibi faktörlerin BIST üzerindeki etkileri ortaya konmuştur. Volatilite yayılımının genellikle kriz dönemlerinde arttığı; emtia ve altın gibi varlıkların volatilite yayıcı, BIST ve petrol gibi varlıkların ise volatilite emici bir rol oynadığı tespit edilmiştir. Ayrıca, volatilite etkilerinin piyasa türüne ve döneme bağlı olarak değişiklik gösterdiği vurgulanmıştır. Bununla birlikte, zaman ve frekans uzayında bu ilişkilerin derinlemesine ele alındığı çalışmalar sınırlıdır. Özellikle kısa, orta ve uzun vadeli etkilerin ayrıştırılması yoluyla volatilite dinamiklerinin daha ayrıntılı bir şekilde analiz edilmesine yönelik eksiklikler, bu alanda yeni araştırmalar yapılmasını gerektirmektedir. Tablo 1'de literatür taraması ayrıntılı bir şekilde özetlenmiştir.

Tablo 1. Literatür Taraması

Yazarlar	Dönem	Değişkenler	Yöntem	Sonuç
Hatipoğlu ve Tekin (2017)	07.02.2002 29.12.2016	Brent Petrol, Döviz Kuru (Dolar), BIST100 Endeksi, VIX	Kantil Regresyon Yaklaşımı (Koanker ve Bassett, 1978)	Analiz sonuçlarına göre, BIST 100 endeksinin tüm dilimlerinde volatilite endeksinden önemli ölçüde etkilendiği tespit edilmiştir. Ayrıca, dolar kuru BIST endeksini yalnızca yüksek kantillerde etkilediği gözlemlenmiştir.
Başarır (2018)	03.01.2000 09.02.2018	BIST100 Endeksi, VIX Endeksi	Frekans Alanı Nedensellik Testi	BIST 100 endeksinden VIX endeksine doğru geçici veya kalıcı bir nedensellik ilişkisi gözlemlenmemiştir. VIX endeksinden BIST 100 endeksine doğru hem geçici hem de kalıcı nitelikte tek yönlü bir nedensellik tespit edilmiştir.
Sakarya ve Akkuş (2018)	05.01.2010 22.06.2018	VIX Endeksi, BIST100 Endeksi, BIST Banka Endeksi, BIST Mali Endeksi, BIST Teknoloji Endeksi	ARDL Sınır Testi Toda-Yamamoto Nedensellik Testi	VIX endeksi ile BIST 100, XBANK, XUMAL ve XUTEK endeksleri arasında uzun dönemli bir ilişki olduğu tespit edilmiş ve VIX endeksinden BIST 100, XBANK, XUMAL ve XUTEK endekslerine doğru tek yönlü nedensellik ilişkisi olduğu gözlemlenmiştir.
Kılıç ve Çütcü (2018)	02.02.2012 06.03.2018	Bitcoin, BIST100 Endeksi	Engle Granger Eşbütünleşme Analizi Gregory Hansen Eşbütünleşme Analizi Toda-Yamamoto Hacker- Hatemi-J Nedensellik Analizi	Eşbütünleşme analizlerine göre, Bitcoin fiyatları ile BIST100 endeksi arasında orta ve uzun vadede bir eşbütünleşme ilişkisinin bulunmadığını göstermektedir. Nedensellik analizlerinde ise yalnızca Toda-Yamamoto nedensellik analizi, BIST100'den Bitcoin fiyatlarına doğru tek yönlü bir nedensellik ilişkisinin olduğunu ortaya koymaktadır.
Kuzu (2019)	03.01.2000 23.01.2019	VIX Endeksi, BIST100 Endeksi	Frekans Alanı Nedensellik Analizi Johansen Eş Bütünleşme Testi Hata Düzeltme Modeli	BIST 100 endeksi ile VIX endeksi arasında kısa, orta ve uzun vadede herhangi bir nedensellik ilişkisi öngörülememiştir. Ancak VIX endeksinden BIST 100 endeksine doğru hem kısa hem de orta ve uzun vadede tek yönlü bir nedensellik ilişkisi tespit edilmiştir.
Sarıtaş ve Nazlıoğlu (2019)	02.01.2009 12.11.2018	Korku Endeksi (VIX), BIST100 Endeksi, Dolar Kuru	Granger Nedensellik Analizi	Analiz sonuçlarına göre, VIX endeksinin hem BIST 100 endeksine hem de dolar kuruna yönelik bir nedensellik ilişkisi gösterdiği tespit edilmiştir.
Malik ve Umar (2019)	Mart 1996 Şubat 2019	Brezilya Reali, Kanada Doları, Çin Yuanı, Hindistan Rupisi Japon Yen, Meksika Pesosu ve Rus Rublesi, Petrol Şokları	Granger Nedensellik Analizi, Dinamik Yuvarlanma Bağlantılılığı	Talep ve risk değişikliklerinden kaynaklanan petrol fiyatı şoklarının döviz kurlarındaki dalgalanmalara önemli ölçüde katkıda bulunduğunu, ancak arz şoklarının neredeyse hiç etkisinin olmadığını görülmüştür. Küresel finansal kriz sonrasında petrol fiyatı şokları ile döviz kurları arasındaki bu ilişkinin bağlantılılığı önemli ölçüde arttığı tespit edilmiştir.

Tablo 1. Devamı

Tunçel ve Gürsoy (2020)	06.08.2010 06.01.2020	VIX Endeksi, Bitcoin, BIST100 Endeksi	Toda-Yamamoto Nedensellik Analizi	Analiz sonuçları, Bitcoin fiyatının iki değişken üzerinde de istatistiksel olarak anlamlı bir etkisinin bulunmadığını gösterirken, VIX endeksinin BIST 100 endeksi üzerinde tek yönlü bir nedensellik ilişkisi sergilediğini ortaya koymaktadır.
Balcilar vd. (2021)	01.07.2005 01.05.2020	11 Tarım Emtiası, Ham Petrol	Tabanlı Genişletilmiş Ortak Bağlantılılık Yaklaşımı (TVP-VAR)	Ekonomik olayların etkisiyle dinamik bağlılığın zaman içinde değiştiği ve özellikle kriz dönemlerinde arttığı ortaya konmuştur. Ham petrol ve bazı tarımsal emtialar şok yayıcısı olurken, mısır ve buğday gibi emtialar şok alıcısı olmuştur. Ayrıca, ham petrolün diğer piyasaları etkilediği kadar onlardan da etkilenerek yüksek bir bağlılık ağı oluşturduğu tespit edilmiştir.
Mensi vd. (2021)	04.01.2005 15.05.2020	Altın Ons, Ham Petrol, Çin'in 10 Sektör Borsa Piyasası	TVP-VAR Bağlantılılık Analizi (2012 ve 2014)	Analiz sonuçlarına göre emtia ve on sektör arasında zamanla değişen asimetrik yayılmalar olduğu sonucuna varılmıştır.
Mensi vd. (2022)	17.09.2010 24.10.2020	Altın Ons, Brent Petrol, 22 Avrupa Hisse Senedi Piyasası	TVP-VAR Bağlantılılık Analizi (2012)	Altın ve petrol piyasaları, sistemden gelen getiri aktarımının net alıcılarıdır, buna karşılık hisse senedi sektörlerinin çoğu, sistemde net getiri yayılmalarının vericisi konumunda olduğu Ayrıca, negatif getiri yayılmaları pozitif yayılmalardan daha güçlü olduğu, getiri yayılmalarında bir asimetri olduğu gözlemlenmiştir.
Akyıldırım vd. (2022)	28.11.2008 19.07.2021	Mevduat Faizi, BİST100, USD/TRY, Tahvil, Kredi Temerrüt Takası (KTT), Emtia Endeksi	TVP-VAR	TVP-VAR model sonuçları, örneklem döneminde hem yerel hem de uluslararası türbülans dönemlerinde ilgili finansal varlıklar arasındaki dinamik bağlantılılık ilişkisinin arttığını gözlemlenmiştir.
Golitsis vd. (2022)	02.01.1986 31.12.2019	Altın, Ham Petrol, ABD Doları, S&P 500 Endeksi, Enflasyon Oranı (TÜFE), Ekonomik Politika Belirsizliği (EPU), Hazine Bonusu	TVP-VAR Bağlantılılık Analizi (2012)	Analiz sonuçlarına göre altının güçlü bir dolar hedge aracı olduğunu, ham petrol ve Hazine bonolarının ise enflasyonu yönlendirdiğini ortaya tespit edilmiş; ayrıca döviz kuru ile altın getirileri arasında güçlü yayılma etkileri olduğu belirlenmiştir.
Doğan vd. (2023)	11.04.2014 11.11.2022	BIST Sürdürülebilirlik Endeksi, BIST 100 Endeksi, S&P, Global Temiz Enerji Endeksi (S&P GCEI), S&P GSCI Karbon Emisyon İzinleri	TVP-VAR Bağlantılılık Analizi (Antonakakis vd., 2019)	Karbon emisyon izinlerinden kaynaklanan oynaklığın S&P GCEI, BIST 100 ve BIST sürdürülebilirlik endekslerine yayıldığı, ancak COVID-19 pandemisi sırasında bu yayılımda önemli azalmalar olduğu tespit edilmiştir. Ayrıca, S&P GCEI'den BIST sürdürülebilirlik ve BIST 100 endekslerine zayıf bir oynaklık yayılımı olduğu belirlenmiştir.

Tablo 1. Devamı

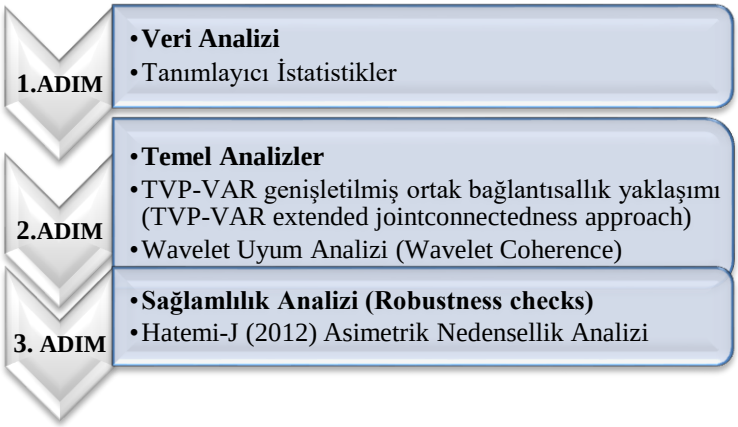
Özdemir Höl (2023)	11.03.2020-01.02.2022	WTI, Altın Ons, Bitcoin, BIST100	TVP-VAR Bağlantılılık Analizi (Antonakakis vd., 2019)	Analiz sonuçlarına göre, Bitcoin ve ons altın fiyatlarının volatiliteyi yaydığı, BIST 100 endeksi, dolar kuru ve WTI ham petrol fiyatlarının ise volatiliteyi emen değişkenler olduğu tespit edilmiştir. Ayrıca, BIST 100 endeksinin ons altın, Bitcoin ve dolar kurundaki dalgalanmalardan etkilendiği, özellikle ons altının BIST 100 endeksini en fazla etkileyen unsur olduğu belirlenmiştir.
Zhao vd. (2024)	10.02.2011 02.04.2024	Ham Petrol, Altın Ons, MSCI Gelişmekte olan ve Gelişmiş Piyasalar, S&P, VIX	TVP-VAR Yaklaşımına Dayalı Wavelet Uyum Analizi	Analiz sonuçlarına göre, etkiler 2015, 2018 ve 2020-2021 dönemlerinin orta ve uzun vadeli aralıklarında yoğunlaşmış ve volatilite ile dinamik toplam bağlılık arasında pozitif bir ilişki olduğu gözlemlenmiştir.
Erdoğan (2024)	12.11.2017 19.11.2023	Brent Petrol S&P500 Endeksi, CAC Endeksi, DAX Endeksi, NIKKEI225 Endeksi, IBEX35 Endeksi, BIST100 Endeksi, S&PBMV Endeksi, IDX Endeksi, TADAWUL Endeksi	TVP-VAR Bağlantılılık Analizi (Antonakakis vd., 2019)	Yapılan analizlere göre, kriz dönemlerinde finansal varlıklar arasındaki dinamik bağlanırlığın arttığı belirlenmiş ve Bitcoin ile Brent petrol fiyatlarının diğer borsa endekslerinden etkilendiği sonucuna ulaşılmıştır.
Mensi vd. (2024)	02.03.2003 22. 07.2021	Ham Petrol, Altın Ons, MSCI Piyasa Endeksleri	Kantil Bağlantılılık Yaklaşımı (Ando vd., 2018)	Çalışma, ayı ve boğa piyasası koşullarında daha güçlü getiri yayılmalarının varlığı gözlemlenmiştir. Ham petrol ve altın, kantil düzeylerinden bağımsız olarak, getiri yayılmalarının net alıcıları konumda olduğu Ayrıca, yüksek stres dönemlerinde önemli ölçüde artan yayılma etkileri gözlemlenmiştir.
Guan vd. (2024)	01.07.2003 05.08.2022	S&P 500, Altın Ons, Ham Petrol, Tahvil	Çarpımsal Hata Modeli (MEM)	Hisse senedi piyasasının volatilite yayılmalarının ana kaynağı olduğunu, ham petrol piyasasının ise bu yayılmaların çoğunlukla alıcısı olarak hareket ettiğini göstermektedir. Ayrıca, volatilite yayılmalarının hisse senedi ve ham petrol piyasalarında genellikle negatif, tahvil piyasasında ise pozitif bir asimetrik etki yarattığı tespit edilmiştir.

Kaynak: Yazar tarafından derlenmiştir.

3. Metodoloji ve Veri Seti

3.1. Metodoloji

Öncelikle TVP-VAR genişletilmiş ortak bağlantısallık yaklaşımını kullanarak Brent petrol, BIST100, altın ons, dolar ve Bitcoin piyasaları arasındaki yayılım etkileri incelenmiştir. Sonrasında ise, TVP-VAR ortak bağlantılılık yaklaşımından elde edilen piyasalar arasındaki dinamik yayılımlardan yararlanarak wavelet uyum analizi ile hem zaman hem de frekans boyutlarında risk şoklarının piyasalar arası dinamik yayılımlar arasındaki birlikte hareket ettiği veya etkileşim içinde olduğu tüm bölgeler tespit edilmiştir. Ayrıca, piyasalar arası yayılmalardaki değişikliklerin dış riski etkileyip etkilemediği incelenmiştir. Son olarak Hatemi-J (2012) asimetrik nedensellik analizi ile risk şokları ile piyasalar arasındaki nedensellik ilişkisi incelenmiştir.



Şekil 1. Analiz Süreci

3.1.1. TVP-VAR Genişletilmiş Ortak Bağlantılılık Yaklaşımı

Diebold ve Yılmaz (2012) tarafından önerilen en popüler ekonometrik teknik, bağlılık ilişkilerini incelemek için kullanılmaktadır. Bu metodoloji, belirli bir ekonomik şoktan kaynaklanan olumsuz etkileri çözmek amacıyla önceden belirlenmiş bir ağda bulaşıcılığı izlemek için uygulanmaktadır. Ancak, bu orijinal yaklaşımın bir sınırlılığı, zamanla değişen bağlılık ölçümleri için rastgele seçilen hareketli pencere boyutuna bağımlı olmasıdır. Bu sorunu çözmek için çeşitli öneriler sunulmuştur. Kullanılan hareketli pencere Vektör Otoregresyon (VAR)'nun ortalama kare tahmin hatasının kullanılmasıyla en uygun pencere boyutunun seçilmesi (Antonakakis vd., 2020) veya ortak yayılma endeksinin kullanılması (Lastrapes ve Wiesen, 2021) örnek olarak ifade edilebilir. Bu çalışmada, Balcilar vd. (2021) izlenerek, risk şokları (Korku Endeksi (VIX)) ile Türkiye'deki finansal varlıklar arasındaki (ham petrol, altın, döviz hisse senedi ve kripto para piyasaları) bağlantıları incelemek amacıyla zamanla değişen parametreli vektör Otoregresyon (TVP-VAR) ve genişletilmiş ortak bağlılık yaklaşımı birlikte uygulanmıştır. Balcilar vd. (2021) tarafından önerilen TVP-VAR genişletilmiş ortak bağlılık yaklaşımı tanıtılmaktadır. İlk olarak, kovaryans durağan K-değişkenli bir TVP- VAR modeli düşünelim. Bayesyen bilgi kriterine (BIC) dayalı olarak bir TVP-VAR modeli tahmin edilmektedir (Denklem 1):

$$y_t = B_t y_{t-1} + \epsilon_t, \epsilon_t \sim N(0, \Sigma_t) \quad (1)$$

$$vec(B_t) = vec(B_{t-1}) + v_t, v_t \sim N(0, R_t) \quad (2)$$

Burada y_t, y_{t-1} ve ϵ_t, Kx1 boyutunda vektörlerdir ve B_t ile Σ_t, KxK boyutunda matrislerdir. $vec(B_t)$ ve v_t, K^2x1 boyutunda vektörlerdir ve R_t, K^2x K^2 boyutunda bir matristir. Bu model, tüm parametrelerin (B_t) ve seriler arasındaki korelasyonun zamanla değişmesine olanak tanır. Ayrıca, varyans-kovaryans matrisleri (Σ_t ve R_t) zamanla değişmektedir.

Bir sonraki adımda, TVP-VAR modeli, Wold temsili teoremine göre $y_t = \sum_{h=0}^{\infty} A_{h,t}\varepsilon_{t-h}$ bir TVP-VMA modeline dönüştürülür. Burada $A_0 = I_K$ ve ϵ_t, zamanla değişen kovaryans matrisi $E(\epsilon_t\epsilon_t')= \Sigma_t$'ye sahip simetrik beyaz gürültü şoklarını ifade eder. Bu nedenle, H-adımlı tahmin katsayısı şu şekilde yazılabilir (Denklem 3):

$$\xi_t(H) = y_{t+H} - E(y_{t+H}|y_t, y_{t-1}, \dots) = \sum_{h=0}^{H-1} A_{h,t}\epsilon_{t+H-h} \quad (3)$$

Tahmin hatası kovaryans matrisi şu şekilde yazılabilir (Denklem 5):

$$E(\xi_t(H)\xi_t'(H) = A_{h,t}\sum_t A_{h,t}' \quad (4)$$

Önerilen çerçeve, Diebold ve Yılmaz'ın (2014) H-adımlı ileriye dönük genelleştirilmiş tahmin hatası varyans ayrıştırmasına (GFEVD) dayanmaktadır. GFEVD, $gSOT_{ij,t}$, j değişkeninden kaynaklanan bir şokun i değişkeni üzerindeki etkisini temsil eder ve şu şekilde yazılabilir (Denklem 5):

$$\varphi_{ij,t}^{gen}(H) = \frac{E\left(\xi_{i,t}^2(H)\right) - E[(\xi_{i,t}(H) - E(\xi_{i,t}(H))|\varepsilon_{j,t+1}, \dots, \varepsilon_{j,t+H}]^2}{E\left(\xi_{i,t}^2(H)\right)} \quad (5)$$

$$= \frac{\sum_{h=0}^{H-1}(e_i'A_{h,t}\sum_t e_j)^2}{\left(e_j'\sum_t e_j\right)\sum_{h=0}^{H-1}(e_i'A_{h,t}\sum_t A_{h,t}'e_{i)}} \quad (6)$$

$$gSOT_{ij,t}(H) = \frac{\varphi_{ij,t}^{gen}(H)}{\sum_{j=1}^{N}\varphi_{ij,t}^{gen}(H)} \quad (7)$$

Burada e_j, i'inci konumundaki bir olan Kx1 boyutunda sıfır seçim vektörüdür. $\varphi_{ij,t}^{gen}(H)$, i değişkenin H- adımlı tahmin katsayısı varyansında, j değişkeninin gelecekteki şoklarına şart koşmasıyla oluşan oransal azalmayı temsil eder. $\sum_{j=1}^{K}\varphi_{ij,t}^{gen}(H) \neq 1$ olduğunda, birliğe normalize edilerek $gSOT_{ij,t}$'nin değeri elde edilir. Daha sonra, toplam yönlü bağlantılılık endeksi şu şekilde elde edilir (Denklem 8 ve Denklem 9):

$$S_{i\leftarrow\bullet,t}^{gen,from}(H) = \sum_{j=i,i\neq j}^{K} gSOT_{ij,t}(H) \quad (8)$$

$$S_{i\rightarrow\bullet,t}^{gen,to}(H) = \sum_{j=i,i\neq j}^{K} gSOT_{ij,t}(H) \quad (9)$$

TCI ağ içindeki birbirine bağlılığı gösterir. TCI'yı şu şekilde tanımlanır (Denklem 10):

$$\mathrm{TCI_t} = \frac{1}{\mathrm{K}}\sum_{\mathrm{i=1}}^{\mathrm{K}} \mathrm{S}_{\mathrm{i\leftarrow\bullet,t}}^{\mathrm{gen,from}}(\mathrm{H}) = \frac{1}{\mathrm{K}}\sum_{\mathrm{i=1}}^{\mathrm{K}} \mathrm{S}_{\mathrm{i\rightarrow\bullet,t}}^{\mathrm{gen,to}}(\mathrm{H}) \tag{10}$$

Lastrapes ve Wiesen (2021) tarafından önerilen ortak bağlantılılık yaklaşımı şuna eşittir: Denklem 11 ve Denklem 12):

$$\mathrm{S}_{\mathrm{i\leftarrow\bullet,t}}^{\mathrm{jnt,from}}(\mathrm{H}) = \frac{\mathrm{E}\left(\xi_{\mathrm{i,t}}^{2}(\mathrm{H})\right) - \mathrm{E}\left[\xi_{\mathrm{i,t}}(\mathrm{H}) - \mathrm{E}\left(\xi_{\mathrm{i,t}}(\mathrm{H})|\epsilon_{\forall\neq\mathrm{i,t+1}}, \ldots, \epsilon_{\forall\neq\mathrm{i,t+H}}\right)\right]^{2}}{\mathrm{E}\left(\xi_{\mathrm{i,t}}^{2}(\mathrm{H})\right)} \tag{11}$$

$$= \frac{\sum_{\mathrm{h=0}}^{\mathrm{H-1}} \mathrm{e_i'A_{h,t}} \sum \mathrm{M_i}(\mathrm{M_i'} \sum \mathrm{M_i})^{-1}\mathrm{M_i'} \sum \mathrm{A_{h,t}'e_i}}{\sum_{\mathrm{h=0}}^{\mathrm{H-1}}\left(\mathrm{e_i'A_{h,t}} \sum \mathrm{A_{h,t}'e_i}\right)} \tag{12}$$

Bu, i değişkeninin H-adımlı tahmin hatası varyansının, i dışındaki tüm değişkenlerin gelecekteki şoklarına birlikte şart koşularak açıklanabilecek oranıdır. Burada $\mathrm{M_i}$, i-inci sütunu elimine edilmiş kimlik matrisine eşit olan $\mathrm{K\,x\,(K-1)}$ boyutunda bir dikdörtgen matristir ve $\epsilon_{\forall\neq\mathrm{i,t+1}}$, t+1'de i'den farklı tüm değişkenlerin şoklarını ifade eder.

Genişletilmiş ortak bağlantılılık yaklaşımını elde etmek için amaç; $gSOT_{ij,t}$'nin eşdeğeri olan $jSOT_{ij,t}$'yi bulmaktır ve şu koşulları sağlar:

$$\mathrm{S}_{\mathrm{i\leftarrow\bullet,t}}^{\mathrm{jnt,from}} = \sum_{\mathrm{j=1,i\neq j}}^{\mathrm{K}} \mathrm{jSOT_{ij,t}} \tag{13}$$

$$\mathrm{S}_{\mathrm{i\leftarrow\bullet,t}}^{\mathrm{jnt,to}} = \sum_{\mathrm{j=1,i\neq j}}^{\mathrm{K}} \mathrm{jSOT_{ij,t}} \tag{14}$$

$$\mathrm{jSOI_t} = \frac{1}{\mathrm{K}}\sum_{\mathrm{i=1}}^{\mathrm{K}} \mathrm{S}_{\mathrm{i\leftarrow\bullet,t}}^{\mathrm{jnt,from}} = \frac{1}{\mathrm{K}}\sum_{\mathrm{i=1}}^{\mathrm{K}} \mathrm{S}_{\mathrm{i\rightarrow\bullet,t}}^{\mathrm{jnt,to}} \tag{15}$$

Ölçekleme yaklaşımını genelleştirmek için Lastrapes ve Wiesen'in (2021) takip edilmekte ve burada ölçekleme faktörü λ her satıra göre aşağıdaki gibi farklılık göstermektedir:

$$\lambda_{\mathrm{i}} = \frac{\mathrm{S}_{\mathrm{i\leftarrow\bullet,t}}^{\mathrm{jnt,from}}}{\mathrm{S}_{\mathrm{i\leftarrow\bullet,t}}^{\mathrm{gen,from}}} \tag{16}$$

$$\lambda = \frac{1}{K}\sum_{i=1}^{K} \lambda_i \tag{17}$$

Son olarak, şunlar elde edilir:

$\mathrm{jSOT_{ij,t}} = \lambda_{\mathrm{i}}\mathrm{gSOT_{ij,t}}$

$\mathrm{jSOT_{ij,t}} = 1 - \sum_{\mathrm{i\leftarrow\bullet,t}}^{\mathrm{jnt,from}}$,

$\mathrm{S}_{\mathrm{i\rightarrow\bullet,t}}^{\mathrm{jnt,to}} = \sum_{\mathrm{j=1,1\neq j}}^{\mathrm{K}} \mathrm{jSOT_{ji,t}}$

Son olarak, ölçeklendirme parametresinin satıra göre değişmesine imkân tanır ve net toplam ve çift yönlü bağlantılılık ölçülerini aşağıdaki gibi hesaplanmasını sağlar:

$$S_{ij,t}^{jnt,net} = jSOT_{ji,t} - jSOT_{ij,t} \tag{18}$$

$$S_{i,t}^{jnt,net}(H) = S_{i\rightarrow\bullet,t}^{jnt,to} - S_{i\leftarrow\bullet,t}^{jnt,from} \tag{19}$$

3.1.2. Wavelet Uyum Analizi

Wavelet Uyum Analizi son yıllarda yaygın bir dinamik ekonometrik yaklaşım haline gelmiştir (Vukovic vd., 2021). Bu analiz açıklamadan önce Torrence ve Compo'nun (1998) çalışmasında belirtildiği gibi "Wavelet Güç Spektrumu (WPS)" ve "Çapraz Wavelet Dönüşüm (XWT)" ölçüleri tanımlanması gerekir. Bu bağlamda, WPS farklı frekanslar için bir zaman serisinin varyansının zaman göre nasıl evrildiğini gösterir ve aynı zamanda farklı zaman ölçeklerindeki varyansların büyüklüğü, gücün büyüklüğü olarak tanımlanır. XWT ölçüsü, her bir zaman ölçeğine ait iki zaman serisi arasındaki lokal kovaryansın hesaplanmasına olanak sağlayan bir ölçü olarak nitelendirilir. Bu ölçü zaman ve frekans uzayında zaman serilerinin ortak varyanslarının yüksek olduğu alanları belirlemek için kullanılır. Wavelet Uyum Analizi ise iki zaman serisi arasındaki ortak hareketler ve nedensellik ilişkisini farklı frekanslara göre zaman içerisinde nasıl değiştiğini araştırmak için kullanılır (Kangallı Uyar, 2021: 126). Ayrıca zaman serilerinin çeşitli ölçeklere ayrıştırılmasını kolaylaştırarak geleneksel zaman serisi teknikleriyle fark edilemeyen içgörüleri ortaya çıkarır (Ferrer vd., 2016) hatta zaman frekansına dayalı özellikleri, daha yüksek (daha düşük) ölçek özelliklerinin daha kapsamlı bir şekilde anlaşılmasına olanak tanır. Daha da önemlisi, bu teknik zaman serisi verilerindeki durağanlık sorununun üstesinden gelmede etkili bir yaklaşım olduğu ifade edilir (Antonakakis vd., 2018). Süreç, zaman içinde büyüme ve düşüşe uğrayan küçük bir dalganın kullanılmasını içerir (Shaik vd., 2023). Son olarak Wavelet Uyum Analiziyle zaman ve frekans uzayında iki zaman serisinin ortak hareket ettiği veya nedensellik bağlantısı içinde olduğu bütün bölgeleri belirlemek mümkündür. Bu bağlamda zaman ve frekans uzayında iki zaman serisi arasındaki lokal korelasyon katsayısı hesaplanmasına olanak tanır (Kangallı Uyar, 2021: 127). Bu çalışmada, Torrence ve Compo (1998) tarafından özetlenen ve wavelet uyum analizinin aşağıda tanımlandığı metodolojiyi izleyerek değişkenler arasındaki ilişkileri tespit etmektir. Torrence ve Compo'nun (1998) çalışmasında $p(t)$ ve $q(t)$ gibi iki farklı zaman serisi için XWT ölçüsünü aşağıdaki gibi tanımlanır (Denklem 20):

$$W_{p,q}(\tau, s) = W_p(\tau, s)W_q^*(\tau, s) \tag{20}$$

Burada $W_p(\tau, s)$ ve $W_q(\tau, s)$ sırasıyla $p(t)$ ve $q(t)$'nin Sürekli Wavelet Dönüşümlerini (*Continuous Wavelet Transforms*-CWT) ifade eder. τ konum, s ölçek parametresini, * işareti ise karmaşık sayının eşliğini gösterir. $p(x)$ ve $q(x)$ iki zaman serisi arasındaki Wavelet uyum ölçüsü şu şekilde tanımlanır (Denklem 21):

$$R^2(\tau, s) = \frac{\left|S\left(t^{-1}W_{p,q}(\tau, s)\right)\right|^2}{S\left(t^{-1}\left|W_p(\tau, s)\right|^2\right)S\left(t^{-1}\left|W_q(\tau, s)\right|^2\right)} \tag{21}$$

Burada $R^2(\tau, s)$ her zaman ve frekansta $p(t)$ ve $q(t)$ arasındaki korelasyonu ölçer. S zaman ve ölçeklerdeki yumuşatma (düzgünleştirme) parametresini gösterir. Wavelet uyum analizi

değeri[1] 0 (sıfır) ile 1 (bir) arasında değişir ($0 \leq R^2(\tau, s) \leq 1$). $R^2(\tau, s)$'un sıfıra yakın değerler alması $p(t)$ ve $q(t)$ gibi iki zaman serisi arasındaki lokal korelasyonun zayıf olduğunu yani etkileşimin veya nedensellik bağlantılarının olmadığını gösterirken, bire yakın değerler alması durumunda ise güçlü olduğunu yani birlikte hareketin olduğu ve nedensellik bağlantılarının güçlü olduğunu göstermektedir (Rua ve Nunes, 2009: 634). Wavelet Uyum Analizinin iki zaman serisi arasındaki etkileşiminin pozitif mi yoksa negatif yönden mi olduğunu göstermemesi gibi bir sınırlaması bulunur ve bu sınırlama "lead-lag" ilişkilerinin hesaplanmasıyla çözülür. Denklem (22), Torrence ve Webster'a (1999) göre iki zaman serisi arasındaki faz farklı bağlantısını tahmin etmek için kullanılır (Denklem 22):

$$\emptyset_{p,q}(\tau, s) = tan^{-1}\left(\frac{\Im\{S(t^{-1}W_{p,q}(\tau, s))\}}{\Re\{t^{-1}W_{p,q}(\tau, s))\}}\right) \quad (22)$$

Burada $\Im$ ve $\Re$ sırasıyla düzgünleştirme güç spektrumunun gerçek ve sanal kısımlarını ifade etmektedir.

3.2. Veri Seti

Bu çalışmanın amacı, risk şokları ile Türkiye'de finansal varlıklar arasındaki yayılım etkisinin TVP-VAR genişletilmiş ortak bağlantılılık yaklaşımına dayalı wavelet uyum analizi ile araştırmaktır. Bu amaç doğrultusunda, hisse senedi piyasası için BIST100 endeksi, petrol piyasası için Brent ham petrol, döviz piyasası için USD/TRY, altın piyasası için altın ons, kripto para birimi piyasası için Bitcoin ve risk şoklarının bir ölçüsü olan S&P 500 VIX değişkenleri kullanılmaktadır. Bu veriler Investing (2024) ve Yahoo Finance'dan (2024) elde edilmiştir (04.08.2024). 08.11.2017 ile 08.09.2024 dönemini kapsayan günlük veri seti tercih edilmiştir. Bu dönem Brexit, Çin-ABD ticaret savaşı, Rahip Brunson krizi, kur şoku, COVID-19 salgını, Rusya-Ukrayna savaşı, İsrail ve Filistin savaşı ve finansal piyasayı etkileyen diğer olaylar gibi önemli şoklar yaşamıştır. Yatırımcı korku endeksi olarak bilinen VIX endeksi, yatırımcıların yatırım stratejilerini değiştirmeleri için önemli bir referans olarak ve piyasanın volatilitesinin bir temsili olarak finansal piyasa çalışmalarında yaygın olarak kullanılır (Basher ve Sadorsky, 2016; Dai vd., 2024). VIX endeksindeki artış genellikle risk şoklarını ve kötümser piyasa duyarlılığını işaret etmektedir ve bu da finansal piyasayı doğrudan etkileyeceği ifade edilebilir (Chung ve Chuwonganant, 2018; Chen ve Sun, 2022). Ayrıca, VIX endeksinin, Ekonomik Politika Belirsizlik Endeksi (EPU)'dan daha büyük bir piyasa etkisine ve öngörü gücüne sahip olduğunu bulmuşlardır (Wang vd., 2020; Chen vd., 2022). Bu nedenle, finansal piyasalardaki risk şoklarını ölçmek için VIX endeksi dikkatte alınmıştır. Zaman serilerinin logaritmik farkı $\mathrm{r_{i,t}} = \ln\left(\frac{\mathrm{P_{i,t}}}{\mathrm{P_{i,t-1}}}\right)$ formül yardımıyla hesaplanmıştır. Formül de yer alan ifadeler şu şekilde tanımlanır: $r_{i,t}$, t zamanında i'nci değişkenin fiyat getirilerini; $P_{i,t}$ ve $P_{i,t-1}$ sırasıyla t ve t-1 zamanında değişkenlerin kapanış fiyatlarını göstermektedir. Tüm değişkenlerin betimleyici istatistikleri Tablo 2'de gösterilmiştir.

Tablo 2. Tanımlayıcı İstatistikler ve Normallik Testi Sonuçları

	BIST100	Altın	Dolar	BTC	Brent Petrol	VIX
Ortalama	0.129	0.038	0.127	0.124	0.013	0.043
Medyan	0.190	0.026	0.073	0.066	0.197	-0.562
Maximum	9.421	5.775	14.75	20.335	19.077	76.824
Minimum	-10.306	-5.113	-20.904	-49.727	-27.976	-33.582
Std.Sapma	1.701	0.947	1.285	4.503	2.627	7.947
Çarpıklık	-0.686	-0.196	-1.123	-0.935	-1.343	1.488
Basıklık	7.665	7.100	66.907	15.119	22.547	12.296
JB	1665.483***	1195.075***	287949.000***	10589.100***	27413.500***	6710.493***
ADF	-40.162***	-42.471***	-35.713***	-41.857***	-38.819***	-44.613***
Gözlem Sayısı	1690	1690	1690	1690	1690	1690

Not: JB normal dağılımın Jarque-Berra testi (1980) ve ADF (1979) genelleştirilmiş en küçük kareler Dickey Fuller birim kök testidir. *, ** ve *** sırasıyla %0,1, %0,05 ve %0,01 değerlerine karşılık gelmektedir. Çarpıklık: D'Agostino testi; Basıklık: Anscombe ve Glynn testleridir.

Tablo 2'de, değişkenlere ait günlük getirilere ilişkin tanımlayıcı istatistikler özetlenmiştir. VIX ve Bitcoin piyasalarının diğer piyasalara göre daha yüksek volatiliteye sahip olduğu görülmektedir. Tüm piyasalar için çarpıklık katsayısı (skewness) değerleri sıfırdan saptığı gözlemlenmiştir. VIX pozitif ve sağa çarpıklık değerine sahipken, diğer piyasalar ise negatif ve sola çarpık değerler aldığı tespit edilmiştir. Tüm piyasalar için basıklık katsayısı (kurtosis) değerlenin üçten büyük olduğu gözlemlenmiştir. Ayrıca, durağanlık testi, tüm piyasaların birim kök içermediğini göstermektedir; çünkü genişletilmiş Dickey-Fuller testi (ADF) %1 anlamlılık seviyesinde reddedilmiştir. Jarque-Bera testi göre tüm piyasa getirilerinin %1 anlamlılık seviyesinde H_0 hipotezi reddedilmiştir ve getirilerin normal dağılmadığını tespit edilmiştir. Bu durum, farklı piyasalar arasındaki ilişkileri araştırmak için zamanla vektör otoregresyon (VAR) modelini kullanabileceğimizi göstermektedir.

4. Analiz Bulguları

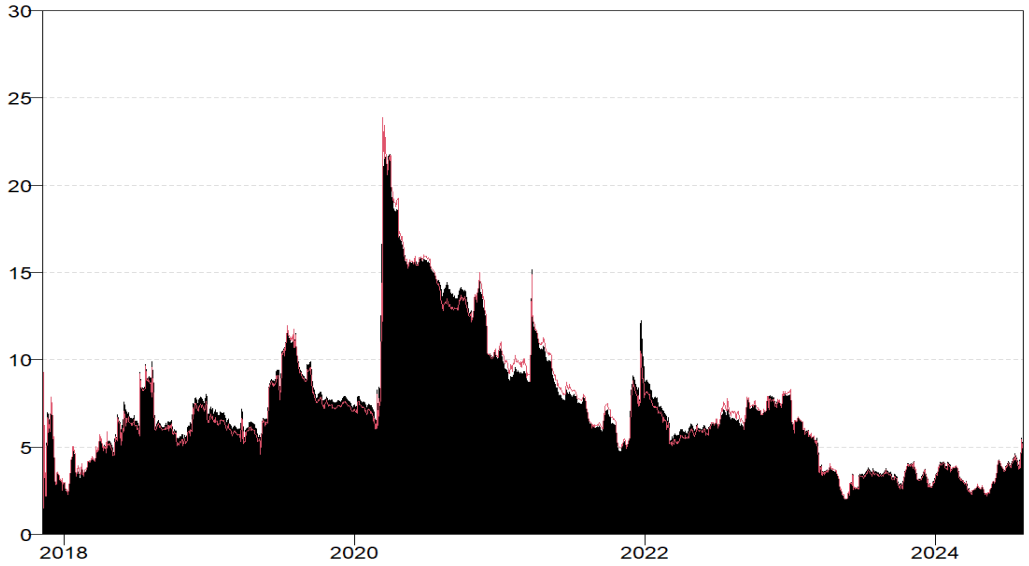
Tablo 3, TVP-VAR modelinin tahmin hata varyans ayrıştırması yoluyla elde edilen farklı varlıklar arasındaki toplam bağlılık ortalama değerlerini sunmaktadır. Bu tablo, volatilitenin değişkenler arasında nasıl dağıldığını ortaya koymaktadır. Burada ana diyagonal elemanlar, değişkenlerin şokların kendi varyans paylarını gösterirken, diyagonal dışı değerler, diğer değişkenlerdeki, diğer bir deyişle finansal varlıklar arasındaki etkileşimleri yansıtmaktadır. Volatilite Yayılımı (FROM), satırların sütun değişkenlerinden nasıl etkilendiğini; Volatilite Yayılımı (TO) ise sütun değişkenlerinin satırları nasıl etkilediğini göstermektedir (Bouri vd., 2021; Aydoğdu ve Durmaz, 2024). Tablo 3'te görüldüğü üzere, tüm piyasaların incelendiği dönemler dikkate alındığında, birkaç dikkat çekici gözlem ortaya çıkmaktadır. İlk olarak, finansal varlıklar arasındaki bağlılığın arttığına dair bulgulara ulaşılmıştır. Örneğin, BIST100 değişkeni için tahmin hata varyansının yaklaşık %90,69'u kendi şoklarından kaynaklanırken, %9,31'i altın, dolar, bitcoin ve Brent petrol değişkenlerinden şok almaktadır. Toplam ortalama ortak bağlantılılık endeksi (TCI) %7,19 olarak hesaplanmış ve bu, tüm değişkenlerin oluşturduğu ağın, ağ içindeki değişimlerin %7,19'nu açıklayabileceğini göstermektedir. Diğer bir ifadeyle bu, ortalama olarak bir finansal varlıktaki tahmin hatası varyansının %7,19'nu diğer tüm piyasalardaki yeniliklere atfedilebileceği anlamına gelmektedir.

Tablo 3. Ortalama Ortak Bağlantılılık Tablosu

	BIST100	Altın	Dolar	BTC	Brent Petrol	Diğerlerinden
BIST100	90.69	1.23	3.74	2.26	2.07	9.31
ALTIN	0.89	95.83	1.00	1.21	1.01	4.17
DOLAR	6.13	0.59	90.91	1.25	1.13	9.09
BTC	2.12	1.97	0.98	93.20	1.73	6.80
BRENT PETROL	1.63	2.30	0.83	1.81	93.44	6.56
Diğerlerine	10.77	6.09	6.55	6.53	6.00	35.94
NET	1.46	1.91	-2.54	-0.27	-0.56	TCI
NPDC	1.00	3.00	1.00	3.00	2.00	7.19

Not: Sonuçlar, bir gecikme uzunluğuna sahip TVP-VAR modeline (BIC) ve 20 adım ileriye dönük genelleştirilmiş tahmin hatası varyans ayrıştırmasına dayanmaktadır (Balcilar vd., 2021).

Özellikle, BIST100 ve altın incelenen dönemde şokların başlıca yayıcıları olarak görülürken, dolar, bitcoin, Brent petrol şok alıcıları olduğu gözlemlenmiştir. Bu durum, uygulanan genişlemeci para politikası tedbirleri ve merkez bankalarının düşük faiz yoluyla sağlanan likidite enjeksiyonlardan kaynaklanabileceğini göstermektedir. Öte yandan hem altın hem de bitcoin piyasalarının Covid-19 pandemisi ve ham petrol piyasasının OPEC+ üretim anlaşmasının bozulmasıyla ortaya çıkan ikili şoktan etkilenmesiyle, ham petrolün pandemi dönemi boyunca net bir şok alıcıya dönüştüğü gözlemlenmektedir. Bu sonuçların incelenen dönemlerde birbirine bağlılıklarına genel bir bakış sağladığını ifade edilebilir. Diğer bir ifadeyle Tablo 3'te sunulan sonuçlar, incelenen dönemin tamamını dikkate alan toplu sonuçlar olup, TCI değerindeki önemli sapmalara yol açabilecek belirli dönemlere odaklanmamaktadır. Bu bağlamda, zaman içindeki finansal varlıklar arasındaki bağlılığı etkileyen belirli dönemleri belirlemek için dinamik yaklaşımla devam edilmiştir. Çalışma dönemi boyunca farklı ekonomik veya politik durumlara TCI'nın nasıl yanıt verdiğini göstermek amacıyla Şekil 2, Dinamik Toplam Bağlantılılık Endeksi'nin (TCI) zaman içerisindeki dinamiklerini sunmaktadır.



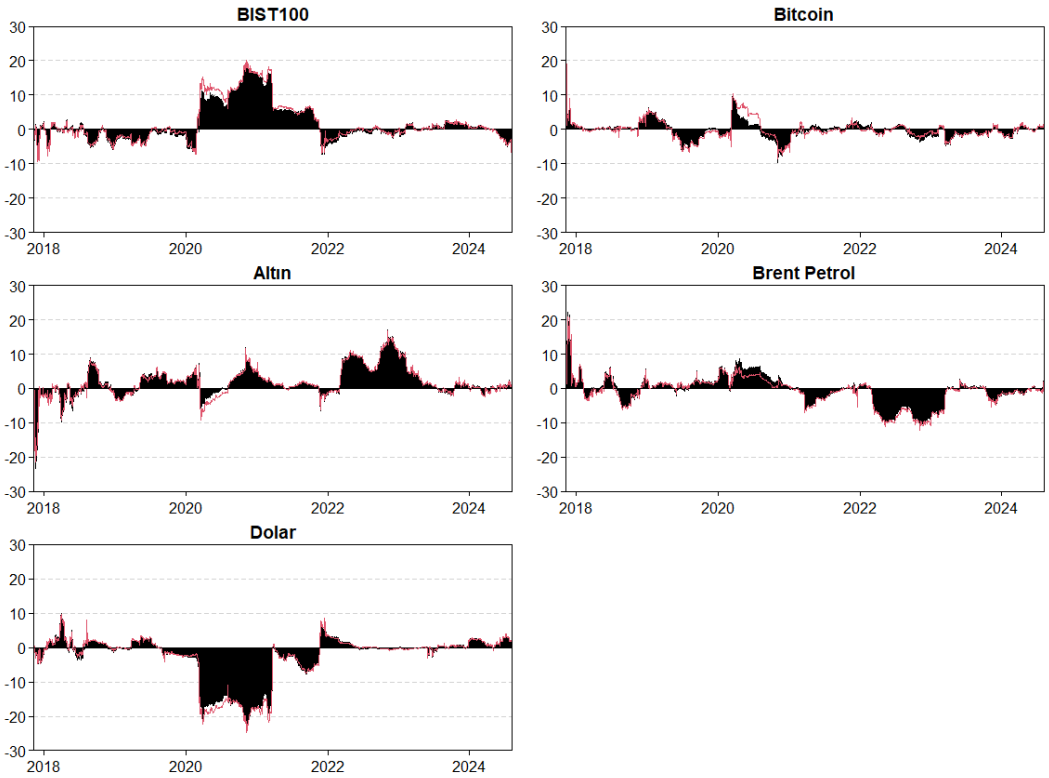
Şekil 2. Dinamik Toplam Bağlantılılık Endeksi (TCI)

Not: Sonuçlar, bir gecikme uzunluğuna sahip bir TVP-VAR modeline (BIC) ve 20 adım ileriye dönük genelleştirilmiş tahmin hatası varyans ayrıştırmasına dayanmaktadır. Siyah gölgeli alan ortak bağlantılılık sonuçlarını temsil ederken, kırmızı çizgi orijinal bağlantılılık sonuçlarını göstermektedir (Balcilar vd., 2021).

Şekil 2'de görüldüğü gibi, ağın dinamik bağlılığı zaman içinde özellikle kriz dönemlerinde önemli ölçüde dalgalandığı görülmektedir. Bu durum, finansal piyasalar arasındaki bağlılığın zamana bağlı olduğuna işaret etmektedir. Şekil 3'te daha yakından incelendiğinde, belirgin bağlantılılıkların, dünya genelinde yeni bulaşıcı hastalık salgınının başlaması ve ikinci bir dalga korkularını tetiklemesiyle örtüşen Mart 2020 yılının ortalarında ortaya çıktığı görülmektedir. TCI'nin örnekleme dönemi başında nispeten yüksek seviyelerde seyrettiği ve belirli dönemlerde dalgalanmalar yaşadığı tespit edilmiştir. Bu dönemler arasında, TCI'nin %24 seviyesine yaklaştığı bir zirve noktasına ulaştığı gözlemlenmiştir. Ancak, zaman içerisinde bu değerlerin düşüş eğilimi gösterdiği ve %8 ile %12 aralığında daha istikrarlı bir seyir izlediği belirlenmiştir. 2018-2020 yılları arasındaki ekonomik ve siyasi gelişmelerin, TCI'de belirgin dalgalanmalara yol açtığı görülmüştür. Bununla birlikte, genel eğilim bu dönemde de düşüş yönünde seyretmiştir. 2019-2020 döneminde, özellikle küresel piyasalardaki toparlanmaya paralel olarak, TCI'nin yeniden yükselerek analiz dönemi içindeki en yüksek seviyesine ulaştığı tespit edilmiştir. Ancak, bu yükseliş eğilimi, petrol fiyatlarındaki keskin düşüşler ve Covid-19 pandemisinin neden olduğu ekonomik belirsizlikler nedeniyle tersine dönmüş ve bağlılık seviyesi yaklaşık %10 seviyesine gerilemiştir. 24 Şubat 2022 yılında başlayan Rusya-Ukrayna savaşının TCI üzerinde yeniden yükselişe neden olduğu ve %13 seviyelerine ulaştığı gözlemlenmiştir. Ancak bu artış, savaşın ardından düşüş trendine dönüşmüştür. Son olarak, 2023 yılının son çeyreğinde meydana gelen İsrail-Filistin savaşı, TCI'de yeni dalgalanmalara neden olmuş ve %7 seviyesine yükselmesine yol açmıştır. Covid-19 salgınıyla birlikte, artan belirsizlik nedeniyle nakit talebindeki artış, bu tür kriz dönemlerinde ekonomik bağlılığı artıran önemli bir faktör olarak değerlendirilebilir. Ancak, Covid-19 sonrası yatırımcıların tepkisi, önceki kriz dönemlerine kıyasla çok daha hızlı ve yoğun bir şekilde gerçekleşmiştir. Benzer bir şekilde, 2022 yılında başlayan Rusya-Ukrayna Savaşı da küresel piyasalarda belirsizliği artırmış, enerji ve emtia piyasalarında ciddi dalgalanmalara yol açmıştır. Bu savaş, özellikle enerji arzına yönelik endişeleri tetikleyerek ham petrol fiyatlarında başlangıçta bir artışa neden olmuş, ancak savaşın uzaması ve küresel talebin yavaşlamasıyla birlikte ham petrol piyasalarında belirgin bir düşüş yaşanmıştır. Bu durum, yatırımcıların risk algısını ve nakit talebini daha da artırmış, özellikle enerji ve emtia odaklı piyasalarda hızlı ve spekülatif hareketlere neden olmuştur. Böylece, Covid-19 pandemisi ve Rusya-Ukrayna Savaşı gibi birbirini izleyen küresel krizler, piyasa davranışlarında ani değişikliklere ve finansal volatilitenin artmasına yol açmıştır. Bir değişkenin net şok yayıcıdan net şok alıcıya geçiş yaptığı ya da tam tersi bir davranış sergilediği durumlarda, davranışındaki değişiklikleri değerlendirmek önemlidir. Pozitif değerlerin bir net yayıcı rolünü, negatif değerlerin ise bir net alıcı rolünü ifade ettiğini belirtmek gerekir. Bu bağlamda, Şekil 3'de değişkenlerin toplam net yönsel grafiğine yer verilmiştir.

Şekil 3'te görüldüğü üzere, BIST100 getirilerinin, incelenen dönemin ilk iki yıl boyunca net şok alıcısı konumunda olduğu görülmektedir. 2020-2022 yılları arasında ise net şok yayıcısı olduğu ve 2022-2024 yıllarında ise net şok alıcısı konumunda olduğu gözlemlenmektedir. Bitcoin ve Brent petrol getirilerinin, çalışma döneminin ilk dönemlerinde hem net şok yayıcısı hem de net şok alıcısı konumunda iken, Covid-19 pandemi dönemiyle beraber net şok yayıcı konumuna geçmiş ve sonraki dönemler de ise genellikle net şok alıcısı konumunda olduğu gözlemlenmektedir. Altın getirilerinin, incelenen dönemde ağırlıklı olarak net şok yayıcısı konumunda olduğu gözlemlenmiştir. Dolar getirilerinin ise 2020-2021 yıllarında net şok alıcısı konumunda olduğu, diğer dönemlerde net şok yayıcı olduğu görülmektedir. Bu bulgular doğrultusunda elde edilen bağlılıklar sonucunda, Kriz dönemlerinde BIST100, Bitcoin, Altın ve

Brent petrol getirilerinin net şok yayıcısı ve dolar getirilerinin ise uzun vade de ne şok alıcısı olduğu sonucuna varılabilir.

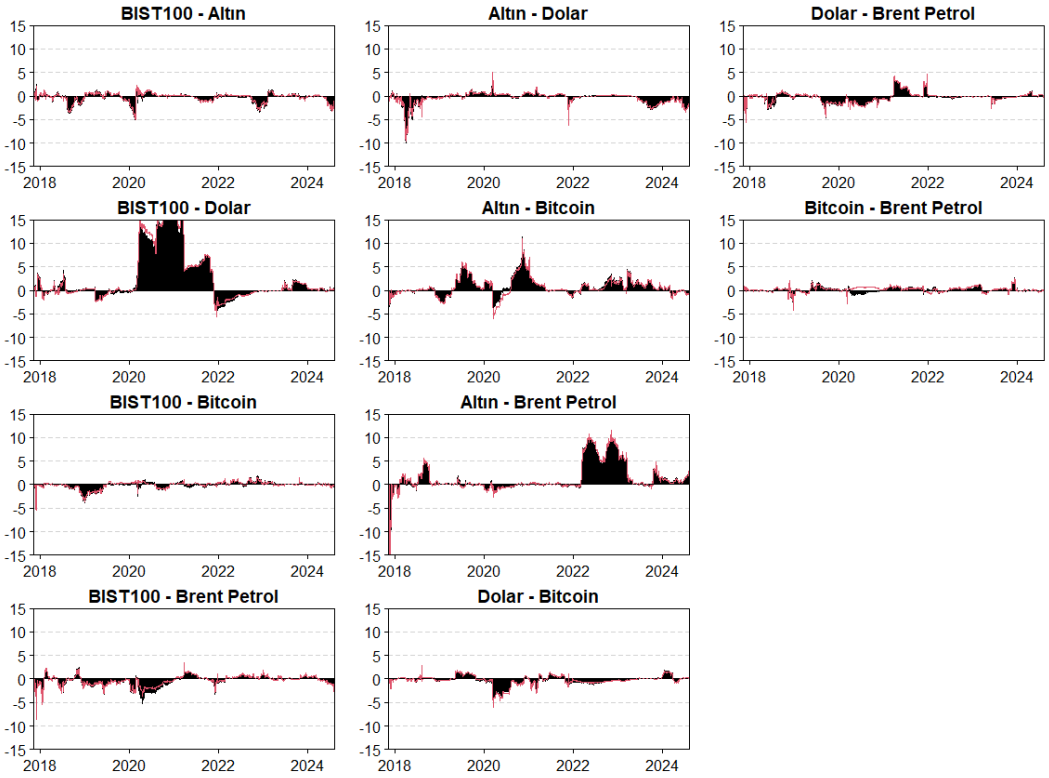


Şekil 3. Net Toplam Yönsel Bağlantılılık Grafiği

Not: Sonuçlar, bir gecikme uzunluğuna sahip bir TVP-VAR modeline (BIC) ve 20 adım ileriye dönük genelleştirilmiş tahmin hatası varyans ayrıştırmasına dayanmaktadır. Siyah gölgeli alan ortak bağlantılılık sonuçlarını temsil ederken, kırmızı çizgi orijinal bağlantılılık sonuçlarını göstermektedir (Balcilar vd., 2021).

Şekil 4'te ise tüm değişkenlerin dinamik net çift yönlü bağlantılılık sonuçlarına yer verilmiştir. Şekil 4'te görüldüğü üzere, BIST100 ile dolar, 2020-2022 yılları arasında BIST100'ün net şok yayıcısı olarak hareket ettiğini göstermektedir. 2022 yılında ise BIST100'ün net şok alıcı konumunda olduğu gözlemlenmiştir. Özellikle Covid-19 pandemisi döneminde yüksek büyüklükte etkiler yarattığı görülmüştür. BIST100 ile altın, Bitcoin ve Brent petrol grafikleri incelendiğinde, ortalama yayılma etkilerinin hem heterojenlik hem de benzerlik sergilediği görülmektedir. Diğer bir ifadeyle, bu değişkenler arasındaki yayılmanın net alıcı konumunda olduğu gözlemlenebilmektedir. Altın ile Bitcoin grafiği incelendiğinde, 2019 yılında altının net şok alıcısı olarak hareket ettiği, ancak 2020 ve 2021 yıllarında net şok yayıcı olduğu anlaşılmaktadır. 2022-2024 yıllarında ise altının net şok yayıcısı olduğu gözlemlenmiştir. Altın ile Brent petrol arasındaki ilişkiye bakıldığında, 2020-2022 yıllarının ilk çeyreğine kadar altının net şok alıcısı olarak hareket ettiği, ancak 2022 yılının ikinci çeyreğinden 2023 yılının son çeyreğine kadar altının net şok yayıcı konumunda olduğu görülmektedir. Diğer ikili bağlılıklar açısından, 2017-2024 yılları arasında büyüklük açısından birbirine benzer bir seyir izlendiği, ancak bu değişkenlerin kayda değer bir bağlantı oluşturmadığı ve az da olsa net şok alıcıları konumunda olduğu anlaşılmaktadır. Sonuç olarak, hisse senedi, dolar, petrol, altın ve Bitcoin getirileri arasında önemli bir bağlılık olduğu gözlemlenmektedir. Özellikle belirli dönemlerde

yaşanan ekonomik ve politik şokların, varlıklar arasındaki korelasyonları anlamlı ölçüde değiştirdiği görülmektedir. Örneğin, 2018'deki Rahip Brunson krizi ve dolar şoku, BIST100 ile dolar arasındaki ilişkinin keskin biçimde negatif hâle gelmesine yol açarken, 2020 yılındaki Covid-19 pandemisi, altın ve Brent petrol gibi güvenli liman veya enerji varlıklarının fiyat oynaklığını artırmıştır. Ayrıca Bitcoin gibi kripto varlıkların geleneksel piyasa göstergeleriyle ilişkisi, yüksek volatilite nedeniyle belirgin bir şekilde değişkenlik göstermekte ve bu durum, kripto paraların yatırım ortamındaki artan önemini yansıtmaktadır. Makroekonomik ve jeopolitik olaylar, özellikle doların hem geleneksel güvenli liman varlıkları hem de gelişmekte olan piyasa göstergeleri üzerindeki merkezi etkisini açıkça ortaya koyarken, Brent petrol gibi emtia fiyatlarının enerji piyasası odaklı etkiler yarattığı ve diğer finansal göstergelerle zayıf bir ilişki sergilediği görülmektedir. Sonuç olarak, varlık sınıfları arasındaki bu ilişkiler, portföy çeşitlendirmesi ve dinamik risk yönetimi açısından kritik bir öneme sahiptir. Ayrıca, politika yapıcılar ve yatırımcılar bu sonuçları potansiyel yayılma etkileri için erken uyarı sinyalleri olarak kullanabilir. Bu nedenle, yalnızca tek bir varlığa odaklanmayan, geliştirilmiş varlık yönetim stratejilerinin uygulanması kritik öneme sahiptir.



Şekil 4. Dinamik Çift Yönlü Net Bağlantılılık Grafiği

Not: Sonuçlar, bir gecikme uzunluğuna sahip bir TVP-VAR modeline (BIC) ve 20 adım ileriye dönük genelleştirilmiş tahmin hatası varyans ayrıştırmasına dayanmaktadır. Siyah gölgeli alan ortak bağlantılılık sonuçlarını temsil ederken, kırmızı çizgi orijinal bağlantılılık sonuçlarını göstermektedir (Balcilar vd., 2021).

Risk şoklarının piyasalar arası yayılmalar üzerindeki zaman-frekans nedenselliğini daha ayrıntılı bir şekilde ölçmek amacıyla, piyasalar arası oynaklık yayılmaları üzerindeki risk şoklarının etkisini ölçmek için VIX endeksi kullanılmıştır. İlk olarak, piyasalar arasındaki

dinamik TCI (Toplam Bağlılık İndeksi) ve bireysel piyasaların NET'ini (Net Bağlılık) elde edilmiştir. TCI'ye logaritmik birinci fark uygulanmış, NET'e ise birinci fark uygulanmıştır ve açıklayıcı istatistikler Tablo 4'te gösterilmiştir.

Tablo 4. Tanımlayıcı İstatistikler

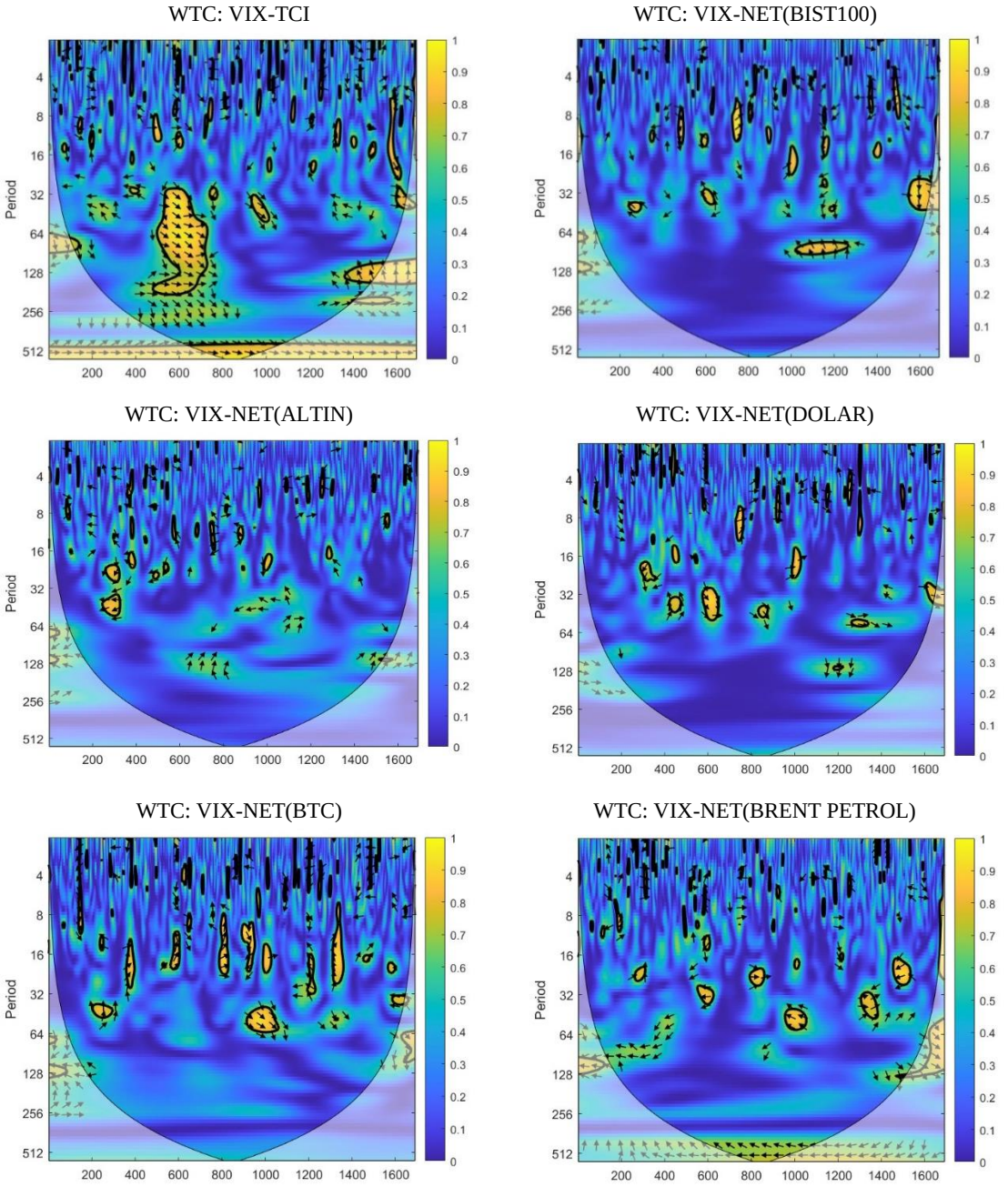
	NET(BIST100)	NET(ALTIN)	NET(DOLAR)	NET(BTC)	NET(BRENT PETROL)	TCI
Ortalama	-114.867	50.439	-62.060	47.866	13.2623	0.075
Medyan	-0.454	-0.2761	-0.162	-0.995	-0.300	-0.163
Maximum	5253.760	79811.180	29274.360	79892.660	12003.580	191.483
Minimum	-106072.200	-8747.894	-98193.890	-10140.780	-11381.310	-103.550
Std. Sapma	2913.450	1982.043	2548.539	1981.959	514.476	8.141
Çarpıklık	-31.275	38.64737	-33.076	38.681	5.7563	7.617
Basıklık	1074.910	1554.483	1313.507	1560.936	394.608	210.658
JB	81183671***	1.70E+08***	1.21E+08***	1.71E+08***	10808216***	3052855.***
ADF	-41.032***	-41.307***	-41.177***	-41.282***	-41.548***	-50.217***

Not: JB normal dağılımın Jarque-Berra testi (1980) ve ADF (1979) genelleştirilmiş en küçük kareler Dickey Fuller birim kök testidir. *, ** ve *** sırasıyla %0,1, %0,05 ve %0,01 değerlerine karşılık gelmektedir. Çarpıklık: D'Agostino testi; Basıklık: Anscombe ve Glynn testleridir.

VIX ile bağlantılılık endeksi arasındaki zaman-frekans uzayında korelasyon ve nedenselliği analiz etmek için wavelet uyum analizi kullanılmıştır. Zaman- frekans uzayı tanımında, 0-4, 4-8, 8-16 kısa dönem frekansı, 16-32, 32-64, 64-128 orta dönem frekansı ve 128-256, 256-512 ve 512 ve üzeri uzun dönem frekansı olarak belirlenmiştir (Crowley, 2007: 214; Jana vd., 2023: 8; Aydoğdu, 2024: 217-218). Sonuçlar Şekil 5'te gösterilmektedir.

Şekil 5 incelendiğinde, iki değişkenin anlamlılık bölgelerinin ağırlıklı olarak 2019 yılının ikinci çeyreğinde ve 2020 yılının ilk çeyreğinde, 2021 ve 2022 yıllarının ilk çeyreğinde orta ve uzun dönemlerinde olduğu görülmektedir. Wavelet uyum analizinde faz farkı okları bu iki bölgede sağa doğru işaret etmekte olup, VIX'in oynaklığı ile TCI'nin oynaklığının pozitif yönde ilişki olduğunu göstermektedir. Bu, kriz dönemlerinde, finansal piyasalar arasındaki oynaklık önemli ölçüde arttığını göstermektedir. Daha spesifik olarak, 2020 ve 2021 yıllarında orta ve uzun döneminde faz farkı oku sağ ve sağ alt köşeyi göstermektedir; bu da bu noktada TCI hareketlerinin VIX hareketlerinden önce geldiğini göstermektedir. Bu, 2020 ve 2021 yıllarında orta ve uzun dönem frekansında TCI'nin oynaklığının risk oynaklıkları üzerindeki etkisini olduğu ifade edilebilir. Kısaca, VIX, piyasalar arası toplam yayılma oynaklığında önemli bir faktör olduğu söylenebilir. VIX ile diğer piyasalara ait wavelet uyum analizinde, incelenen zaman-frekans alanlarında (kısa, orta ve uzun dönemlerde) belirgin bir ilişki veya anlamlı bir nedensellik bulunmadığını ifade etmektedir. Bu durum, VIX'in diğer piyasalar üzerindeki etkisinin sınırlı ya da istatistiksel olarak anlamlı olmadığını, dolayısıyla piyasa yayılmaları üzerindeki etkisinin zayıf kaldığını göstermektedir. Sonuç olarak, VIX'in TCI endeksi üzerindeki önemli, zamanla değişen dinamik nedensellik ilişkisi tespit edilmiştir. Bu etkinin, özellikle Covid-19 salgını sırasında daha belirgin hale geldiği ve risk şoklarındaki değişikliklerin TCI üzerinde yönlendirici ve olumlu bir etkisinin olduğu görülmüştür. Ayrıca, VIX'ten bireysel piyasalara yönelik net yayılmalarda frekans alanında ve zamanla değişen önemli nedensellik ilişkileri olmadığı tespit edilmiştir. Bu durum, VIX'in diğer piyasalar üzerindeki etkisinin kriz veya finansal şok dönemlerinde daha belirgin hale geldiğini, ancak stabil dönemlerde piyasa koşullarına bağlı olarak sınırlı kaldığını göstermektedir. Aynı zamanda, diğer piyasaların VIX'e karşı daha bağımsız veya dayanıklı bir

yapıya sahip olabileceği, özellikle gelişmiş piyasa ekonomilerinde bu etkinin daha sınırlı hissedilebileceği düşünülmektedir. Kısa, orta ve uzun dönemlerde genel olarak zayıf bir ilişkinin gözlenmesi, VIX'in etkisinin yalnızca belirli frekanslarda değil, piyasa sistemi genelinde düşük seviyede olduğunu işaret etmektedir. Bu bulgu, VIX'in piyasa oynaklıkları üzerindeki etkisini değerlendirme açısından kritik bir içgörü sunmakla birlikte, söz konusu ilişkinin piyasa dinamikleri, analiz edilen dönem veya kullanılan metodoloji gibi faktörlere bağlı olarak değişebileceğini de vurgulanabilir.



200	400	600	800	1000	1200	1400	1600
2018/08	2019/06	2020/03	2021/01	2021/11	2022/08	2023/06	2024/03

Şekil 5. VIX ve Bağlantılılık Endekslerine Dayalı Wavelet Uyum (WTC) Analizi

VIX ile TCI endeksi arasındaki ilişkiyi, yukarıdaki sonuçlara dayanarak, VIX'in TCI endeksi üzerinde zamanla değişen bir etkisinin olduğunu, bu etkinin özellikle Covid-19 pandemisi sırasında en belirgin olduğunu gözlemlenmiştir. Mevcut çalışmalarda, Hatemi-J asimetrik nedensellik testi, piyasa ilişkilerini analiz etmek için yaygın ve etkili bir yöntem olarak kullanılmaktadır. Bu nedenle, bir sağlamlık testi olarak, Hatemi-J asimetrik nedensellik testini VIX ile TCI endeksi ve diğer piyasalar arasındaki nedenselliği analiz etmek için kullanılmış ve sonuçlar Tablo 5'te sunulmuştur.

Tablo 5. Sağlamlılık Testi- Değişkenlere Ait Hatemi-J Asimetrik Nedensellik Sonuçları

H_0 Hipotezi	Test Değeri	Kritik Bootstrap Değerleri %1	%5	%10	H_0 Hipotezi	Test Değeri	Kritik Bootstrap Değerleri %1	%5	%10
Panel A					**Panel A**				
$VIX^+ \not\Rightarrow TCI^+$	0.004	8.088	3.766	2.641	$TCI^+ \not\Rightarrow VIX^+$	1.213	9.979	3.921	2.786
$VIX^+ \Rightarrow TCI^-$	12.037***	10.715	3.664	2.317	$TCI^+ \Rightarrow VIX^-$	4.621**	8.187	3.629	2.225
$VIX^- \not\Rightarrow TCI^-$	0.988	14.801	4.142	2.152	$TCI^- \not\Rightarrow VIX^-$	1.211	11.606	3.633	2.130
$VIX^- \Rightarrow TCI^+$	5.007**	5.766	3.260	2.417	$TCI^- \not\Rightarrow VIX^+$	1.645	11.058	3.953	2.289
Panel B					**Panel B**				
$VIX^+ \not\Rightarrow NET(BIST100)^+$	0.148	10.951	3.904	2.268	$NET(BIST100)^+ \not\Rightarrow VIX^+$	0.052	10.052	4.183	2.453
$VIX^+ \not\Rightarrow NET(BIST100)^-$	0.085	9.076	3.791	2.306	$NET(BIST100)^+ \not\Rightarrow VIX^-$	0.000	6.526	3.456	2.408
$VIX^- \not\Rightarrow NET(BIST100)^-$	0.265	7.202	3.767	2.749	$NET(BIST100)^- \not\Rightarrow VIX^-$	0.028	8.826	4.408	3.068
$VIX^- \not\Rightarrow NET(BIST100)^+$	0.841	16.353	4.109	2.431	$NET(BIST100)^- \not\Rightarrow VIX^+$	0.080	6.857	4.126	2.900
Panel C					**Panel C**				
$VIX^+ \not\Rightarrow NET(ALTIN)^+$	0.035	7.875	3.581	2.518	$NET(ALTIN)^+ \Rightarrow VIX^+$	3.698*	7.383	3.742	2.751
$VIX^+ \not\Rightarrow NET(ALTIN)^-$	0.816	6.496	3.705	2.725	$NET(ALTIN)^+ \not\Rightarrow VIX^-$	1.660	8.524	3.404	2.071
$VIX^- \not\Rightarrow NET(ALTIN)^-$	1.292	19.889	3.983	1.961	$NET(ALTIN)^- \not\Rightarrow VIX^-$	0.690	11.830	3.530	2.195
$VIX^- \not\Rightarrow NET(ALTIN)^+$	1.156	7.443	4.116	2.898	$NET(ALTIN)^- \not\Rightarrow VIX^+$	0.864	11.811	3.678	2.224
Panel D					**Panel D**				
$VIX^+ \not\Rightarrow NET(BTC)^+$	1.123	8.565	4.026	2.634	$NET(BTC)^+ \not\Rightarrow VIX^+$	0.001	8.148	3.904	2.508
$VIX^+ \not\Rightarrow NET(BTC)^-$	0.326	7.237	3.768	2.397	$NET(BTC)^+ \not\Rightarrow VIX^-$	0.170	9.510	3.076	2.053
$VIX^- \not\Rightarrow NET(BTC)^-$	0.174	20.719	4.170	1.953	$NET(BTC)^- \not\Rightarrow VIX^-$	0.091	9.836	3.244	2.070
$VIX^- \not\Rightarrow NET(BTC)^+$	1.821	7.951	3.655	2.561	$NET(BTC)^- \not\Rightarrow VIX^+$	0.000	12.568	3.864	2.507
Panel E					**Panel E**				
$VIX^+ \not\Rightarrow NET(BRENT\ PETROL)^+$	0.000	11.860	3.730	1.943	$NET(BRENT\ PETROL)^+ \not\Rightarrow VIX^+$	0.320	13.249	5.219	2.297
$VIX^+ \not\Rightarrow NET(BRENT\ PETROL)^-$	0.003	10.277	3.035	1.584	$NET(BRENT\ PETROL)^+ \not\Rightarrow VIX^-$	0.246	10.849	3.319	1.884
$VIX^- \not\Rightarrow NET(BRENT\ PETROL)^-$	0.172	11.465	3.069	1.596	$NET(BRENT\ PETROL)^- \not\Rightarrow VIX^-$	0.398	11.670	3.098	1.725
$VIX^- \not\Rightarrow NET(BRENT\ PETROL)^+$	0.312	11.716	3.963	1.909	$NET(BRENT\ PETROL)^- \Rightarrow VIX^+$	12.719**	13.805	3.579	2.012
Panel F					**Panel F**				
$VIX^+ \not\Rightarrow NET(DOLAR)^+$	0.013	12.584	3.915	1.933	$NET(DOLAR)^+ \not\Rightarrow VIX^+$	0.030	14.853	4.251	2.130
$VIX^+ \not\Rightarrow NET(DOLAR)^-$	0.108	13.498	3.330	1.856	$NET(DOLAR)^+ \not\Rightarrow VIX^-$	0.727	13.128	2.865	1.818
$VIX^- \not\Rightarrow NET(DOLAR)^-$	0.661	19.596	3.498	1.612	$NET(DOLAR)^- \Rightarrow VIX^-$	2.382*	18.384	3.237	1.631
$VIX^- \not\Rightarrow NET(DOLAR)^+$	0.007	18.884	3.845	2.076	$NET(DOLAR)^- \not\Rightarrow VIX^+$	0.748	11.669	3.710	2.065

Not: *, ** ve *** sırasıyla %0,1, %0,05 ve %0,01 değerlerine karşılık gelmektedir.

Tablo 5'te görüldüğü gibi, Hatemi-J asimetrik nedensellik testi sonuçları, VIX ile TCI endeksi arasında %1 ve %5 anlamlılık seviyelerinde çift yönlü nedensellik olduğunu göstermektedir. Bu durum, VIX endeksi ile piyasalar arasındaki bağlantı hem korelasyon hem de nedensellik açısından ortaya koymaktadır. Elde edilen bulgular, wavelet uyum analizi sonuçlarıyla da tutarlı bir görünüm sergilemektedir.

5. Sonuç

08.11.2017-08.09.2024 yılları arasındaki BIST100 Endeksi, Brent ham petrol, dolar, altın ons, Bitcoin ve (VIX) piyasalar arasındaki yayılma etkileri inceleyerek risk şokları ve yayılma etkileri arasındaki ilişkiyi kapsamlı şekilde analiz edilmiştir. Çalışmada, pay senedi, altın, petrol, dolar ve bitcoin piyasaları arasında önemli yayılma etkiler olduğu gözlemlenmiştir. Toplam yayılma etkileri, 2018 yılındaki Rahip Brunson krizi ve dolar şoku, 2020 yılındaki meydana gelen Covid-19 pandemisi, 2022 yılında Rusya-Ukrayna çatışması ve 2023 yılında başlayan İsrail-Filistin savaşı ve diğer finansal gelişmeler sırasında önemli derece de artmıştır. Dinamik ortak bağlantılılık net yayılma etkileri, BIST100 getirilerinin incelenen dönemin ilk iki yılında net şok alıcısı olarak hareket ettiği görülmektedir. 2020-2022 döneminde ise net şok yayıcısı konumunda olup, 2022-2024 döneminde tekrar net şok alıcısı rolünü üstlendiği tespit edilmiştir. Bitcoin ve Brent petrol getirileri, çalışma dönemi başlangıcında hem net şok alıcısı hem de yayıcısı iken, Covid-19 pandemisiyle net şok yayıcı konumuna geçmiş ve sonraki dönemlerde genellikle net şok alıcısı olarak değerlendirilmiştir. Altın getirileri, analiz sürecinde çoğunlukla net şok yayıcısı olarak karşımıza çıkarken, dolar getirileri 2020-2021 yıllarında net şok alıcısı, diğer zaman dilimlerinde ise net şok yayıcısı olarak belirlenmiştir. Dinamik ikili net yayılma etkileri, 2020-2022 yılları arasında BIST100 ile dolar arasındaki ilişki, BIST100'ün net şok yayıcısı olarak hareket ettiğini ortaya koymaktadır. Ancak, 2022 yılında BIST100'ün net şok alıcı konumuna geçtiği gözlemlenmiştir. Özellikle Covid-19 pandemisi sırasında, BIST100'ün yüksek büyüklükte etkiler yarattığı dikkat çekmektedir. Elde edilen bu bulgu Akyıldırım vd. (2022) tarafından yapılan çalışma ile uyumludur. BIST100 ile altın, Bitcoin ve Brent petrol arasındaki ilişkiler incelendiğinde, ortalama yayılma etkilerinin hem heterojenlik hem de benzerlik sergilediği, bu değişkenlerin çoğunlukla net alıcı konumunda olduğu sonucuna varılmıştır. Altın ile Bitcoin arasındaki ilişki, 2019 yılında altının net şok alıcısı olarak hareket ettiğini, ancak 2020 ve 2021 yıllarında net şok yayıcı olduğunu göstermektedir. 2022-2024 döneminde ise altının net şok yayıcı konumunu sürdürdüğü tespit edilmiştir. Altın ile Brent petrol arasındaki bağlamda, 2020-2022 yıllarının ilk çeyreğine kadar altının net şok alıcısı olduğu, ancak 2022 yılının ikinci çeyreğinden 2023 yılının son çeyreğine kadar net şok yayıcı konumuna geçtiği belirlenmiştir.

Piyasalar arasındaki yayılma etkileri üzerindeki risk şoklarının etkileri zaman ve frekans alanlarında heterojendir. VIX'in TCI üzerindeki etkisi, 2020 ve 2021 yıllarında pozitif olup orta ve uzun vadede yoğunlaşmaktadır. Bu bulgu, TCI'nin oynaklığının risk oynaklıkları üzerinde etkili olduğunu ortaya koymaktadır. Özetle, VIX'in piyasalar arası toplam yayılma oynaklığında önemli bir faktör olduğu belirtilmektedir. Bununla birlikte, VIX ile diğer piyasalara yönelik yapılan wavelet uyum analizlerinde, kısa, orta ve uzun dönemlerde belirgin bir ilişki ya da anlamlı bir nedensellik tespit edilememiştir. Bu, VIX'in diğer piyasalar üzerindeki etkisinin sınırlı olduğunu veya istatistiksel olarak anlamlı olmadığını, dolayısıyla piyasa yayılmaları üzerindeki etkisinin zayıf kaldığını göstermektedir. Özetle VIX ile TCI endeksi arasında, özellikle Covid-19 pandemisi sırasında daha belirgin hale gelen, önemli ve zamanla değişen bir dinamik nedensellik

ilişkisi bulunmuştur. Bu etkinin, risk şoklarındaki değişimlerin TCI üzerinde yönlendirici ve olumlu bir etkisi olduğu görülmüştür. Ancak, VIX’ten bireysel piyasalara yönelik net yayılmalarda, frekans alanında ve zamanla değişen anlamlı nedensellik ilişkilerinin olmadığı tespit edilmiştir.

Sonuç olarak, varlık sınıfları arasındaki ilişkiler, finansal piyasaların dinamik yapısı içinde portföy çeşitlendirmesi ve risk yönetimi açısından kritik öneme sahiptir. Bu ilişkiler, yatırımcıların farklı varlık sınıfları arasında risklerini yayarak portföylerini optimize etmelerine olanak tanırken, politika yapıcılar için de piyasa şoklarına karşı etkili önlemler geliştirme fırsatı sunar. Özellikle yayılma etkileri, finansal sistemlerin birbirine olan bağlılığını göstererek sistemik risklerin anlaşılmasında ve yönetilmesinde önemli bir kavramsal çerçeve sunmaktadır. Yayılma etkilerinin doğru şekilde analiz edilmesi, olası krizlerin önceden tahmin edilmesine ve daha etkin politika müdahalelerinin geliştirilmesine katkı sağlayabilir. Bu bağlamda, politika yapıcılar ve yatırımcıların tek bir varlık sınıfına aşırı bağımlılıktan kaçınarak daha dengeli ve çeşitlendirilmiş varlık yönetim stratejilerini benimsemeleri büyük önem taşır. Özellikle küresel düzeyde yaşanan şoklar, örneğin Covid-19 pandemisi veya Rusya-Ukrayna çatışması, piyasa bağlantılarını ve yayılma etkilerini şekillendirmiştir. Politika yapıcıların piyasa bağlantılarını dikkate alarak yapısal olarak genişletici nitelikte para ve maliye politikaları uygulaması, sermaye piyasalarının gelişmesine katkı sağlayabilir. Bu politikalar aynı zamanda kamuoyu beklentilerini olumlu yönde değiştirerek piyasa aktörlerinin güvenini artırabilir. Gelişmekte olan piyasaların politika yapıcıları, gelişmiş ekonomilerden kaynaklanabilecek şokların etkilerini en aza indirmek adına düzenleyici çabalarını güçlendirmeleri gerekmektedir. Bu çabalar, orta ve uzun vadeli risk yönetim stratejileriyle desteklenmelidir; zira yayılma etkileri genellikle uzun vadeli sonuçlar doğurur. Yatırımcılar açısından, portföylerini çeşitlendirerek piyasa yayılma risklerine karşı korunmak önemlidir. Rasyonel bir portföy dağılımı, yatırımcıların risk-getiri dengesini sağlamasına yardımcı olur. Ayrıca risk şoklarına karşı uzun vadeli bir perspektif benimsemek, ani panik satışlarından kaçınmak ve stratejik bir yaklaşımı sürdürmek, finansal karar alma süreçlerinde önemli bir avantaj sağlayabilir. Finansal piyasa bağlantılılıklarının artan karmaşıklığı ve sistemik risklerin yayılma potansiyeli, politika yapıcılar ve yatırımcılar açısından etkin stratejiler geliştirilmesini zorunlu hale getirmektedir. Bu bağlamda, politika yapıcıların piyasalar arası yayılma etkilerini izlemek için erken uyarı sistemleri geliştirmesi büyük önem taşımaktadır. Böyle bir yaklaşım, özellikle kriz dönemlerinde sistemik risklerin minimize edilmesini sağlayarak finansal istikrarın korunmasına katkıda bulunabilir.

Merkez bankaları ve düzenleyici otoriteler, VIX volatilite göstergelerini yakından takip etmeli ve piyasa müdahalelerini bu göstergeler doğrultusunda şekillendirilmesi önerilebilir. Volatilitenin yüksek olduğu dönemlerde daha sıkı düzenleyici önlemler alınması, piyasa dalgalanmalarının olumsuz etkilerini sınırlandırabilir. Bu doğrultuda, para politikalarının tasarımı sürecinde finansal piyasa bağlantılılıkları dikkate alınmalı ve belirli varlık sınıflarının sistemik risk taşıma potansiyeli göz önünde bulundurulmalıdır. Böyle bir yaklaşım, risklerin piyasa genelinde yayılımını önlemek açısından önemli bir rol oynayabilir. Yatırımcılar açısından ise, portföy çeşitlendirme stratejileri risk yönetiminin temelini oluşturabilir. Volatilite yayıcı ve şok alıcı varlıkların bir araya getirildiği dengeli bir portföy, kriz dönemlerinde yatırımcıların risklerini azaltmasına yardımcı olabilir. Özellikle altın gibi güvenli liman varlıklarının bu tür dönemlerde portföyde önemli bir yer tutması faydalı olabilir. Bunun yanı sıra, piyasalar arası bağlantılılık analizlerini izlemek ve portföyü bu doğrultuda yeniden dengelemek, ani piyasa şoklarına karşı bir koruma mekanizması sağlayabilir. Sonuç olarak hem politika yapıcıların hem de yatırımcıların

finansal piyasalar arasındaki dinamik ilişkileri ve sistemik risklerin potansiyel yayılımını dikkate alarak strateji geliştirmesi, sürdürülebilir bir finansal ekosistemin inşasında önemli bir rol oynayabilir. Bu tür proaktif yaklaşımlar yalnızca risklerin azaltılmasına değil, aynı zamanda piyasa fırsatlarının değerlendirilmesine de olanak sağlayabilir.

Araştırma ve Yayın Etiği Beyanı
Etik kurul izni ve/veya yasal/özel izin alınmasına gerek olmayan bu çalışmada araştırma ve yayın etiğine uyulmuştur.

Araştırmacıların Katkı Oranı Beyanı
Yazar, makalenin tamamına yalnız kendisinin katkı sağlamış olduğunu beyan eder.

Araştırmacıların Çıkar Çatışması Beyanı
Bu çalışmada herhangi bir potansiyel çıkar çatışması bulunmamaktadır.

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ANALYSIS OF THE SPILLOVER EFFECT BETWEEN RISK SHOCKS AND FINANCIAL ASSETS IN TURKEY USING TVP-VAR-BASED WAVELET COHERENCE ANALYSIS

EXTENDED SUMMARY

Aim of the Study

This study examines the volatility spillovers among financial assets in Turkey and the effects of risk shocks within the framework of TVP-VAR extended collinearity and wavelet coherence analysis. The study analyses market linkages using different financial assets such as the BIST100 Index, Brent crude oil, USD/TRY exchange rate, gold ounce, Bitcoin, and S&P 500 Volatility Index (VIX). The main objective of this study is to understand the effects of the dynamic relationships of financial assets in time and frequency dimensions to determine the volatility spread and how this spread changes during crisis periods.

Literature Review

In the existing literature, volatility spillovers and interconnectedness effects in financial markets have been frequently discussed. For example, studies on the relationship between international markets and Borsa Istanbul (BIST) have revealed that market dynamics become more pronounced during crises. It is frequently emphasized in the literature that gold and commodity markets play a volatility-spreading role while stock markets generally play an absorbing role. However, there are limited studies on the decomposition of these cross-market effects in time and frequency dimensions. To fill this literature gap and analyze volatility dynamics in more depth, this study aims to contribute to the existing studies with advanced econometric methods.

Methodology

The research is conducted within a methodological framework based on the TVP-VAR extended collinearity approach, wavelet coherence analysis, and Hatemi-J asymmetric causality test. The TVP-VAR model analyses the dynamic spillover effects among financial assets. This model makes it possible to measure the impact of shocks on markets more precisely with time-varying parameters. Wavelet coherence analysis is used to understand how market linkages change in time and frequency dimensions. The Hatemi-J causality test assessed the robustness of the results by analyzing asymmetric relationships between market variables. In the study, the daily data set covering 08.11.2017 to 08.09.2024 is preferred, and the effects of major economic and political crises and market shocks are examined in the analyses.

Findings

According to the study results, volatility spillovers across financial assets in Turkey increase significantly during crisis periods. While BIST100 and gold ounce stand out as volatility

shock-spreading assets, the dollar, Bitcoin, and Brent oil are found to be volatility-absorbing assets. For example, it was found that approximately 90.69% of the volatility shocks of BIST100 returns were caused by internal dynamics. In comparison, 9.31% were affected by other assets such as gold, dollar, Bitcoin, and Brent oil. Similarly, the gold market generally plays a shock-spreading role during crises, while Brent oil and Bitcoin markets are shock absorbers. The results of the Wavelet coherence analysis reveal that the dynamic linkages between financial markets change over time and that these changes are concentrated at specific frequencies. In particular, the COVID-19 pandemic, the Russia-Ukraine war in 2022, and other geopolitical events are the main factors that strengthen the link between financial markets. For example, it was found that the VIX index positively affected the Total Connectivity Index (TCI) during crisis periods, and this effect intensified in the medium and long term, especially between 2020 and 2023. These findings suggest that market shocks are limited to short-term impacts and affect long-term market dynamics. Hatemi-J asymmetric causality analysis reveals that the causality relationship between VIX and TCI is bidirectional and intensifies this effect during crisis periods. However, the impact of VIX on markets such as Bitcoin and Brent oil is limited so these markets may have a more independent structure.

Conclusion

This study provides a detailed analysis of the dynamic linkages between financial markets and the effects of volatility spillovers in time and frequency dimensions. The findings provide important insights for portfolio diversification and dynamic risk management strategies. Policymakers should develop early warning mechanisms that consider market linkages to take more effective measures against financial crises. Moreover, investors are advised to diversify their portfolios and avoid over-reliance on a particular asset class. In addition to providing methodological contributions to the literature, the study offers a new perspective for understanding the dynamic structure of financial markets. Especially in times of crisis, increased market interconnectedness requires investors and policymakers to monitor market dynamics more closely. In conclusion, this study provides an essential framework for a better understanding of the financial system and makes a meaningful contribution to filling the literature gaps.

Ekonomi, Politika & Finans Araştırmaları Dergisi, 2025, 10(1): 332-358
Journal of Research in Economics, Politics & Finance, 2025, 10(1): 332-358
Araştırma Makalesi / Research Article, https://doi.org/10.30784/epfad.1598165

DeFi, PETROL, ALTIN VE VIX KORKU ENDEKSİNİN KIRILGAN BEŞLİ ÜLKELERİNDEKİ HİSSE SENEDİ PİYASALARIYLA BAĞLANTISI: BİR DALGACIK TUTARLILIĞI ANALİZİ

The Connection between DeFi, Oil, Gold, and the VIX Fear Index with Stock Markets in the Fragile Five Countries: A Wavelet Coherence Analysis

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Anahtar Kelimeler:
Kırılgan Beşli Hisse Senedi Piyasaları, Defi, Emtia Piyasaları, Korku Endeksi, Dalgacık Dönüşümü

JEL Kodları:
E44, G15, O43

Öz

Bu çalışma, DeFi (merkeziyetsiz finans) piyasaları, emtia piyasaları ve korku endeksi (VIX) ile kırılgan beşli ülkelerin (Brezilya, Hindistan, Endonezya, Türkiye ve Güney Afrika) borsa fiyatları arasındaki dinamik ilişkileri zaman ve frekans boyutunda incelemeyi amaçlamaktadır. Çalışma kapsamında 2019-2024 dönemi arasındaki DeFi piyasalarını temsilen en uzun örneklem geçmişine sahip olan Link, Maker ve Basic Attention Token varlıkları, emtia piyasalarını temsil eden petrol ve altın fiyatları ile VIX korku endeksi kullanılmıştır. Elde edilen sonuçlar, DeFi, altın ve petrol piyasaları ile kırılgan beşli ülkelerin hisse senedi getirileri arasında farklı zaman dilimlerinde pozitif bir korelasyon olduğunu göstermektedir. Öte yandan, VIX endeksi ile kırılgan beşli ülkelerin borsa endeksleri arasında kısa, orta ve uzun vadede negatif yönlü bir ilişki tespit edilmiştir. Ancak, değişkenler arasındaki öncülük ilişkisine dair belirgin bir bulgu elde edilememiştir. Bu bulgular, DeFi piyasaları, emtia fiyatları ve VIX korku endeksinin kırılgan beşli ülkelerinin borsa piyasaları üzerindeki etkilerini daha iyi anlamaya katkı sağlamaktadır. Özellikle, kırılgan beşli ülkelerin küresel piyasa şoklarına karşı duyarlılığının yüksek olması nedeniyle, risk yönetimi stratejilerinin güçlendirilmesi gerektiği sonucuna varılmıştır.

Keywords:
Fragile Five Stock Markets, Defi, Commodity Markets, Fear Index, Wavelet Transformation

JEL Codes:
E44, G15, O43

Abstract

This study aims to examine the dynamic relationship between DeFi (decentralized finance) markets, commodity markets, fear index (VIX), and stock prices of fragile five countries (Brazil, India, Indonesia, Turkey, and South Africa) in time and frequency dimensions. Within the scope of the study, Link, Maker, and Basic Attention Token assets with the longest sample history representing DeFi markets between 2019-2024, oil and gold prices representing commodity markets, and the VIX fear index were used. The results obtained show that there is a positive correlation between DeFi, gold and oil markets, and stock returns of fragile five countries in different time periods. On the other hand, a negative relationship was found between the VIX index and stock indices of fragile five countries in the short, medium and long term. However, no clear finding was obtained regarding the leading relationship between the variables. These findings contribute to a better understanding of the effects of DeFi markets, commodity prices and VIX fear index on stock markets of fragile five countries. In particular, it was concluded that risk management strategies should be strengthened due to the hogh sensitivity of the fragile five countries to global market shocks.

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Makale Geliş Tarihi (Received Date): 08.12.2024 *Makale Kabul Tarihi (Accepted Date): 24.02.2025*

1. Giriş

Ekonomiler arasındaki artan yatırım ve ticaret faaliyetleri, ülkelerin hisse senedi piyasalarının küresel piyasalar ve farklı varlık sınıflarıyla olan korelasyonunu güçlendirmiştir (Badshah vd., 2019; Ghallabi vd., 2024). Piyasalar arasındaki ilişkilerin güçlenmesiyle dünya genelinde finansal dalgalanmaların yayılmasını hızlandırmıştır. Özellikle finansal krizler, salgınlar ve savaş gibi küresel riske yol açan olaylar, küresel ve bölgesel belirsizlikleri tetikleyerek emtia fiyatlarında ve finansal piyasalarda ciddi oynaklıkların yaşanmasına neden olmuştur. Dalgalanmalardan en çok etkilenenler ise gelişmemiş ve gelişmekte olan ülkelerin finansal piyasalarıdır. Gelişmekte olan ülkeler arasında yer alan Kırılgan Beşli (Brezilya, Hindistan, Endonezya, Türkiye ve Güney Afrika), iç ve dış şoklara karşı daha hassas yapıları nedeniyle diğer gelişmekte olan ülkelere kıyasla daha fazla risk taşımaktadır. Yüksek dış borç yükleri, siyasi belirsizlik ve ham petrol gibi emtialara bağımlı üretim yapmaları bu ülkelerin finansal piyasalarını daha kırılgan hale getirmektedir (Ali ve Khan, 2020). Dolayısıyla, bu ülkelere yatırım yapmak isteyen yatırımcılar ve portföy yöneticileri için riskten korunma daha karmaşık ve zorlu bir süreç haline gelmiştir.

Yatırımcılar ve portföy yöneticilerinin, beklenmeyen piyasa şoklarından kaynaklanan kayıplara karşı korunmak için doğru varlıkları ve piyasaları seçerek portföy çeşitlendirmesi yapmaları gerekmektedir. Etkili bir portföy çeşitlendirmesi farklı varlık sınıflarının getiri, volatilite, karşılıklı bağımlılık ve birlikte hareket etme özelliklerinin derinlemesine incelenmesini gerektirir (Frikha vd., 2024). Bu noktada, yatırımcıların göz önünde bulundurması gereken önemli göstergelerden birisi VIX endeksidir. Zira VIX endeksi, piyasadaki volatiliteyi ölçen ve yatırımcıların risk iştahını arttırıp azaltabilen bir güvenlik göstergesidir. VIX'in yüksekliği, piyasada belirsizliğin arttığını; düşük seviyeleri ise daha sakin bir piyasa ortamını işaret etmektedir (Bouri vd., 2017; Coronado vd., 2018; Shi vd., 2021; Drake, 2022). Özellikle belirsizliğin arttığı dönemlerde, hisse senedi piyasaları düşüş gösterirken, altın ve petrol gibi varlıkların fiyatlarının yükselmesi, bu varlıklar arasında negatif korelasyon olabileceğini düşündürmektedir (Sarwar, 2017; Shaikh, 2018; Uludağ ve Khurshid, 2019; Chittineni, 2022; Mensi vd., 2023).

Yatırımcılar, riskten korunmak ve yüksek getiri elde etmek için ham petrol ve altın gibi önemli emtia varlıklarına yönelmektedir. Bu emtialar, hem finansal piyasalarda önemli bir rol oynamakta hem de ekonomik belirsizlik dönemlerinde yatırımcılara güvenli liman sağlamaktadır. Küresel piyasalarda en fazla işlem gören ve makro-finansal değişkenlerden doğrudan etkilenen emtialardan biri, Batı Teksas Ham Petrolü (WTI) olarak öne çıkmaktadır (Choi ve Hammoudeh, 2010; Choi ve Hong, 2020; Demirer vd., 2020). Bir enerji kaynağı olarak görülen petrol, firmalar için üretim girdisi ve ulaşım ile ısıtma gibi günlük operasyonlarda önemli bir maliyet unsuru olmanın yanı sıra, ekonomik risklere karşı korunmak amacıyla da kullanılmaktadır (Ghazani ve Jafari, 2021). Bundan dolayı, ham petrol fiyatlarının firmaların hisse senedi fiyatlarıyla bağlantılı olduğu düşünülmektedir (Çevik vd., 2022). Öte yandan, ham petrolün yanı sıra altın da yatırımcıların portföylerinde güvenli bir varlık olarak bulundurdukları bir emtiadır. Altın, özellikle risk çeşitlendirmesi yapmak isteyen yatırımcıların tercih ettiği bir araçtır. Dünya genelinde altının ons fiyatı, genellikle emtia piyasasında referans alınan ana ölçüt olarak kabul edilmektedir. Ayrıca, finansal piyasalarda belirsizliklerin arttığı dönemlerde altın, değerini koruma özellikleriyle öne çıkmakta ve yatırımcılara ekonomik dalgalanmalara karşı güçlü bir koruma sağlamaktadır (Siddiqui ve Roy, 2019; Coronado vd., 2018; Shi vd., 2021).

Son yıllarda ise dijitalleşme süreçlerinin hız kazanması ve blok zincir teknolojilerindeki gelişmeler, finansal varlıklar ile piyasa dinamiklerini önemli ölçüde dönüştürmüştür. Dijitalleşme, özellikle güvenli liman arayışında olan yatırımcılar, spekülatörler ve politika yapıcılar arasında dijital varlıklar ile geleneksel finansal varlıklar arasındaki ilişkiyi derinlemesine inceleme ihtiyacı doğurmuştur (Liao vd., 2024). Özellikle merkezi olmayan finans (DeFi) tokenleri gibi dijital varlık sınıflarının yükselişi, yeni finansal araçların gelişimini ve piyasa davranışlarını yeniden şekillendirmektedir. DeFi tokenleri, akıllı sözleşmeler ve blok zincir teknolojilerini finansal araçlar olarak kullanan yenilikçi bir finansal hizmettir (Ramos ve Zanko, 2020). Aynı zamanda, kripto para piyasasının hızla büyüyen alt sektörlerinden biri olarak tanımlanmaktadır (Şoiman vd., 2023). Kısacası, DeFi, finansal varlıklar ve ürünler üzerindeki işlemlerin aracılara ihtiyaç duyulmadan, kamuya açık ve merkeziyetsiz bir blok zincir ağı üzerinden gerçekleştirildiği bir sistemdir (Corbet vd., 2022). Bu sistem sayesinde, DeFi varlıklarıyla müşteriler, finansal hizmetlerde aracılara gerek duymadan birbirleriyle borç alıp verme, sigorta sözleşmeleri yapma, spot ticaret gibi işlemleri gerçekleştirebilmektedir (Yousaf ve Yarovaya, 2022; Bejaoui vd., 2023).

DeFi alanında LINK-Chainlink, MKR-Maker ve BAT-Basic Attention Token gibi birden fazla dijital varlık bulunmaktadır. Bunlardan LINK, ağ düğümü operatörlerinde ödeme aracı olarak kullanılan bir token iken, MKR, Ethereum blok zincirine dayanan MakerDAO ve Maker Protokolü'nün yönetim tokenidir. BAT ise, Brave tarayıcısının yerel token'idir ve Ethereum blok zinciri üzerinde çalışarak, farklı web sayfalarında reklamları görüntüleyen kullanıcılara küçük miktarlarda tazminat sağlamaktadır (Yousaf vd., 2023). DeFi sektörü, gelişmekte olan bir alan olmasına rağmen, işlem hacimlerinde olağanüstü bir büyüme göstererek fiyatlarını hızla arttırmaktadır. İşlem hacmindeki hızlı büyüme, yatırımcıları büyük ölçüde etkilemiş ve özellikle aşırı piyasa koşullarından ve riskten korunmak isteyen yatırımcılar, portföylerini oluştururken ve risk yönetimi kararları alırken DeFi fiyatlarını dikkate almaya başlamıştır (Ugolini vd., 2023). Gelişmekte olan ülkelerde, finansal ve ekonomik dalgalanma dönemlerinde güvenli liman olarak kabul edilen altın ile DeFi dijital varlıkları arasındaki bağlantılar, asimetrik modellerle test edilmiştir. Yapılan testler, DeFi dijital varlıklarının portföy yönetimi, yatırım stratejileri belirleme ve çeşitlendirme potansiyelini değerlendirme konularında önemli faydalar sağladığını ortaya koymuştur. Test sonuçları, yatırımcılar, portföy yöneticileri ve araştırmacılar için DeFi dijital varlıklarının finansal stratejilerde nasıl etkili bir araç olabileceğine dair değerli çıkarımlar sunmaktadır (Bejaoui vd., 2023).

Çalışmada, gelişen piyasalardaki riskler ve fırsatlar üzerine yapılan analizlerin artan önemi göz önünde bulundurularak, DeFi, Petrol, Altın ve VIX endeksi ile Kırılgan Beşli ülkeleri olarak tanımlanan Brezilya, Hindistan, Endonezya, Türkiye ve Güney Afrika'nın hisse senedi getirileri arasındaki karşılıklı bağımlılıklar incelenmektedir. Bu ülkeler, ekonomik ve finansal sistemlerindeki kırılganlık nedeniyle genellikle küresel piyasa şoklarına daha duyarlı hale gelmektedir. Bu bağlamda çalışmanın amacı, bu kırılgan ülkelerle diğer küresel varlıklar arasındaki ilişkilerin dinamiklerini anlamak ve bu ilişkilerin zaman içinde nasıl değiştiğini ortaya koymaktır. Bununla birlikte bu bağımlılıkların analizi, yatırımcıların portföy çeşitlendirme stratejilerini daha etkin bir şekilde geliştirmelerine ve küresel piyasa şoklarının etkilerini daha doğru bir biçimde değerlendirmelerine olanak sağlayacaktır. Bölgesel ekonomik krizlerin ve küresel finansal dalgalanmaların daha iyi anlaşılabilmesi için bu ülkelerin analizine özellikle önem verilmektedir. Kırılgan beşli ülkelerin bu tür analizlere dâhil edilmesinin temel nedeni, bu ülkelerin gelişmekte olan piyasalarda daha fazla dışsal şoka maruz kalmasıdır. Bu dışsal şoklar,

bu ülkelerin ekonomik sistemlerini ve finansal piyasalarını daha fazla etkileyebilmekte ve dolayısıyla yatırımcıların bu ülkelerdeki finansal varlıklar arasındaki bağımlılıkları daha iyi analiz etmeleri gerekmektedir Ekonomik şoklar karşısında kırılgan ülkelerin nasıl tepki verdiğini ve bu süreçte nasıl adapte olduklarını anlamak, küresel finansal dinamikleri daha kapsamlı bir şekilde analiz etmeyi mümkün kılacaktır. Çalışmada, dalgacık tutarlılığı yöntemi kullanılarak, varlıklar arasındaki karşılıklı bağımlılık yapısı hem zaman hem de frekans düzeyinde ele alınmıştır. Bu yöntem, varlıklar arasındaki ilişkiyi sadece genel anlamda değil, zaman içindeki değişimi ve farklı frekans seviyelerinde nasıl farklılaştığını da ayrıntılı bir şekilde inceleyebilme olanağı sunmaktadır. Dolayısıyla, bu yenilikçi yaklaşım, sadece kısa vadeli şokların değil, aynı zamanda uzun vadeli finansal dinamiklerin nasıl şekillendiğine dair farklı frekanslar üzerinden bilgi sunarak, kırılgan beşli ülkelerindeki piyasa ilişkilerinin farklı boyutlarını anlamaya yardımcı olacaktır.

Çalışmanın geri kalan bölümleri şu şekilde yapılandırılmıştır: İkinci bölümde, ilgili literatür taraması yapılmıştır. Üçüncü bölümde, kullanılan ekonometrik metodoloji açıklanmaktadır. Dördüncü bölümde, veri seti tanıtılmakta, yapılan ön testlerin sonuçları sunulmakta ve dalgacık tutarlılığı analizinin ampirik bulguları değerlendirilmektedir. Son olarak, beşinci bölümde ise çalışmanın bulguları özetlenmekte ve bu bulgulara dayalı bir tartışma yapılmaktadır.

2. Literatür Taraması

Çalışmada, Brezilya, Hindistan, Endonezya, Türkiye ve Güney Afrika olarak anılan kırılgan beşli ülkelerinin borsa kapanış fiyatlarının, ekonomik belirsizlik ve piyasa volatilitesine dair çeşitli göstergelerden nasıl etkilendiği incelenmektedir. Kırılgan beşli ülkeler, dışsal şoklara karşı yüksek duyarlılıkları, ekonomik ve politik belirsizlikleri ve finansal piyasalarındaki aşırı dalgalanmalar nedeniyle, gelişmekte olan piyasalarda en riskli ve kırılgan bölgeler arasında yer almaktadır. Bu doğrultuda, Ali ve Khan (2020), bu ülkelerin ekonomik dalgalanmalara ve dış şoklara karşı yüksek duyarlılıkları nedeniyle volatilite ve belirsizlik risklerinin arttığını belirtmiştir. Bu bulgular, kırılgan beşkli ülkelerin ekonomik belirsizlik ve piyasa volatilitesi etkilerini araştırmak için uygun bir grup olduğunu göstermektedir. Benzer şekilde Gnangnon (2021) çalışmasında, bu ülkelerin dış şoklara karşı yüksek hassasiyetleri nedeniyle ekonomik dalgalanmalara maruz kalma risklerinin arttığını ifade etmiştir. Bu bulgular, kırılgan beşli ülkelerin ekonomik belirsizlik ve piyasa volatilitesi etkilerini araştırmak için uygun bir grup olduğunu göstermektedir. Çalışmada yalnızca borsa kapanış fiyatları değil, DeFi platformlarına ait varlıklar, volatilite endeksleri ve diğer ekonomik göstergeler de dikkate alınarak, ekonomik dinamiklerin daha kapsamlı bir şekilde analiz edilmesi amaçlanmaktadır.

Son dönemde, finansal piyasalarda kripto paraların önemli bir yükseliş göstermesiyle birlikte, akademik literatürde hisse senedi piyasaları ile kripto para piyasaları arasındaki ilişkinin incelendiği çok sayıda araştırma yayımlanmıştır. Ancak, mevcut literatürde, DeFi sistemlerinin bu piyasalarla olan etkileşimini ele alan çalışmalar henüz sınırlıdır. Kripto paralara ilişkin yapılan araştırmalar genellikle Bitcoin ve Ethereum gibi önde gelen dijital varlıkların, geleneksel finansal piyasalardaki fiyat hareketleriyle nasıl bir ilişki içinde olduğunu, bunların korelasyonlarını ve volatilite ilişkilerini irdelemektedir (Caferra ve Vidal-Tomas, 2021; Aydoğan vd., 2022; Karabulut ve Sarı, 2022; Kim, 2023; Yen ve Ha, 2023; Eldomiaty ve Khaled, 2024; Khan, 2024). Bu çalışmalar, COVID-19 pandemisi gibi ekonomik belirsizlik dönemlerinde, kripto paraların

hisse senedi piyasaları üzerindeki etkilerini ve piyasalardaki volatilitenin birbirine nasıl yayıldığını ortak bir tema olarak ele almaktadır. Fakat, her bir çalışma farklı bir teorik çerçeve ve metodolojik yaklaşım benimseyerek alana derinlemesine ve çok boyutlu bir perspektif kazandırmaktadır. Örneğin, Aydoğan vd. (2022) çalışmasında tek yönlü şokların yayılımını (yalnızca kripto para piyasasından gelen etkilerin hisse senedi piyasasında nasıl yayıldığını) ele alırken, Eldomiaty ve Khaled (2024) kripto paraların bir riskten korunma aracı olarak işlevini irdelemişlerdir. Kim (2023), pandeminin ilk aşamalarındaki etkileri sorgularken, Khan (2024) genel piyasa dalgalanmalarını ele almıştır. Caferra ve Vidal-Tomas (2021), yüksek co-movement (varlıkların birbirleriyle olan yüksek korelasyonu) dinamiklerini belirlerken, Yen ve Ha (2023) asimetrik yayılma etkilerini ortaya koymuşlardır. Bunget ve Lazea (2023) ise yatırımcıların bu iki piyasa arasındaki etkileşimi doğru bir şekilde anlamalarının önemine dikkat çekmişlerdir. Bu çeşitlilik, kripto paraların geleneksel finansal piyasalardaki rolünü daha kapsamlı ve çok boyutlu bir şekilde değerlendirmemizi sağlamaktadır. Kripto para ve hisse senedi piyasaları arasındaki ilişkiye dair yapılan çalışmalar yaygınken, DeFi platformları ve diğer yeni nesil dijital varlıkların finansal piyasalarla olan etkileşimlerine yönelik araştırmalar henüz sınırlı kalmakta ve bu alandaki literatür giderek daha fazla önem kazanmaktadır. Bu bağlamda, DeFi sistemlerinin geleneksel finansal piyasalarla olan ilişkilerini inceleyen çalışmaların hala yeterince gelişmediği gözlemlenmektedir. Bu çalışma, DeFi sistemlerinin hisse senedi piyasalarıyla olan ilişkisini, literatürde genellikle yeterince ele alınmayan bir açıdan incelemeyi amaçlamaktadır. Çalışmamızda, kripto para dışındaki merkezi olmayan dijital DeFi varlıkları ve volatilite endeksleri gibi göstergeler de dahil edilerek, ekonomik dinamikler daha geniş bir perspektiften değerlendirilecektir.

2.1. DeFi ile Borsa Arasındaki İlişki

DeFi ile ilgili yapılan araştırmalar, genellikle merkeziyetsiz finans sistemlerinin geleneksel bankacılık ve finansal aracıları nasıl dönüştürdüğüne, sağladığı fırsatlara ve büyüme potansiyeline odaklanmaktadır. Ancak, DeFi'nin hisse senedi piyasalarıyla olan doğrudan ilişkisini ele alan çalışmalar daha az sayıda ve genellikle daha yüzeysel olmuştur (Zetzsche vd., 2020; Chohan, 2021; Schär, 2021; Hung, 2024; Muhammad vd., 2024). Bu eksiklik, her iki alan arasındaki etkileşimin piyasa dinamikleri ve yatırımcı stratejileri üzerindeki etkilerini daha derinlemesine anlamamıza olanak tanıyabilir. Schär (2021), DeFi'nin blockchain teknolojisi ve akıllı sözleşmeler temelinde, geleneksel finansal hizmetlerin ötesinde yeni fırsatlar sunduğunu vurgulamaktadır. Bu bağlamda, DeFi ile hisse senedi piyasaları arasındaki ilişkinin daha detaylı bir şekilde incelenmesi gerekliliği ortaya çıkmaktadır. Hung (2024) ise DeFi ve dijital varlıkların geleneksel borsa sistemleri üzerinde önemli bir etkiye sahip olduğunu ve bu sistemler arasında karşılıklı bir etkileşim bulunduğunu belirtmektedir. Zetzsche vd. (2020) merkeziyetsiz finans ile geleneksel finans arasındaki ilişkileri ele alarak, DeFi'nin hisse senedi piyasalarına daha hızlı erişim imkânı sunduğunu ve likiditeyi artırarak yatırımcı davranışlarını dönüştürebileceğini öne sürmüşlerdir. Muhammad vd. (2024), DeFi'nin geleneksel bankacılığa karşı sunduğu alternatiflerle aracılara olan ihtiyacı sorgulayarak, bu durumun yatırımcıları hisse senedi piyasalarından uzaklaştırabileceğini ifade etmişlerdir. Ayrıca, Chohan (2021) DeFi'nin geleneksel finansal yapıları, özellikle hisse senedi piyasalarını potansiyel olarak bozabileceğini iddia etmiştir. Özetle, DeFi ile hisse senedi piyasaları arasındaki ilişkiyi doğrudan inceleyen araştırmalar henüz gelişmekte olsa da mevcut çalışmalar bu ilişkinin önemli olduğunu ve daha derinlemesine incelenmesi gerektiğini göstermektedir. DeFi'nin dönüştürücü doğası ve

geleneksel finansal sistemleri etkileme potansiyeli, yatırımcılar ve politika yapıcıların bu gelişmeleri yakından izlemelerini ve piyasa davranışları üzerindeki etkilerini daha iyi anlamalarını zorunlu kılmaktadır.

2.2. Emtia Fiyatları ve Hisse Senedi Piyasaları İlişkisi

Ham petrol fiyatları, özellikle WTI ve hisse senedi piyasaları arasındaki ilişki, son dönem akademik literatürde önemli bir araştırma konusudur ve enerji fiyatları ile finansal piyasalar arasındaki karşılıklı etkileşimi ortaya koymaktadır. Alandaki temel bulgulardan biri, petrol fiyatları ile hisse senedi piyasası volatilitesi arasındaki etkileşimin zamanla değişen bir yapıya sahip olduğudur. Örneğin, Kuhe (2019), petrol fiyatlarının volatilitesinin uzun süreli ve öngörülemez olduğunu belirtirken, Chen vd. (2022), hisse senedi getirilerinin petrol volatilitesine duyarlı olduğunu ve bu piyasalarda büyük reaksiyonlar görüldüğünü ifade etmişlerdir. Choi ve Hong (2020), şeyl gaz devriminden önce petrol fiyatları ile hisse senedi volatilitesi arasındaki ilişkinin güçlü olduğunu, ancak bu ilişkinin devrim sonrası zayıfladığını göstermişlerdir. Demirer vd. (2020) ise petrol fiyatı şoklarının dünya çapındaki hisse senedi piyasalarında geniş etkiler yaratabileceğini vurgulamışlardır. Youssef ve Mokni (2019), petrol fiyatlarının ithalatçı ve ihracatçı ülkelerdeki hisse senedi piyasalarını farklı şekilde etkilediğini belirlemiş, ithalatçı ülkelerde negatif etkiler gözlemlenirken, ihracatçı ülkelerde hisse senedi piyasalarının petrol fiyat artışlarından olumlu yönde etkilendiğini ortaya koymuşlardır. Cheikh vd. (2018), GCC ülkelerinde petrol fiyatları ile hisse senedi piyasaları arasında pozitif bir korelasyon tespit etmiş ve petrol ihraç eden ülkelerin hisse senedi piyasalarının petrol fiyatlarına duyarlı olduğunu göstermişlerdir. Altın fiyatları ile hisse senedi piyasaları arasındaki ilişki de son yıllarda akademik çalışmalarda sıklıkla ele alınmıştır. Örneğin, Siddiqui ve Roy (2019), Coronado vd. (2018), Shabbir vd. (2020) ve Shi vd. (2021) gibi araştırmacılar, altının hisse senedi fiyatlarıyla negatif korelasyon sergilediğini ve yüksek piyasa volatilitesi dönemlerinde güvenli liman varlığı olarak işlev gördüğünü bulmuşlardır. Choudhry vd. (2015), Baur ve Lucey (2010), Al-Ameer vd. (2018) ve Drake (2022) ise altının hisse senedi piyasalarındaki düşüşlere karşı her zaman koruma sağlamadığını, belirli piyasa koşulları ve bölgesel bağlamlara göre bu ilişkinin değişebileceğini göstermişlerdir. Dolayısıyla, bu çalışmalara göre altın ve hisse senedi arasındaki ilişki zamanla değişebilmektedir. Mensi vd. (2023), özellikle piyasa krizleri (örneğin Covid-19 pandemisi) sırasında altın ve WTI fiyatlarının hisse senedi piyasalarına daha güçlü bir bağlılık gösterdiğini, normal piyasa koşullarında ise bu bağlılığın zayıf kaldığını bulmuşlardır.

2.3. Volatilite Endeksleri ve Hisse Senedi Piyasaları İlişkisi

Volatilite endeksleri, özellikle CBOE Volatilite Endeksi (VIX) ve CBOE Ham Petrol Volatilite Endeksi (OVX) son yıllarda hisse senedi piyasalarıyla olan ilişkileri nedeniyle artan ilgi görmektedir. Bu endeksler, piyasa duyarlılığı ve riskin önemli göstergeleri olarak işlev görmekte olup yatırımcı davranışları ve hisse senedi piyasası dinamikleri üzerinde önemli etkiler yaratmaktadır. Son yapılan çalışmalar, VIX'in hisse senedi piyasası performansı üzerindeki etkisini vurgulamaktadır. Benzer şekilde OVX'in özellikle petrol fiyatlarındaki dalgalanmalara duyarlı sektörlerde hisse senedi piyasalarını etkileyebileceği gözlemlenmektedir (Coronado vd., 2018; Shaikh, 2018; Siddiqui ve Roy, 2019; Uludağ ve Khurshid, 2019; Choi ve Hong, 2020; Demirer vd., 2020; Shabbir vd., 2020; Hamal ve Gautam, 2021; Shi vd., 2021; Chittineni, 2022;

Drake, 2022; Mensi vd., 2023). Çalışmalarda, volatilite endekslerinin (özellikle VIX ve OVX) hisse senedi piyasalarındaki etkileri ile birlikte, bu etkilerin piyasa duyarlılığı, yatırımcı davranışları ve dışsal şoklar gibi faktörlerden nasıl etkilendiği detaylı bir şekilde incelenmiştir. Endekslerin yüksek olduğu dönemlerde, piyasalarda genellikle daha fazla volatilite ve olumsuz fiyat hareketlerinin gözlemlendiği bulgusu öne çıkmaktadır. Bu durumu destekleyen pek çok akademik çalışma, yüksek volatilite hisse senedi piyasaları üzerinde negatif etki yarattığını ortaya koymaktadır. Örneğin, Coronado vd. (2018), Shaikh (2018), Siddiqui ve Roy (2019), Demirer vd. (2020), Shabbir vd. (2020), Hamal ve Gautam (2021), Shi vd. (2021) ve Drake (2022) gibi çalışmalar, volatilite endekslerinin artışıyla birlikte, piyasalarda belirsizliğin ve risk algısının da arttığını ve bu durumun yatırımcı kararlarını olumsuz yönde etkileyebileceğini vurgulamaktadır. Bununla birlikte, yüksek volatilite endekslerinin, yatırımcıların güvenli liman varlıklarına yönelme eğilimlerini artırdığına dair pek çok çalışma bulunmaktadır. Shi vd. (2021), VIX ve OVX'in hisse senedi piyasaları üzerindeki etkisini değerlendirirken, volatilite artışlarının genellikle yatırımcıların güvenli limanlara yönelmesine neden olduğunu vurgulamışlardır. Bu bulgular, yüksek volatilite dönemlerinde, riskten kaçınma davranışlarının arttığını ve yatırımcıların daha düşük riskli varlıklara yöneldiğini ortaya koymaktadır. Volatilite endekslerinin etkileri, sadece yerel piyasalarda değil, aynı zamanda küresel borsalar arasında da önemli etkileşimlere yol açabilmektedir. Uludağ ve Khurshid (2019), Çin borsa volatilitesinin, özellikle E7 ve G7 ülkelerindeki borsalar üzerinde önemli etkiler yarattığını ortaya koymuşlardır. Çalışmada, Çin piyasalarındaki volatilite artışlarının, gelişmiş ve gelişen piyasa borsalarına da yansıdığı bulunmuştur. Ayrıca, VIX ve OVX endekslerinin, geleneksel finansal piyasalardaki etkilerinin yanı sıra, kripto para piyasalarına da farklı düzeylerde yansıdığı gözlemlenmiştir. Mensi vd. (2023), VIX ve OVX'in kripto para piyasaları üzerindeki etkilerini inceleyerek, volatilite artışlarının kripto paralarda da dalgalanmalara yol açtığını bulmuşlardır. Ancak, kripto para piyasalarının volatilitesi genellikle daha yüksek olduğu için, etkileşimin geleneksel piyasalara göre farklı boyutlarda gözlemlenmektedir. Kısaca VIX, OVX ve hisse senedi piyasaları arasındaki etkileşim, çok yönlü ve karmaşık bir yapıya sahiptir.

3. Ekonometrik Yöntem: Dalgacık Tutarlılık Analizi

DeFi, petrol, altın ve VIX endeksi ile kırılgan beşli ülkelerin hisse senedi piyasaları arasındaki ilişkiyi zaman ve frekans düzleminde incelemek için dalgacık tutarlılığı (Wavelet Coherence) analizi tercih edilmiştir. Bu yöntemin seçilmesindeki temel neden, finansal ve ekonomik zaman serilerinde sıkça rastlanan karmaşık ve doğrusal olmayan veri yapılarının analizinde sağladığı üstünlüktür. Özellikle geleneksel korelasyon ve regresyon analizlerinin zaman içerisinde değişen ilişkileri tespit etmekte yetersiz kalması, dalgacık analizinin sağladığı yerelleştirilmiş ve frekans bazlı detaylı inceleme kapasitesinin öne çıkmasını sağlamaktadır (Torrence ve Compo, 1998).

Dalgacık tutarlılığı analizini güçlü bir yöntem kılan en önemli özelliklerinden biri hem pozitif hem de negatif ilişkileri eş zamanlı olarak belirleyebilmesidir. Bu sayede, değişkenler arasındaki ilişkinin yönü ve gücü belirli bir zaman-frekans noktasında açıkça gözlemlenebilir. Ayrıca, bu yöntem geleneksel korelasyon analizlerinin aksine, ilişkilerin zaman içindeki evrimini tespit ederek, farklı dönemlerde nasıl değiştiğini analiz etme imkânı sunmaktadır. Böylece, ilgili değişkenler arasındaki eş hareketlerin dinamik yapısı daha kapsamlı bir şekilde ortaya çıkarılabilmektedir (Fareed vd., 2020). Dalgacık tutarlılığını öne çıkaran bir diğer önemli avantaj

klasik Fourier dönüşümüne kıyasla sunduğu esnekliktir. Fourier dönüşümü, bir zaman serisini sabit frekans bileşenlerine ayırırken, zaman bilgisinin kaybolmasına neden olmakta ve bu durum geçici ilişkilerin ya da yapısal değişikliklerin belirlenmesini zorlaştırmaktadır. Buna karşın, dalgacık dönüşümü durağanlık varsayımına ihtiyaç duymamakta ve frekans bileşenlerini zaman ölçeğinde detaylandırarak, özellikle finansal zaman serilerinin dalgalı ve değişken doğasını hassas bir şekilde analiz etme imkânı sağlamaktadır (Piotrkowski vd., 2005; Aguiar-Conraria vd., 2008). Dolayısıyla dalgacık tutarlılığı yöntemi, geleneksel analiz tekniklerinin sağlayamadığı detaylı zaman-frekans çözümlemeleri sunarak, finansal seriler arasındaki ilişkileri dinamik bir perspektiften ele alma imkânı sunmaktadır. Bu yöntemin sağladığı avantajlar nedeniyle, ampirik literatürde giderek daha fazla çalışmada kullanılmakta ve finansal zaman serileri arasındaki ilişkileri anlamada güçlü bir araç olarak öne çıkmaktadır (Yang vd., 2016; Orhan vd., 2019; Kartal vd., 2023; Korsah vd., 2024; Annamalaisamy ve Jayaraman, 2024).

Rua ve Nunes (2009), Wang vd., (2012) çalışmaları temel alınarak, analiz edilen zaman serisine (X_t) sürekli dalgacık dönüşümünün uygulanması durumu matematiksel olarak şu şekilde ifade edilmektedir:

$$W_x(\tau, s) = \int_{-\infty}^{\infty} x(t)\widetilde{\psi^*_{\tau,s}}(t)dt \quad (1)$$

Denklem (1)'de s ölçek parametresi olarak kullanılmaktadır. Bu, dalgacığın sıkışma veya genişleme derecesini belirlemektedir. Eğer | s |<1 ise, temel dalgacık $\psi(t)$ daha yüksek frekanslara doğru sıkışır; bu, dalgacığın daha kısa süreli (daha hızlı değişen) bir yapı kazanması anlamına gelmektedir. Eğer | s | >1 ise, dalgacık daha düşük frekanslara doğru gerilmektedir. Yani dalgacık daha uzun süreli (daha yavaş değişen) bir yapıya bürünmektedir. τ parametresi, dalgacığın zaman içerisindeki konumunu kontrol eden bir çeviri parametresidir. $\widetilde{\psi^*_{\tau,s}}(t)$ ifadesi, dalgacığın karmaşık eşlenik fonksiyonunu temsil etmektedir. Ayrıca, $\psi^*_{\tau,s}(t)$ ve $\hat{\psi}$ terimleri, temel dalgacık ψ'nin ölçeklendirilen ve kaydırılan versiyonlarıdır (Madaleno ve Pinho, 2014; Jiang vd., 2015). Bu eşlenik, şu şekilde tanımlanmaktadır (Choi, 2020):

$$\widetilde{\psi^*_{\tau,s}}(t) = \frac{1}{\sqrt{|s|}}\psi\left(\frac{t-\tau}{s}\right), s, \tau \in \mathbb{R}, s \neq 0 \quad (2)$$

Goupillaud vd. (1984) tarafından tanıtılan karmaşık değerli dalgacık yelpazesi, çok değişkenli analiz yöntemlerine olanak tanıyan geniş bir araç seti sunmaktadır. Bu set içerisinden, zaman ve frekans yerelleştirmesi arasında etkin bir denge kurabilen Morlet dalgacığı tercih edilmekte olup, bu dalgacık, temel dalgacık ψ olarak kullanılmıştır (Grinsted vd., 2004).

Zhou (2010), Vacha ve Barunik (2012) çalışmaları referans alınarak iki zaman serisi $x\ (t)$ ve $y\ (t)$ verildiğinde, sürekli dalgacık dönüşümünün çapraz dalgacık dönüşümüne dönüştürülme işlemi şu şekilde gerçekleştirilmektedir:

$$W_{xy}(\tau, s) = W_x(\tau, s)W_y^*(\tau, s) \quad (3)$$

Denklem (3) kapsamında tanımlanan çapraz dalgacık dönüşümü temel alınarak, Torrence ve Webster (1999) tarafından önerilen yöntem doğrultusunda, iki zaman serisi $x\ (t)$ ve $y\ (t)$ arasındaki kare dalgacık tutarlılığı hesaplanmaktadır. Bu hesaplama, belirli bir zaman diliminde x(t) ve y(t) serileri arasındaki ilişkiyi ve benzerlikleri ölçen bir gösterge sunmaktadır:

$$R^2(\tau,s) = \frac{\left|S\left(s^{-1}W_{xy}(\tau,s)\right)\right|^2}{S(s^{-1}|W_x(\tau,s)|^2)S\left(s^{-1}\left|W_y(\tau,s)\right|^2\right)} \quad (4)$$

Denklem (4)'deki S parametresi zaman ve ölçek açısından bir düzeltme operatörü olarak işlev görmekte ve $0 \leq R^2(\tau,s) \leq 1$ aralığında değerler alarak bu ilişkileri anlamlandırmaktadır. $R^2(\tau,s)$ iki zaman serisi değişkeni arasındaki ilişkiyi nicel olarak ölçen bir korelasyon göstergesidir. Bu değer, zaman serilerinin belirli bir ölçek (s) ve frekans (f) düzeyindeki ilişkisini analiz eder ve 0 ile 1 arasında bir değere sahip olur. R²(k, f) değeri 1'e yakın olduğunda, bu, x(t) ve y(t) zaman değişkenleri arasında belirgin bir birlikte hareket (co-movement) olduğunu göstermektedir. Bu durum, genellikle grafiklerde kırmızı renk ve kalın siyah bir çizgiyle vurgulanmaktadır. R²(k, f) değeri 0'a yakın olduğunda bu, iki değişken arasında herhangi bir ilişki ya da etkileşim olmadığını göstermektedir. Yani, bu durumda değişkenler arasında ne bir nedensellik ilişkisi ne de bir korelasyon bulunmamaktadır. Bu durum, görsel temsillerde mavi renk ile gösterilmektedir (Masih ve Majid, 2013; Asafo-Adjei, 2020).

Zaman-frekans bağlamında zaman serileri arasındaki eş-hareket alanlarını tanımlamak için dalgacık kareli tutarlılığın grafiksel sunumu, genellikle faydalı bir yaklaşım olarak öne çıkmaktadır. Ancak bu tür bir gösterim, pozitif ve negatif korelasyonlar arasındaki net ayrımı sağlamakta yeterli olmayabilir. Bundan dolayı, zaman serileri arasındaki eş-hareketlerin yanı sıra, seriler arasındaki nedensel bağlantıları daha derinlemesine inceleyebilmek amacıyla, Torrence ve Compo (1998) tarafından tanımlanan faz farkı tekniği uygulanmıştır. Bu bağlamda, incelenen iki zaman serisi arasındaki ilişkinin ayrıntılarını net bir şekilde ortaya koyabilen dalgacık tutarlılığı faz farkı, belirli bir formülasyonla aşağıdaki şekilde hesaplanmaktadır:

$$\varphi_{xy}(u,s) = \tan^{-1}\left(\frac{\Im\{S\left(s^{-1}W_{xy}(\tau,s)\right)\}}{\Re\{S\left(s^{-1}W_{xy}(\tau,s)\right)\}}\right) \quad (5)$$

Burada $\Im$ ve $\Re$ sırasıyla yumuşatılmış çapraz dalgacık dönüşümünün hayali ve gerçek kısımlarını temsil etmektedir. Faz, dalgacık tutarlılığı grafiklerinde oklarla gösterilmektedir. Grafiklerdeki yönlü oklar, iki sinyalin hizalanma şeklini yansıtmaktadır. Faz farkı sıfır olduğunda bu durum iki zaman serisinin birlikte hareket ettiğini, yani aynı anda artıp azaldığını belirtmektedir. Okların yönü, bu ilişkilerin yorumlanmasında önemlidir: sağa doğru oklar, faz tutarlılığını ve pozitif korelasyonu gösterirken; sola doğru oklar, faz uyumsuzluğunu ve negatif korelasyonu belirtmektedir. Bununla birlikte, yukarıya doğru oklar, birinci zaman serisinin ikinciyi önde taşıdığını, yani gecikmeli bir yanıt gösterdiğini, aşağıya doğru oklar ise ikinci zaman serisinin birinciyi önde taşıdığını, yani ikinci serinin değişiklik gösterdiğinde birinci serinin onu takip ettiğini göstermektedir (Kang vd., 2019; Asafo-Adjei vd., 2020; Ramzan vd., 2023).

Son olarak, dalgacık tutarlılığının incelenmesinde, teorik dağılımın kesin bir şekilde bilinmemesi nedeniyle, istatistiksel anlamlılık düzeyleri Monte Carlo yöntemlerine dayalı tahminler kullanılarak belirlenmiştir. Bu yaklaşım, elde edilen sonuçların güvenilirliğini artırmaya yardımcı olmakta ve anlamlılık seviyelerinin daha doğru bir şekilde tespit edilmesine olanak sağlamaktadır (Grinsted, vd. 2004; Fareed vd., 2020; Wu vd., 2020).

4. Ampirik Analiz

Bu bölümde çalışmada kullanılan veri seti tanıtılmakta ve analiz sonucunda elde edilen temel bulgular sunulmaktadır.

4.1 Veri Seti

DeFi, WTI, altın ve VIX endeksleri ile Kırılgan Beşli ülkelerin borsa piyasaları arasındaki ilişkilerin araştırıldığı bu çalışmada, Kırılgan Beşli ülkelerin günlük borsa kapanış fiyatları temel alınmıştır. Bu ülkeler ve ilgili borsa endeksleri şunlardır: Brezilya (Bovespa Endeksi), Endonezya (Jakarta Bileşik Endeksi), Hindistan (BSE30 SENSEX Endeksi), Türkiye (BIST100 Endeksi) ve Güney Afrika (TOP40 Endeksi). DeFi piyasalarını temsilen, en uzun örneklem geçmişine sahip LINK (Chainlink), MKR (Maker) ve BAT (Basic Attention Token) seçilmiş; petrol piyasası için WTI (Batı Teksas Ham Petrol) fiyatları, altın piyasası için LMBA (USD/Ons) spot fiyatları ve piyasa oynaklığını ölçmek için VIX korku endeksi kullanılmıştır. Veriler, borsa endeksleri, petrol ve VIX için Investing (2024), DeFi için Coinmarketcap (2024) ve altın fiyatları için Bloomberg veri terminali üzerinden temin edilmiştir. Tüm piyasalar günlük verilere dayanmaktadır ve toplam gözlem sayısı 1774'tür. Veriler, 2 Ocak 2018 ile 11 Kasım 2024 arasındaki dönemi kapsamaktadır. DeFi piyasalarının veri erişimi 2018 yılıyla sınırlı olduğu için çalışma başlangıç yılı bu tarih olarak belirlenmiştir. Ayrıca, hafta sonları da işlem gören DeFi piyasalarının diğer piyasalarla uyumlu bir şekilde karşılaştırılabilmesi adına hafta sonu verileri analizden çıkarılmıştır (Martens ve Poon, 2021; Das ve Kannadhasan, 2018; Kumah ve Odei-Mensah, 2022). Son olarak, tüm piyasalarda fiyat serilerinden $100 \times log(P_t/P_{t-1})$ formülü ile logaritmik getiri serileri elde edilerek analizde logaritmik getiriler kullanılmıştır. Bu doğrultuda çalışma kapsamında kullanılan değişkenlerin özet istatistikleri aşağıdaki Tablo 1'de sunulmaktadır.

Tablo 1. Tanımlayıcı İstatistikler

	Brezilya	**Hindistan**	**Endonezya**	**Türkiye**	**G. Afrika**	**LNK**
Ortalama	0.029	0.048	0.007	0.113	0.021	0.163
Maksimum	13.022	8.594	9.704	9.421	9.056	48.06
Minimum	-15.993	-14.101	-6.805	-10.306	-10.450	-61.457
Std. Sapma	1.520	1.114	0.955	1.677	1.241	7.226
Çarpıklık	-1.387	-1.547	-0.175	-0.663	-0.312	-0.189
Basıklık	24.156	26.514	13.997	7.751	11.198	10.412
Jarque-Bera	33655.0*	41577.7*	8949.7*	1799.1*	4997.5*	4071.9*
N	1774	1774	1774	1774	1774	1774
	MKR	**BAT**	**WTI**	**Altın**	**VIX**	
Ortalama	0.016	-0.068	0.009	0.039	0.027	
Maksimum	45.846	42.795	58.123	6.789	76.824	
Minimum	-81.818	-51.447	-56.858	-5.400	-33.068	
Std. Sapma	6.624	6.652	3.354	0.870	7.897	
Çarpıklık	-0.582	-0.266	-0.461	0.056	1.511	
Basıklık	20.517	8.767	107.061	7.485	12.045	
Jarque-Bera	22782.1*	2479.4*	800496.1*	1488.0*	6723.6*	
N	1774	1774	1774	1774	1774	

Not: * %1 önem seviyesini göstermektedir.

Tablo 1'deki tanımlayıcı istatistikler incelendiğinde, BAT haricindeki tüm varlıkların pozitif bir ortalamaya sahip olduğu görülmektedir. Bununla birlikte en yüksek günlük ortalama getiri LNK'de (0.163) gözlemlenirken, en düşük ortalama BAT'ta (-0.068) kaydedilmiştir. BAT'ın ortalama getirisinin negatif olması, bu varlığın analiz edilen dönem boyunca genel olarak değer kaybettiğini göstermektedir. Diğer varlıkların pozitif ortalama getiriye sahip olması ise uzun vadede değer kazandıkları ya da en azından kazançlarının kayıplarından fazla olduğu anlamına gelmektedir. Kırılgan Beşli ülkeler arasında ise Türkiye (0.113) diğer ülkelere kıyasla daha yüksek bir ortalama getiriyi işaret ederken, Endonezya (0.007) en düşük günlük ortalama

getiriyi sergilemektedir. Oynaklık açısından DeFi varlıklarının LNK (7.226), BAT (6.652) ve MKR (6.624), geleneksel varlıklara kıyasla çok daha yüksek volatilite sergilemesi, bu varlıkların fiyat dalgalanmalarına karşı daha duyarlı olduğunu ve spekülatif yatırımlara açık olduğunu göstermektedir. Buna karşın, altın (0.870) ve Endonezya (0.955) en düşük oynaklığa sahip olup, daha istikrarlı risk profiline sahiptir. Maksimum ve minimum getiriler incelendiğinde, WTI'nin %58 ile en yüksek, MKR'nin ise %-80 ile en düşük günlük getiriyi kaydetmesi, piyasalardaki ani şokların ve aşırı fiyat hareketlerinin varlığını doğrulamaktadır. Çarpıklık değerleri, altın ve VIX hariç tüm varlıkların negatif çarpıklık sergilediğini, yani büyük kayıpların büyük kazançlara kıyasla daha olası olduğunu göstermektedir. Tüm serilerin yüksek basıklık değerleriyle leptokurtik dağılım sergilemesi, aşırı uç değerlerin sıklığını ve piyasalardaki oynaklığın sürekliliğini ortaya koymaktadır. Jarque-Bera test sonuçları ise serilerin normal dağılımdan sapmalarını doğrulamaktadır. Bu bulgular, dalgacık tutarlılığı analizinin, serilerdeki doğrusal olmayan dinamikleri modellemek için uygun bir yöntem olduğunu desteklemektedir.

4.2. Bulgular

Kırılgan Beşli ülkelerindeki hisse senedi getirileri ile DeFi, petrol, altın ve VIX endeksi arasındaki zaman-frekans boyutundaki hareketleri incelemek için dalgacık tutarlılığı analizi gerçekleştirilmiştir (Reboredo vd., 2017). Bu kapsamda, Şekil 1, Şekil 2, Şekil 3, Şekil 4 ve Şekil 5 sırasıyla Brezilya, Hindistan, Endonezya, Türkiye ve Güney Afrika piyasalarından elde edilen dalgacık tutarlılığı ve faz farklarının grafiklerini göstermektedir. Ancak sonuçların doğru yorumlanabilmesi için aşağıdaki dalgacık tutarlılığı görsellerine ilişkin bazı açıklamalar faydalı olacaktır. Görsellerde yatay eksen zaman bileşenini, dikey eksen ise frekans bileşenlerini temsil etmektedir. Zaman ölçeklendirmesi, (0-64) bandının kısa vade olarak yaklaşık çeyrek yıla (3 aya), (64-256) bandının orta vade olarak yaklaşık bir yıla, (256-1024) bandının ise uzun vade olarak yaklaşık dört yıla karşılık geldiğini göstermektedir. Renk skalası ise bağımlılık düzeyini göstermektedir; kırmızı tonlar güçlü bağımlılığı, mavi tonlar ise zayıf bağımlılığı ifade etmektedir. Bununla birlikte, siyah kontur çizgileri, 1000 kez tekrarlanan Monte Carlo simülasyonları sonucunda %5 anlamlılık düzeyinde istatistiksel olarak anlamlı bulunan alanları işaret ederken, beyaz kesintisiz eğriyle gösterilen etki konisi, veri uzunluğunun sınırlı olması nedeniyle güvenilir sonuçların elde edilemediği bölgeleri belirtmektedir.

Renk haritası kodlamasına ek olarak, iki değişken arasındaki ilişkileri anlamada ok yönleri (faz bilgisi) değişkenler arasında hem korelasyon hem de öncüllük sırasını vermektedir. Sağa ve sola dönük oklar faz içi (aynı yönde hareket) ve faz dışı (ters yönde hareket) olduğunu gösterir. Doğrudan yukarı bakan ok, birinci değişkenin ikinci değişkene öncülük ettiğini; aşağıya bakan ok ise ikinci değişkenin birinci değişkene öncülük ettiğini belirtir. Daha kompleks bir kombinasyon durumunda ise sağ yukarı ok her iki değişkenin faz içi olduğunu ancak birinci değişkenin ikinci değişkene öncülük ettiğini, sağ aşağı ok ise her iki değişkenin faz içi olduğunu fakat ikinci değişkenin birinci değişkene öncülük ettiğini gösterir. Sol aşağı ok, her iki değişkenin faz dışı olduğunu ancak birinci değişkenin ikinci değişkene öncülük ettiğini, sol yukarı ok ise yine her iki değişkenin faz dışı olduğunu ancak ikinci değişkenin birinci değişkene öncülük ettiğini ifade eder.

Bu kavramları somutlaştırmak için bir örnek verilebilir. Örneğin, DeFi varlıkları ve hisse senedi piyasası arasındaki ilişki incelendiğinde, yukarı yönlü bir ok, DeFi piyasalarının hisse senedi piyasalarına öncülük ettiğini gösterir. Yani DeFi piyasalarında gözlenen fiyat

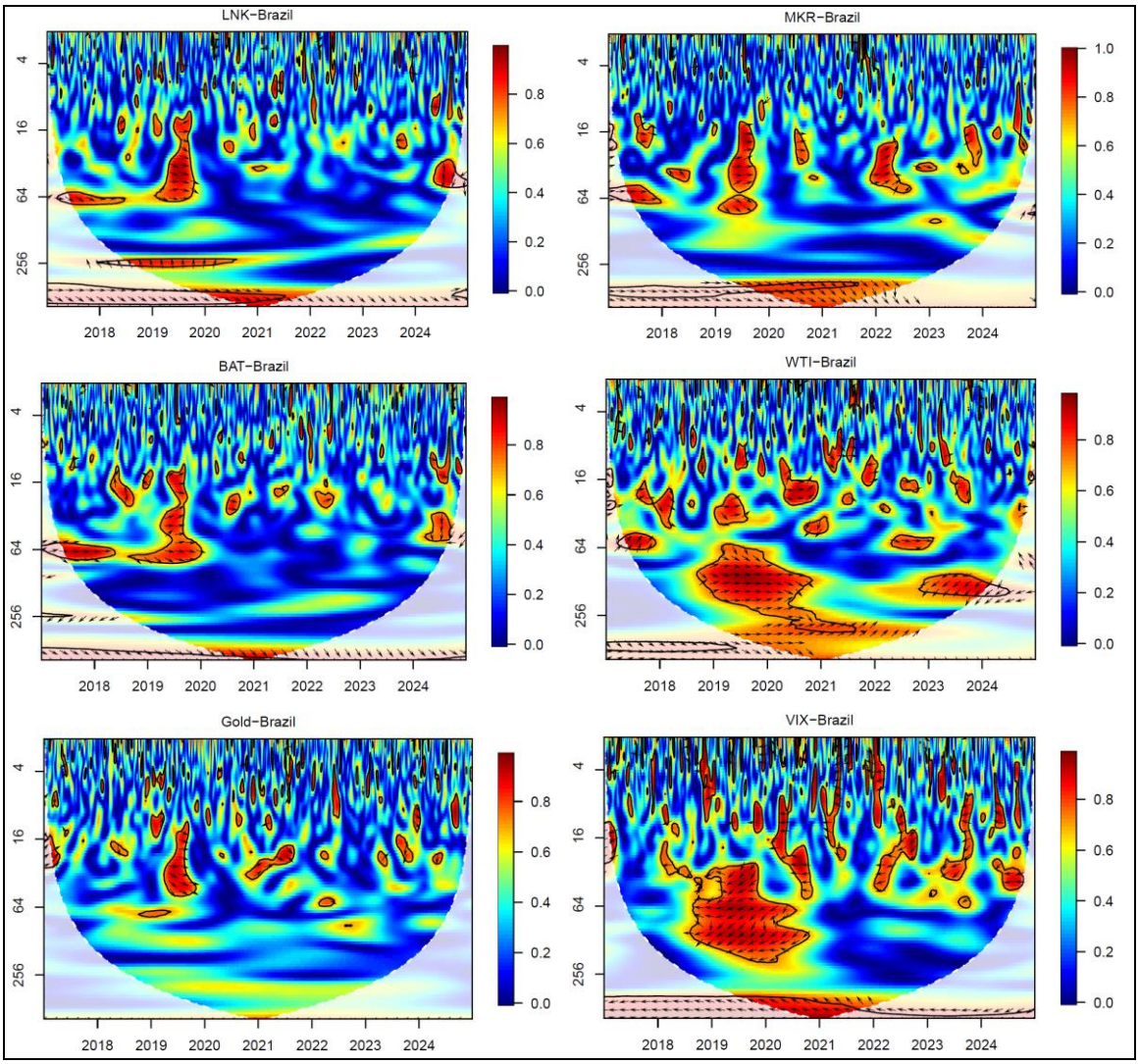
hareketlerinin belirli bir zaman dilimi içerisinde hisse senedi piyasalarına yansıdığına işaret eder. Buna karşılık, aşağı yönlü bir ok ise tam tersine hisse senedi piyasalarının DeFi piyasalarına öncülük ettiğini ve bu piyasalarda meydana gelen fiyat değişimlerinin belirli bir gecikmeyle DeFi piyasalarına yansıdığını gösterir. Doğrudan sağa bakan oklar, DeFi piyasaları ile hisse senedi piyasaları arasında pozitif korelasyonun mevcut olduğunu, sola bakan oklar ise negatif korelasyonu ifade eder. Sağ yukarı yönlü bir ok, iki piyasanın faz içi hareket ettiğini ve DeFi piyasalarının öncü olduğunu gösterir; bu durumda, DeFi piyasalarında fiyatlar arttığında, belirli bir süre sonra hisse senedi piyasalarında da fiyat artışı görülür. Buna karşılık, sol yukarı yönlü bir ok, iki piyasanın faz dışı hareket ettiğini ve hisse senedi piyasalarının öncü olduğunu gösterir; böyle bir durumda, hisse senedi piyasalarında fiyatlar yükseldiğinde, belirli bir zaman sonra DeFi piyasalarında fiyatlar düşer.

Okların yönü ve konumu şu şekilde görselleştirilebilir (Rösch ve Schmidbauer, 2018; Ye vd., 2020):

Tablo 2. Dalgacık Tutarlılığı Haritasında Ok Yönlerinin Anlamı

→	x(t) ve y(t) pozitif bir ilişkiye sahiptir.
←	x(t) ve y(t) negatif bir ilişkiye sahiptir.
↗	Faz içi x(t) öncülük eder.
↘	Faz içi y(t) öncülük eder.
↖	Faz dışı y(t) öncülük eder.
↙	Faz dışı x(t) öncülük eder.

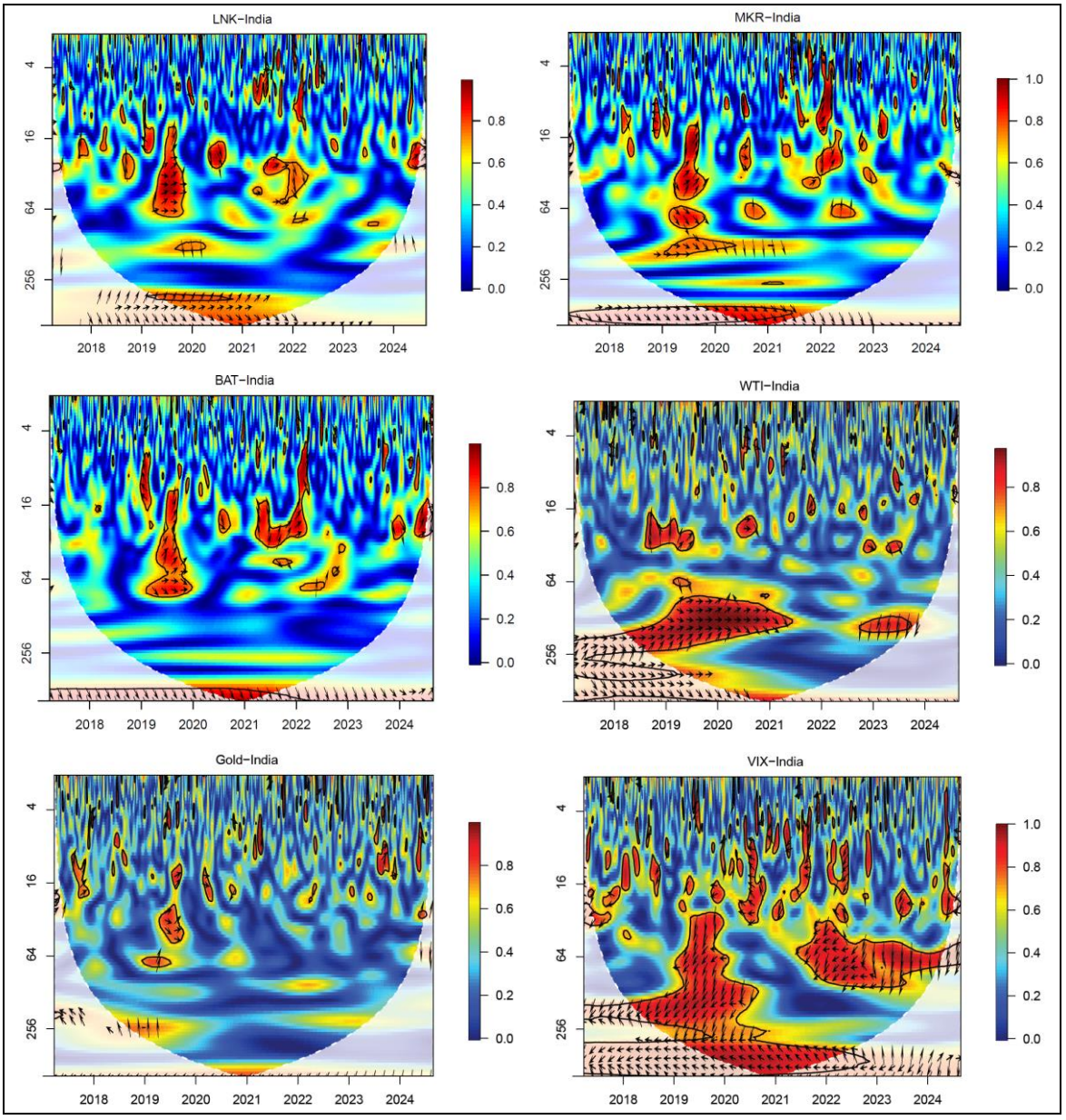
Şekil 1, Brezilya hisse senedi getirileri piyasasından elde edilen dalgacık tutarlılığı sonuçlarını göstermektedir. DeFi piyasaları ile etkileşimleri incelendiğinde, LNK ve hisse senedi getirisi arasında 2019-2020 döneminde kısa vadede okların sağa doğru olması, iki piyasa arasında güçlü bir pozitif korelasyon olduğunu göstermektedir. Aynı dönemde orta vadede okların yukarı yönelmesi ise LNK'nin Brezilya hisse senedi getirilerine öncülük ettiğini ortaya koymaktadır. MKR ve hisse senedi getirileri arasında, 2019 yılında kısa vadede okların sağa yönelmesi, iki seri arasında pozitif bir korelasyona işaret ederken, aynı dönemde orta vadede okların sağ aşağı yönelmesi aynı faz içerisinde hisse senedi getirilerinin MKR'ye öncülük ettiğini göstermektedir. 2022 yılında ise kısa vadede okların sağ yukarı yönelmesi, bu kez MKR'nin hisse senedi getirilerine öncülük ettiğini ifade etmektedir. BAT ile hisse senedi getirileri arasındaki ilişki ise 2018-2020 döneminde kısa vadede pozitif yönlüdür. Genel olarak, DeFi ile Brezilya hisse senedi getirileri arasındaki ilişki ifade edilecek olursa, 2019-2020 dönemlerinde kısa vadede pozitif bir ilişkinin olduğu görülmektedir. WTI ile hisse senedi getirileri arasındaki ilişkiye bakıldığında, kırmızı tonların çoğunlukta olduğu 2019-2020 dönemlerinde orta vadede pozitif bir ilişki vardır. Ayrıca, 2023-2024 dönemleri arasında orta vadede faz dışında petrol piyasasının hisse senedi getirilerine öncülük ettiğini görülmektedir. Altın piyasası ile hisse senedi getirileri arasındaki ilişkinin ise 2019-2020 arasındaki dönemde kısa vadede pozitif bir eğilim olmasının dışında bir sonuç bulgulanmamıştır. VIX ile hisse senedi getirileri arasındaki bağlantıya bakıldığında, 2019'un başından 2020'nin sonuna kadar kısa ve orta vadede VIX'in hisse senedi piyasasına faz dışı olarak öncülük ettiğine ve negatif bir ilişkinin bulunduğuna ulaşılmaktadır. Ayrıca, kısa vadede VIX ile hisse senedi getirileri arasındaki negatif korelasyonun sürekliliğini desteklemektedir. Genel olarak, Brezilya hisse senedi getirileri ile diğer piyasalar arasındaki ilişkiler, döneme ve vade uzunluğuna bağlı olarak değişkenlik göstermektedir. Bu ilişkiler, bazı dönemlerde pozitif yönde, bazı dönemlerde ise negatif yönde belirginleşmiştir.



Şekil 1. Brezilya Dalgacık Tutarlılığı Sonuçları

Şekil 2, Hindistan hisse senedi piyasası getirileri ile DeFi varlıkları, petrol, altın fiyatları ve VIX endeksi arasındaki dalgacık tutarlılıklarını ve bu faktörler arasındaki frekans bazlı etkileşimleri göstermektedir. 2019-2020 döneminde LNK ile hisse senedi getirileri arasında, kısa vadede pozitif korelasyon gözlemlenmiş olup, LNK'ın hisse senedi piyasalarıyla uyumlu bir hareket sergilediği ve her iki piyasanın benzer yönde hareket ettiği görülmektedir. MKR ile hisse senedi piyasaları arasındaki etkileşime bakıldığında, 2019-2020 döneminde kısa vadede MKR'nin hisse senedi piyasa getirilerine aynı fazda öncülük edecek şekilde hareket ettiği anlaşılmaktadır. Orta vadede ise aynı fazda hisse senedi getirileri MKR'ye öncülük etmektedir. BAT ile hisse senedi piyasaları arasındaki ilişki incelendiğinde, 2019-2020 döneminde kısa vadede okların belirgin bir yön göstermediği söylenebilir. Ancak, sağ üst yönlü oklar faz içinde BAT'ın Hindistan hisse senedi getirilerine öncelik verdiğine işaret etmektedir. Orta vadede ise piyasalar arasında pozitif bir korelasyonun oluştuğu ve bu ilişkinin güçlendiği ifade edilebilir. WTI ve hisse senedi getirileri arasındaki bağlantı değerlendirildiğinde, 2018'in ortalarından 2021'in sonuna kadar orta vadede değişkenler arasında pozitif korelasyon vardır. Altın piyasası ile hisse senedi getirileri arasındaki ilişki konusunda ise belirgin bir görünüme ulaşılmamaktadır. VIX endeksi ile hisse senedi getirileri arasındaki etkileşim ise oldukça karmaşık yönler

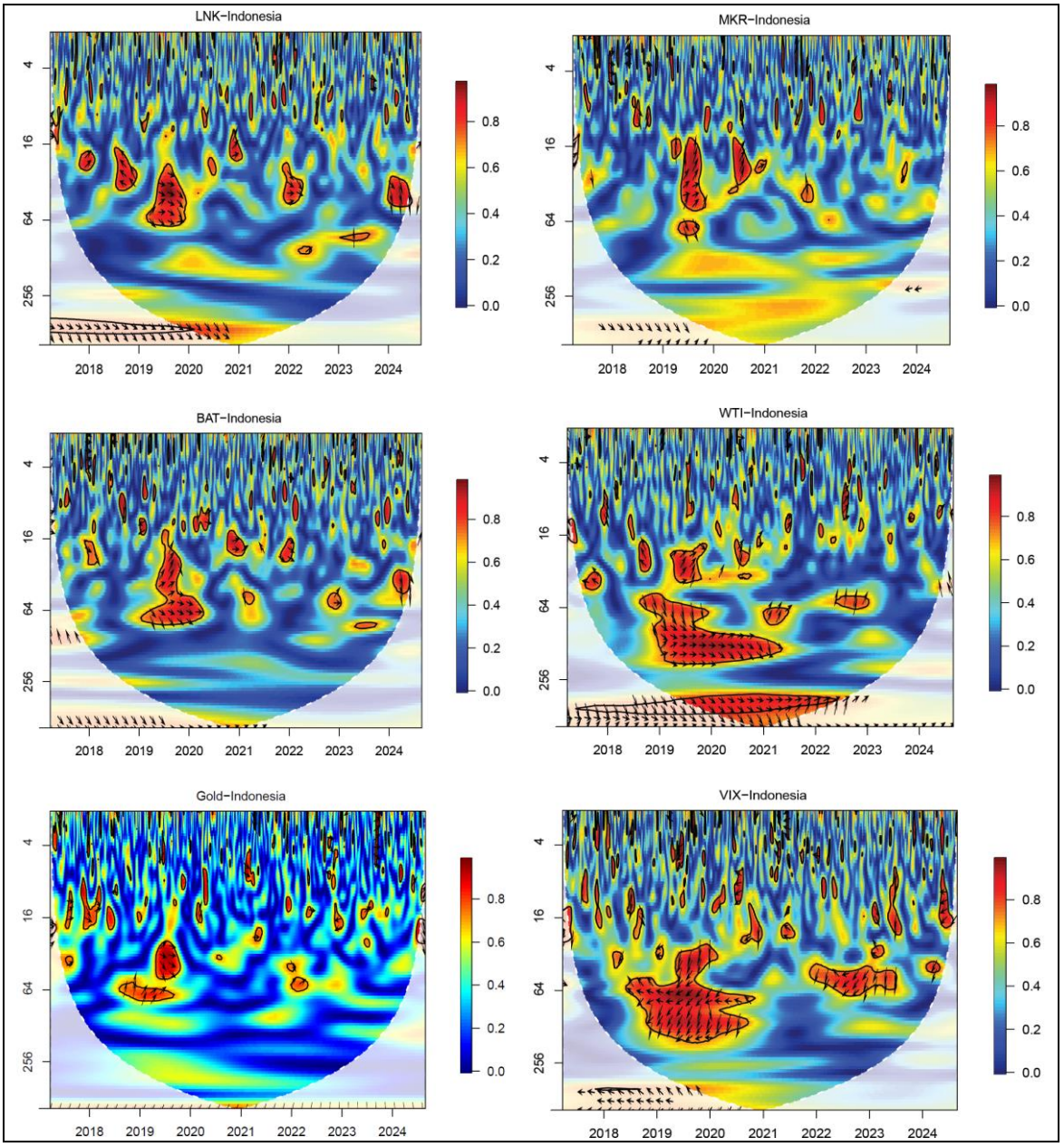
göstermektedir. 2018 başından 2020 ortasına kadar olan dönemde kısa ve orta vadede aynı fazda hisse senedi getirileri korku endeksine öncülük etmektedir. 2021 başı ile 2022 ortaları arasında ise göstergeler sol aşağı yönlü bir hareket sergilemiştir. Faz dışı hareketi gösteren bu durum, korku endeksinin hisse senedi piyasasına öncülük ettiğini kanıtlamaktadır. Son olarak, uzun dönemde 2019 ve 2022 yıllarında her iki değişkenin faz dışı hareket sergilemesi, hisse senedi getirilerinin korku endeksine öncülük ettiğini ortaya koymaktadır.



Şekil 2. Hindistan Dalgacık Tutarlılığı Sonuçlar

Şekil 3, Endonezya hisse senedi piyasası getirileri ile DeFi varlıkları, emtia fiyatları (petrol ve altın) ve VIX endeksi arasındaki dalgacık tutarlılığına dayalı bağlantıları ve bu ilişkilerin zaman içindeki evrimini incelemektedir. Piyasalar arasındaki etkileşimin ayrıntılı incelenmesiyle elde edilen bulgular 2018-2019 döneminde LNK ile hisse senedi getirileri arasında ilişkinin kısa vadeli dönemde faz dışı olduğunu ve hisse senedi getirilerinin LNK'ye öncülük ettiğini ortaya

koymaktadır. 2019'un ortalarına gelindiğinde, aynı vadede iki piyasa arasındaki pozitif korelasyonun varlığını doğrulanmaktadır.

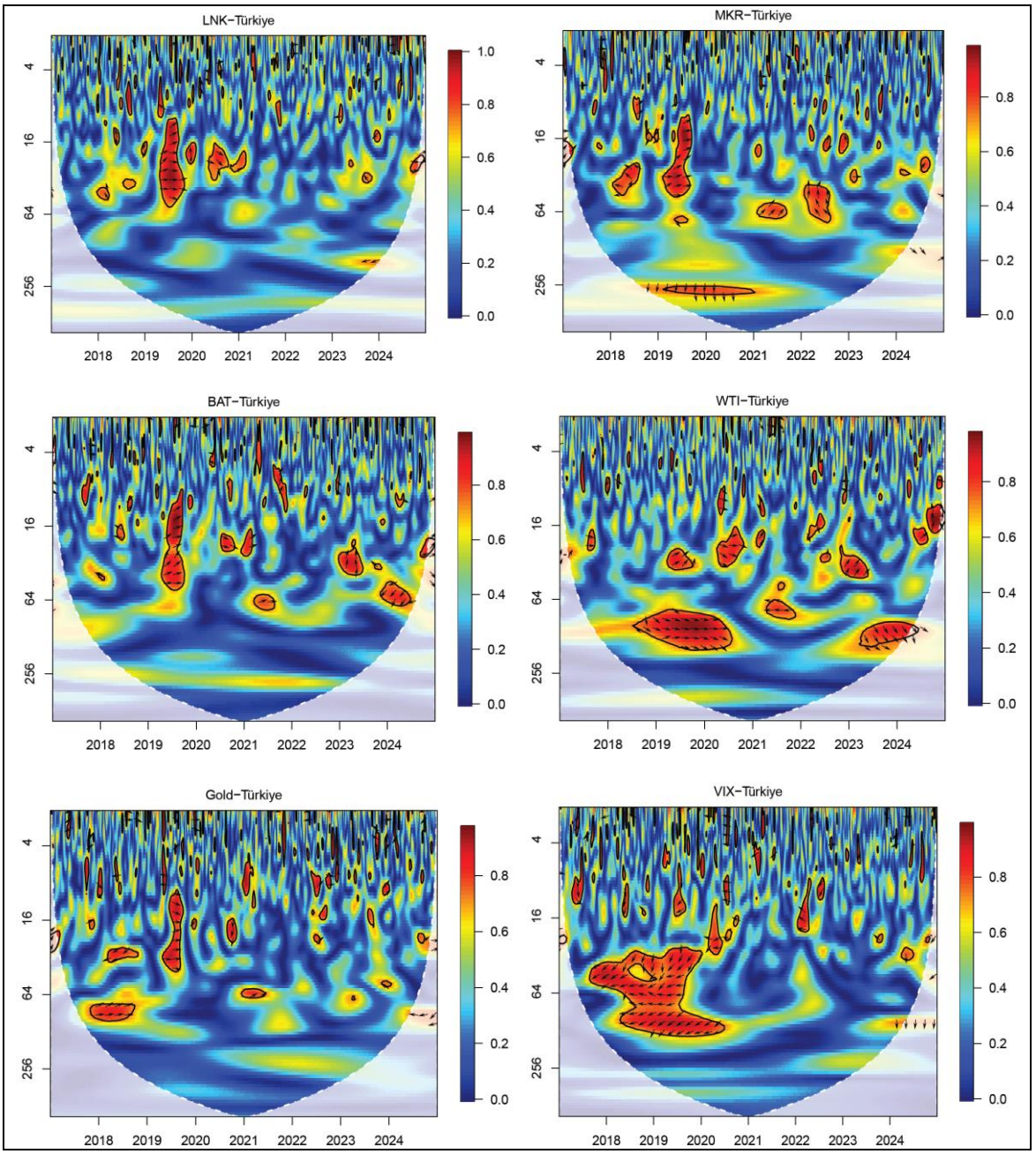


Şekil 3. Endonezya Dalgacık Tutarlılığı Sonuçları

MKR ile hisse senedi piyasaları arasındaki bu inceleme sürdürüldüğünde, 2019-2020 döneminde okların kısa vadede belirgin bir yön göstermediği, ancak birkaç okla sağa yönelmenin iki piyasa arasındaki pozitif ilişki olasılığını işaret ettiği söylenebilir. BAT ile Endonezya hisse senedi getirileri arasındaki etkileşim incelendiğinde, 2019-2020 döneminde kısa vadede BAT'ın hisse senedi piyasasına öncülük ettiğini ortaya koymaktadır. Orta vadede ise iki piyasa arasındaki pozitif ilişkinin var olduğu ve aynı fazda Endonezya piyasalarının BAT'a liderlik ettiğini ortaya konmaktadır. WTI ile hisse senedi getirileri arasındaki ilişki incelendiğinde, 2019-2020 döneminde kısa vadede WTI'nın hisse senedi piyasasına yön veren bir unsur olduğu söylenebilir.

2019-2021 arasında, iki piyasanın orta vadede pozitif korelasyonun güçlendiği görülmektedir. Ayrıca, pozitif yönlü korelasyonun, 2019-2021 yılları arasında uzun vadede devam ettiği gözlemlenmektedir. Bu da petrol piyasası ile hisse senedi piyasaları arasındaki güçlü etkileşimin, uzun vadede de devam ettiğini ve iki piyasanın birbirini etkileme düzeyinin istikrarlı bir şekilde korunduğunu göstermektedir. Altın fiyatları ile hisse senedi getirileri arasındaki ilişkiye bakıldığında, 2019-2020 yılları arasında kısa vadede belirgin bir yön değişikliği gözlemlenmemekle birlikte, genel olarak pozitif bir ilişki olduğu belirlenmektedir. Son aşamada, VIX ile hisse senedi getirileri arasındaki etkileşim değerlendirildiğinde, 2018 ile 2020 sonrası dönemde orta vadede ters bir ilişki olduğu gözlemlenmiştir. Ardından, okların sol aşağıya doğru yönelmesi, bu dönemdeki hareketin faz dışı olduğunu göstermektedir. Bu durum, korku endeksinin hisse senedi piyasasına öncülük eden bir gösterge işlevi gördüğünü vurgulamaktadır. Son olarak 2022-2023 yılının sonlarına doğru, kısa vadede benzer bir ilişkinin gözlemlendiği anlaşılmaktadır.

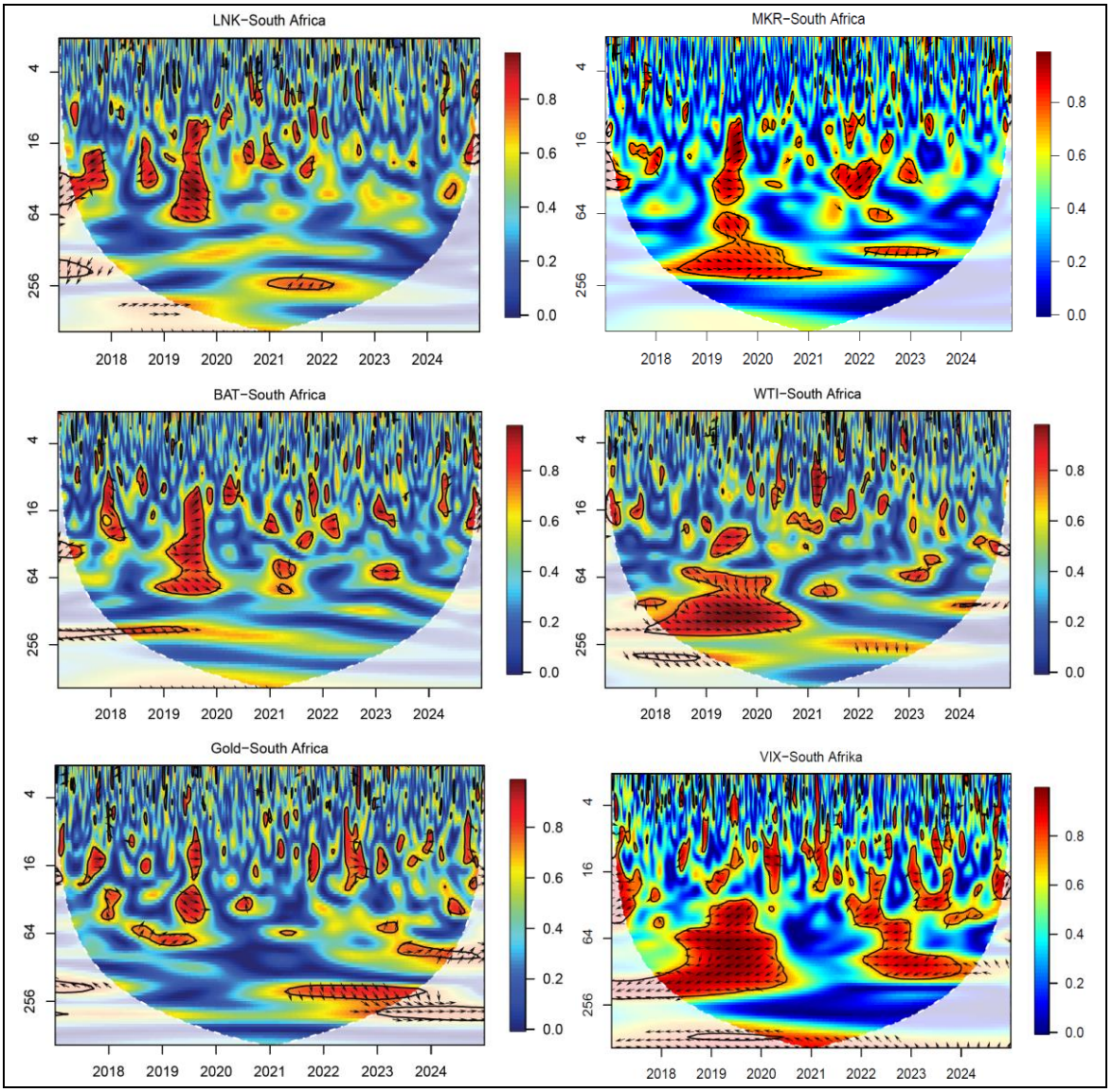
Şekil 4 Türkiye'deki hisse senedi piyasa getirileri ile DeFi varlıkları, petrol fiyatları, altın fiyatları ve VIX endeksi arasındaki dalgacık tutarlılığı bağlantılarını göstermektedir. Sonuçlar incelendiğinde, DeFi piyasaları ile hisse senedi getirileri arasında 2019-2020 döneminde kısa vadede güçlü bir pozitif korelasyon olduğuna ulaşılmıştır. Bu piyasalar arasındaki etkileşime daha detaylı bakıldığında, LNK ve hisse senedi getirileri arasında belirgin bir ilişki gözlemlenmezken, MKR ile hisse senedi getirileri arasında 2018'in ortalarında faz dışı ilişki olduğu ve hisse senedi getirilerinin önde olduğu görülmektedir. MKR ile hisse senedi piyasası arasındaki ilişkiler incelenmeye devam edildiğinde, kısa vadede 2021'in ortalarında ve 2023'ün ortalarında aynı fazda MKR'nin hisse senedi piyasa getirilerine öncülük ettiği görülmektedir. Ayrıca, uzun vadeye yakınmasa da 2019'dan 2021'in sonuna kadar hisse senedi getirilerinin MKR piyasasına öncülük ettiğine ulaşılmıştır. BAT ile hisse senedi getirileri arasındaki ilişki, kısa vadede, 2021'in sonu ile 2022'nin başına kadar ara ara pozitif korelasyon göstermiştir. 2023'ün ortalarında kısa vade BAT'ın hisse senedi getirilerine öncülük ettiği belirlenmiştir. Ancak, 2024'ün başlarında kısa vadede faz dışı BAT'ın öncülük işlevini üstlendiği görülmektedir. Petrol fiyatları ile hisse senedi getirileri arasındaki ilişkiye bakıldığında ise, 2019-2021 yılları arasında kısa ve orta vadede iki piyasa arasında pozitif bir korelasyonun bulunduğu belirlenmiştir. 2021'in sonlarına doğru orta vadede iki piyasa arasında kısa süreli bir negatif korelasyona vardır. 2023 yılı itibarıyla, kısa vadede aynı fazda petrol fiyatlarının hisse senedi getirilerine öncülük ettiğine, orta vadede aynı fazda hisse senedi getirilerinin petrole öncülük ettiğine ulaşılmıştır. Altın ile hisse senedi getirileri arasındaki ilişkiyi incelediğimizde, 2018-2019 yılları arasında orta vadede ve 2019'un ortalarında kısa vadede iki piyasa arasında pozitif bir korelasyon bulunduğu görülmektedir. Bunun dışında, aynı dönemde iki piyasa arasında çok fazla hareketliliğin olmadığı belirlenmiştir. Son olarak, VIX endeksi ile hisse senedi getirileri arasındaki ilişkiye baktığımızda, güçlü bir bağlantıyı gösteren kırmızı tonlarının belirginleştiği gözlemlenmektedir. Bu ilişki, okların büyük çoğunluğunun hem kısa vadede hem de orta vadede doğrudan sola dönük olması, VIX endeksi ile hisse senedi getirileri arasında negatif bir korelasyon olduğunu ortaya koymaktadır. Genel olarak değerlendirildiğinde, VIX endeksi dışında, Türkiye'nin hisse senedi getirileri ile DeFi, petrol ve altın piyasaları arasında olumlu faz içi ortak hareketler gözlemlenmektedir. Ancak, hangi piyasanın diğerine öncülük ettiği konusunda net bir tutarlılık bulunmamaktadır.



Şekil 4. Türkiye Dalgacık Tutarlılığı Sonuçları

Son olarak, Şekil 5'de verilen Güney Afrika hisse senedi getirileri ile DeFi varlıkları, petrol fiyatları, altın fiyatları ve VIX endeksi arasındaki dalgacık tutarlılığı bağlantıları incelendiğinde, LNK ile Güney Afrika hisse senedi getirileri arasında kısa vadede okların sağa yukarı yöneldiği görülmektedir. Bu durum, LNK'nin aynı faz içerisinde hisse senedi getirilerine öncülük ettiğini ortaya koymaktadır. Ayrıca, 2019-2020 dönemi boyunca kısa vadede iki piyasa arasında pozitif bir korelasyon ilişkisi olduğunu göstermektedir. MKR ile hisse senedi getirileri arasında 2019-2020 döneminde ve 2022 yılında kısa vadede pozitif bir korelasyon ilişkisi vardır. BAT ile hisse senedi getirileri arasındaki ilişkiye baktığımızda ise, 2019-2020 dönemlerinde kısa vadede okların sağ yukarı yönelmesi, BAT'ın hisse senedi getirilerine öncülük ettiğini; orta vadede ise okların sağ aşağıya yönelmesi, hisse senedi getirilerinin BAT'tan önce hareket ettiğine işaret etmektedir. WTI ile hisse senedi getirileri arasındaki bağlantı incelendiğinde, 2018-2021 dönemleri arasında

orta vadede iki piyasa arasında pozitif ve güçlü bir etkileşimin sürdüğü görülmektedir. Altın piyasası ile hisse senedi getirileri arasındaki ilişki ise 2019-2020 dönemlerinde kısa ve orta vadede karmaşık bir görünüme sahiptir. Ancak, 2022-2024 dönemleri arasında orta vadede hisse senedi getirilerinin altın piyasasına öncülük ettiği görülmektedir. Son olarak, VIX ile hisse senedi getirileri arasındaki etkileşim incelendiğinde, 2018-2020 ve 2022-2024 dönemlerinde iki piyasa arasında negatif bir ilişki olduğu ve birbirlerinin tersi yönünde hareket ettikleri görülmektedir.



Şekil 5. Güney Afrika Dalgacık Tutarlılığı Sonuçları

5. Sonuçlar ve Öneriler

Bu çalışma, Ocak 2018 ile Kasım 2024 arasındaki günlük verileri kullanarak DeFi, WTI, Altın ve VIX endeksi ile Kırılgan Beşli ülkeler olarak tanımlanan Brezilya, Hindistan, Endonezya, Türkiye ve Güney Afrika hisse senedi getirileri arasındaki karşılıklı bağımlılıkları incelemektedir. Kırılgan beşli ülkelerin konvansiyonel hisse senedi piyasaları ile diğer varlık sınıfları arasındaki karşılıklı bağımlılıklarını inceleyen yatırımcılar, beklenen getirilerinden taviz

vermeden portföy risklerini minimuma indirebilmektedir. Verimli bir portföyün oluşturulması için varlıklar arasındaki korelasyonun anlaşılması gerekmektedir. Bunun için, dalgacık tutarlılık yöntemi kullanılarak serilerin belirlenen dönemler arasındaki zaman ve frekans boyutları ele alınmakta ve bu dönemlerde kırılgan beşli ülkelerin hisse senedi piyasaları ile emtia ve DeFi varlık sınıfları arasındaki ilişki belirlenmektedir. Aynı zamanda, bu ülkelerin hisse senedi piyasaları ile VIX endeksi arasındaki etkileşim ölçülerek, yatırım stratejileri, risk yönetimi ve finansal piyasa istikrarı için bilgi sağlanmaktadır.

Bu doğrultuda, dalgacık tutarlılığından elde edilen bulgular, DeFi piyasaları ile kırılgan beşli ülkelerin borsaları arasındaki bağlantının özellikle 2019-2020 yılları arasında kısa vadede pozitif hareketler sergilediğini göstermektedir. Bu dönemde, her iki piyasa arasındaki eş hareketin, Covid-19 pandemisiyle birlikte küresel piyasalardaki belirsizlikten kaynaklandığı ve yatırımcıların her iki piyasada benzer tepkiler vermesine neden olduğunu ortaya koymaktadır. Bu bulgu, literatürdeki (Yılancı ve Pata, 2023; Frikha vd., 2024) çalışmalarıyla tutarlıdır. Ancak, iki piyasa arasında kimin diğerine öncüllük ettiği konusunda net bir sonuç bulunmamaktadır. Bazı piyasalarda DeFi öncül olurken, bazı piyasalarda ise hisse senedi getirileri öncül olmaktadır. Petrol fiyatları ile kırılgan beşli ülkelerin borsaları arasındaki ilişkiye bakıldığında ise, 2018'in sonlarından 2020'nin ortalarına kadar, orta ve uzun vadede her iki piyasanın getirilerinin pozitif korelasyonlu olduğu gözlemlenmektedir. Bu dönemin, küresel ekonomik belirsizliklerin ve Covid-19 pandemisinin etkisiyle şekillenmiş olması, petrol fiyatlarının artışının ihracat gelirlerini artırarak borsa performansını güçlendirdiğine işaret etmektedir. Yani, yatırımcı algısı üzerinde olumlu bir etki yaratan bu gelişme, aynı zamanda gelişen piyasalara olan ilgiyi de artırmıştır Dolayısıyla petrol fiyatlarının yükselmesi, kırılgan beşli ülkelerin hisse senedi getirilerinde de benzer bir eğilim sergilemesine yol açtığını göstermektedir. Bu sonuçlar (Cai vd., 2017; Cui vd., 2021; Mudiangombe ve Mwamba, 2023) çalışmalarıyla örtüşmektedir. Yine, bu iki piyasa arasında petrol fiyatlarının Endonezya ve Türkiye piyasalarında kısa vadede bazı dönemlerde hisse senedi getirilerine öncülük ettiği görülse de genel olarak öncülük ilişkisinde net bir görüntü yoktur. Diğer taraftan, altın fiyatları ile kırılgan beşli ülkelerin borsaları arasındaki ilişki genellikle 2019'un sonlarında kısa vadede pozitif bir eş hareket sergilediğini ortaya koymaktadır. Aslında altın, genellikle ekonomik kriz dönemlerinde güvenli liman olarak bilinir ve genellikle hisse senetleriyle ters yönde hareket eder. Ancak, pandemi döneminde, altın ile kırılgan beşli borsaları arasındaki pozitif ilişki, altının geleneksel güvenli liman rolünü eskisi kadar etkili bir şekilde yerine getiremediğini ve kriz dönemlerinde yatırımcılara beklenen düzeyde koruma sağlamadığını ortaya koymaktadır. Bu durum literatürdeki (Raza vd., 2016; Frikha vd., 2024) çalışmalarla desteklenmektedir. Ayrıca, bu iki piyasa arasındaki öncelikli ilişkiye bakıldığında, Endonezya piyasasında altının hisse senedi getirilerine öncülük ettiği, Güney Afrika piyasasında ise altın ve hisse senedi getirilerinin zaman zaman karşılıklı olarak öncülük ettiği gözlemlenmiştir. Ancak diğer ülkeler için öncüllük ilişkisinde net bir sonuç bulunmamaktadır. Son olarak, VIX korku endeksi ile kırılgan beşli ülkelerin borsaları arasındaki bağlantının, farklı zaman dilimlerinde kısa, orta ve uzun vadede negatif bir korelasyon gösterdiği tespit edilmiştir. Bu durum, belirsizlik dönemlerinde söz konusu ülkelerin borsalarının, yatırımcı güveninin azalması ve risk iştahının düşmesi nedeniyle genellikle olumsuz yönde etkilendiğini göstermektedir. Yani, VIX Endeksi'nin yükselmesi, küresel piyasalarda artan belirsizlik ve volatiliteye işaret ettiğinden, bu tür dönemlerde kırılgan beşli ülkelerin borsaları sermaye çıkışları, değer kaybı ve düşük performans gibi zorluklarla karşılaşabilmektedir. Bu sonuçlar (Sarwar ve Khan, 2017; Junior vd., 2021) çalışmalarıyla desteklenmektedir. Ayrıca, iki piyasa

arasındaki öncüllük ilişkisi incelendiğinde, faz dışı VIX endeksi genellikle kırılgan beşli ülkelerin hisse senedi getirilerine öncülük etmektedir.

Bulgular, kırılgan beşli ülkelerinin finansal piyasalarının küresel risk iştahı, emtia fiyatları ve alternatif yatırım araçlarıyla yüksek düzeyde ilişkili olduğunu göstermektedir. Ancak, 2018-2024 dönemi incelendiğinde, bu ülkelerdeki ekonomik kırılganlığın yalnızca küresel faktörlerden değil, aynı zamanda içsel makroekonomik dinamikler, yapısal sorunlar ve siyasi gelişmelerden de kaynaklandığı söylenebilir. Brezilya'da siyasi belirsizlikler ve yüksek kamu borcu, Endonezya'da dış ticarete bağımlılık ve para birimi oynaklığı, Hindistan'da finansal istikrarsızlık ve büyüme dalgalanmaları, Güney Afrika'da yapısal işsizlik ve enerji arz sorunları, Türkiye'de ise yüksek enflasyon, faiz politikalarındaki belirsizlik ve kur istikrarsızlığı yatırımcı güvenini zayıflatarak finansal piyasalar üzerinde baskı oluşturarak DeFi, petrol, altın ve VIX endeksine verilen tepkilerin ülkelere göre farklılaşmasına neden olduğu ifade edilebilir.

Dalgacık tutarlılığı analizinden elde edilen bulgulara dayanarak, çalışma yatırımcılara ve politika yapıcılara önemli stratejik çıkarımlar sunmaktadır. Yatırımcılar, portföy çeşitlendirme stratejilerini oluştururken DeFi piyasaları ile kırılgan beşli ülkelerin borsaları arasındaki kısa vadeli pozitif eş hareketi göz önünde bulundurmalı ve kriz dönemlerinde bu piyasaların aynı yönde hareket edebileceği riskini değerlendirmelidir. Petrol fiyatlarının artışının kırılgan beşli borsalarında ekonomik kazançları artırarak olumlu etkiler yarattığı göz önüne alındığında, enerji fiyatlarındaki dalgalanmaları yakından izlemek ve enerjiye dayalı ekonomilerde yatırım stratejilerini optimize etmek büyük önem taşımaktadır. Pandemi döneminde altının güvenli liman statüsündeki zayıflama ise kriz dönemlerinde yalnızca altına bağımlı kalınmaması gerektiğini ve alternatif güvenli liman araçlarının araştırılmasının faydalı olacağını ortaya koymaktadır. VIX endeksindeki artışların, küresel piyasalarda belirsizlik ve volatiliteyi artırdığı dönemlerde yatırımcıların daha korunaklı stratejiler benimsemesi, politika yapıcıların ise sermaye çıkışlarını engelleyici ve yatırımcı güvenini artırıcı politikalar geliştirmesi kritik önem taşımaktadır. Ayrıca, DeFi piyasalarının düzenlenmesi ve bu piyasaların finansman potansiyelinin değerlendirilmesi, piyasa entegrasyonunu artırabilir. Hem yatırımcılar hem de politika yapıcılar, bu piyasalar arasındaki öncülük ilişkilerinin dinamik yapısını anlayarak daha bilinçli ve esnek stratejiler geliştirmeli, makroekonomik göstergeler ve kriz dönemlerine yönelik proaktif planlamalarla piyasa istikrarını ve güvenini desteklemelidir.

Çalışmada, Kırılgan Beşli ülkelerinin hisse senedi getirileri ile diğer varlık sınıfları (DeFi, WTI, Altın ve VIX) arasındaki ilişki incelenmiş olup, diğer bazı önemli makroekonomik değişkenlerin (örneğin faiz oranları ve döviz kuru) etkisi göz ardı edilmiştir. Bu nedenle, gelecekteki çalışmalarda faiz oranları ve döviz kuru gibi makroekonomik faktörlerin de dikkate alınması, piyasaların etkileşim biçimlerini daha kapsamlı bir şekilde anlamak için kritik öneme sahip olacaktır. Ayrıca, gelişen piyasalarda ve kripto piyasalarında daha geniş kapsamlı veri setleri ve uzun vadeli analizler kullanılarak, bu piyasalardaki potansiyel riskler ve fırsatlar daha net bir şekilde ortaya konulabilir. Bunun yanı sıra, yatırımcı duyarlılığı ve haber akışı gibi ek faktörlerin dikkate alınması, piyasa hareketlerinin daha iyi anlaşılmasına katkı sağlayacaktır.

Araştırma ve Yayın Etiği Beyanı
Etik kurul izni ve/veya yasal/özel izin alınmasına gerek olmayan bu çalışmada araştırma ve yayın etiğine uyulmuştur.
Araştırmacıların Katkı Oranı Beyanı
Yazarlar makaleye eşit oranda katkı sağlamış olduklarını beyan eder.
Araştırmacıların Çıkar Çatışması Beyanı
Bu çalışmada herhangi bir potansiyel çıkar çatışması bulunmamaktadır.

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THE CONNECTION BETWEEN DEFI, OIL, GOLD, AND THE VIX FEAR INDEX WITH STOCK MARKETS IN THE FRAGILE FIVE COUNTRIES: A WAVELET COHERENCE ANALYSIS

EXTENDED SUMMARY

Aim of the Study

The aim of this study is to examine the interdependencies between the stock returns of Brazil, India, Indonesia, Turkey, and South Africa, defined as the "Fragile Five" and the DeFi, oil, gold, and VIX index. The analysis of these dependencies plays an important role in the development of investment portfolio diversification strategies and a better understanding of the impacts of global market shocks. Especially, the greater sensitivity of the economic and financial systems of the Fragile Five countries to external stocks necessitates. Therefore, this study aims to make a significant contribution to the literature on emerging markets by providing a new perspective on the market dynamics of the fragile five countries.

The Literature

Fragile five countries are among the most precarious and vulnerable regions in emerging markets due to their high sensitivity to external shocks, economic and political uncertainties, and excessive fluctuations in financial markets. Ali and Khan (2020) emphasized that these countries are more vulnerable to economic fluctuations and sensitive to external shocks, resulting in an increased likelihood of experiencing high volatility and uncertainty. Similarly, Gnangnon (2021) stated that the heightened sensitivity of these countries to external shocks increases their chance of experiencing economic fluctuations. Hung (2024) asserts that DeFi and digital assets significantly influence traditional exchange systems and that there exists a reciprocal interaction between these systems. Shabbir et al. (2020) and Hamal and Gautam (2021) indicated that the VIX adversely affects stock markets. Shabbir et al. (2020) also stated that gold serves as a hedge during stock market declines, while Choudhry et al. (2015) argued the opposite, claiming that gold has an inverse relationship with stocks.

Methodology

To examine the relationship between DeFi, oil, gold, and the VIX index with the stock markets of the Fragile Five countries in the time and frequency domain, wavelet coherence analysis has been preferred. This method is a powerful analytical tool, especially for complex and nonlinear data structures frequently encountered in financial and economic time series. In the study, the daily stock closing prices of the Fragile Five countries were used as the basis. These countries and their respective stock indices are as follows: Brazil (Bovespa Index), Indonesia (Jakarta Composite Index), India (BSE30 SENSEX Index), Turkey (BIST100 Index), and South Africa (TOP40 Index). To represent the DeFi markets, LINK (Chainlink), MKR (Maker), and BAT (Basic Attention Token) were chosen. For the oil market, WTI (West Texas Intermediate) prices were chosen while LMBA (USD/Ons) spot prices and the VIX fear index were chosen to

represent the gold market and market volatility, respectively. All markets consist of daily data and cover the period from January 2, 2018, to November 11, 2024, with a total of 1774 observations. Finally, in all markets, logarithmic return series were obtained from the price series using the formula $100 \times log(P_t/P_{t-1})$, and logarithmic returns were used in the analysis.

Results

According to the findings, a short-term positive relationship was observed between DeFi markets and the stock exchanges of the fragile five countries between 2019-2020, but there is no clear conclusion on which of these markets leads the other. The relationship between oil prices and these stock exchanges has been positively correlated in the medium and long term from the end od 2018 to mid-2020, but the leading relationship is uncertain. The relationship between gold prices and stock markets was positive in the short term at the end of 2019, with gold leading stock returns in some markets, but there is no general leading relationship. The relationship between the VIX fear index and the stock markets has generally been negatively correlated in the short, medium, and long term, and the VIX index usually leads the stock markets. These results indicate that market relationships can vary based on time periods and country-specific factors.

Conclusion

The findings of the wavelet coherence analysis provide strategic inferences for investors and policymakers. Investors should consider the short-term co-movement between DeFi markets and the Fragile Five countries and take into account the risk that these markets may move in the same direction during times of crisis. It is emphasized that the increase in oil prices has boosted economic gains in the fragile five stock markets and that fluctuations in energy prices should be closely monitored. The weakness of gold during the pandemic period indicates that gold-based investments may be insufficient, highlighting the need to explore alternative safe-haven assets. The VIX index, on the other hand, directs investors towards safe-haven strategies during periods of global uncertainty, necessitating policymakers to develop policies that will prevent capital outflows.

Ekonomi, Politika & Finans Araştırmaları Dergisi, 2025, 10(1): 359-388
Journal of Research in Economics, Politics & Finance, 2025, 10(1): 359-388
Araştırma Makalesi / Research Article, https://doi.org/10.30784/epfad.1602273

FİNANSAL BİLGİ MANİPÜLASYONUNUN BENEISH TR MODELİ KULLANILARAK TAHMİN EDİLMESİ: BIST İMALAT SANAYİ ÜZERİNE BİR UYGULAMA

Estimation of Financial Information Manipulation Using Beneish TR Model: An Application on BIST Manufacturing Industry

Hakan YILMAZ*

Anahtar Kelimeler:
Finansal Manipülasyon, Beneish TR Modeli, BIST İmalat Sanayi Sektörü, Multinominal Logit, Multinominal Probit

JEL Kodları:
G17, G10, C10

Öz

Çalışmada BIST imalat sanayi sektöründe faaliyet gösteren 205 işletmenin 2022-2023 yılları için finansal bilgi manipülasyonu yapıp yapmadıkları, Beneish TR modeli kullanılarak tahmin edilmiştir. Ayrıca çalışmada, Multinominal Logit modeli ve Multinominal Probit modeli de kullanılmıştır. Modellerin kullanımı ile değişkenlerin finansal bilgi manipülasyonu olasılığının belirlenmesindeki marjinal etkiler ve modellerin finansal bilgi manipülasyonu sınıflandırma başarıları hesaplanarak, gerekli karşılaştırmalar yapılmıştır. Beneish TR modeli sonucunda 116 işletmenin herhangi bir finansal manipülasyona başvurduğuna ilişkin bulgunun olmadığı, 16 işletmenin finansal manipülasyon yapma olasılığının bulunduğu, 37 işletme için finansal manipülasyon yapmaya yönelik ciddi bulguların belirlendiği ve 36 işletmeye dair finansal manipülasyon yapmaya yönelik çok önemli bulguların var olduğu belirlenmiştir. Multinominal Logit regresyon modeli ve Multinominal Probit regresyon modeli analizleri sonucunda brüt kâr marjı endeksinin finansal manipülasyon yapma olasılığını azaltıcı en önemli değişken olduğu belirlenmiştir. Bununla birlikte kullanılan Multinominal Logit modeliyle %89,27'lik ve Multinominal Probit modeliyle %85,85'lik sınıflandırma başarısı gerçekleştirilmiş ve sınıflandırmaya ilişkin modellerin gücü ve güvenirlik düzeyleri hesaplanmıştır.

Keywords:
Financial Manipulation, Beneish TR Model, BIST Manufacturing Industry Sector, Multinominal Logit, Multinominal Probit

JEL Codes:
G17, G10, C10

Abstract

In the study, whether 205 enterprises operating in the BIST manufacturing industry sector have engaged in financial information manipulation for the years 2022-2023 is estimated using the Beneish TR model. In addition, the Multinominal Logit model and Multinominal Probit model were also used in the study. With the use of the models, the marginal effects of the variables in determining the probability of financial information manipulation and the success of the models in classifying financial information manipulation were calculated and necessary comparisons were made. As a result of the Beneish TR model, it has been determined that 116 enterprises have no evidence of any financial manipulation, 16 enterprises are likely to engage in financial manipulation, 37 enterprises have serious findings for financial manipulation and 36 enterprises have very important findings for financial manipulation. As a result of the Multinominal Logit regression model and Multinominal Probit regression model analyses, it is determined that the gross profit margin index is the most important variable that reduces the probability of financial manipulation. In addition, a classification success of 89.27% was achieved with the Multinominal Logit model and 85.85% with the Multinominal Probit model and the power and reliability levels of the classification models were calculated.

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Makale Geliş Tarihi (Received Date): 16.12.2024 Makale Kabul Tarihi (Accepted Date): 11.03.2025

1. Giriş

Finansal bilgiye ihtiyaç duyan işletme içi ve dışı tüm taraflar, gereksinim duydukları bilgilerin tamamına finansal tablolar üzerinden erişebilmektedir. Türkiye'de finansal tabloların gerektiği gibi hazırlanması ve sunulması amacıyla kullanılması gereken ölçütler, Türkiye Muhasebe Standardı (TMS) 1 ile belirlenmiştir. Bu standart kapsamında tabloların tarafsız, tam, gerçeğe uygun vb. özellikleri taşıyarak hazırlanması ve sunulması istenmektedir. Bu doğrultuda finansal tablolarda yer alan bilgiler değiştirilmiş, hileli, yanıltıcı ve gerçek dışı olmamalıdır. Borsada faaliyet gösteren ya da göstermeyen işletmeleri yönetenler ya da finansal tabloları hazırlayanlar, birtakım sebeplerle bahsedilen bu usulsüz işlemleri yapabilmektedir. Payları borsada işlem gören işletmeler için bahsi geçen manipülatif işlemleri yapmak oldukça zordur. Buna rağmen finansal tablolarının bağımsız denetimden geçmesi mecburi olan ve yatırımcılar için oldukça güvenilir kabul edilen borsa işletmelerinin de çeşitli manipülasyonlara başvurma ihtimalleri bulunmaktadır (Peker, 2023: 322).

Manipülatif işlemlerde üzerinde değişiklik yapılan, birden çok boyuta ve ölçüte sahip olan finansal bilginin kalitesi, bilgiye başvuranların karar verirken kullandıkları bilgiden elde ettikleri fayda olarak açıklanmaktadır. Finansal bilginin fayda sağlaması için birtakım niteliksel özellikleri içermesi gerekmektedir. Bahsi geçen özellikler temel ve destekleyici özellikler olarak belirtilmektedir. Temel özellikler, ihtiyaca uygunluk ve gerçeğe uygun sunum, destekleyici özellikler ise anlaşılabilirlik, karşılaştırılabilirlik, zamanında sunum ve doğrulanabilirlik olarak ifade edilmektedir. Buradan hareketle finansal tablolar üzerinde gerçekleştirilen finansal bilgi manipülasyonu, finansal bilgilerin kalitesini etkilemekte ve önemli düzeyde kalite düşürücü bir etki meydana getirmektedir (Günlük, 2023: 366).

Finansal tablolarda yer alan finansal bilgilerdeki kalite düşüklüğü ile sonuçlanan finansal bilgi manipülasyonuna başvurulmasında; varlıklarda ve kaynaklarda, performans göstergelerinde, nakit akışlarında ve özsermaye hareketlerinde çeşitli değişiklikler yapılarak, ortaklara ve yeni yatırımcılara yanlış ve hileli bilgiler verilerek, işletmenin olduğundan farklı ve daha iyi bir konumdaymış gibi gösterilmesi amaçlanmaktadır. Manipülatif işlemlerle amaçlanan bu durum, işletmelere kısa sürede yarar getirecek gibi algılansa da uzun zaman periyodunda başta itibar kaybı olmak üzere, piyasa fiyatında düşme, pazar payında azalma, müşteri kaybı, yüklü miktarda cezalar ve işletmenin iflas etmesi gibi istenmeyen birçok olumsuz durumla karşılaşılmasına sebep olabilmektedir. İşletmeler özelinde ortaya çıkacak bu durumlar beraberinde ülke ekonomilerini de olumsuz bir biçimde etkilemektedir. Manipülatif işlemlerin fark edilmesi soncunda yabancı yatırımcılar güven ve itibar kaybı yaşayarak farklı ülke piyasalarına yönelmektedir. Böylelikle ülke ekonomileri için hayati önem taşıyan yabancı sermayenin kaybedilmesi kaçınılmaz olmaktadır (Erduru, 2022: 2304).

Gerçekleştirilen çalışma BIST imalat sanayi sektöründe faaliyet gösteren işletmeler üzerinedir. Türkiye ekonomisi için oldukça önemli bir konumda olan sektör, özellikle üretim ve istihdam yönünden göz ardı edilemeyecek bir durumdadır. Ekonomik yapı içerisinde üretim ve istihdam açısından yüksek bir payı elinde bulunduran imalat sanayi sektörü, bu yönüyle ülke ekonomisi için diğer sektörlere kıyasla oldukça değerlidir. Bilindiği üzere ülkelerin büyüme, gelişme ve kalkınmaları noktasında imalat sanayi sektörü öncü rolü taşımaktadır. Türkiye içinde gelişmişlik düzeyi açısından önemli bir gösterge olarak kabul edilen imalat sanayi sektörü, sürekli bir şekilde büyümek ve gelişmek durumundadır (Polat, 2011: 30). Tüm bunların yanı sıra imalat sanayi sektöründe faaliyet gösteren işletmelerin finansal tabloları, diğer sektör işletmelerine

karşın daha homojen bir yapıdadır. Sektörde bulunan işletme sayıları incelendiğinde ise diğer sektörlere göre imalat sanayi sektöründe oldukça fazla sayıda işletmenin bulunduğu görülmektedir (Ünver Kiracı ve Şengül Çelikay, 2020: 246).

Çalışmada, Beneish modelinin Türkiye'ye uyarlanması sonucu geliştirilen Beneish TR modeli kullanılmıştır. Tahmin yöntemleri içerisinde araştırmacılar tarafından sıkça kullanılması ve Türkiye'ye özgü uyarlanmış olması nedeniyle çalışmada, Beneish TR modelinin kullanımı tercih edilmiştir. Ayrıca çalışmada belirtilen yönteme ilave olarak Multinominal Logit ve Multinominal Probit yöntemleri de kullanılmıştır. Çalışmada kullanılan bağımlı değişken 2'den fazla kategorik değişken içerdiği için Benish TR modeli dışında kullanılması gereken analiz yöntemi, çok değişkenli istatistik tekniklerinden olan Multinominal Logit ve Multinominal Probit modelleridir. Bununla birlikte herhangi bir işletmenin finansal bilgi manipülasyonu kategorisinde hangi kategoriye ait olduğunu sınıflandırabilmek amacıyla Multinominal Logit ve Multinominal Probit modellerinin kullanılması gerekmektedir. Çalışmada kullanılan değişkenlerin finansal bilgi manipülasyonu kategorisinde istatistiksel açıdan anlamlı olup olmadığını belirlemek, istatistiksel açıdan anlamlı olan değişkenlerin ve finansal bilgi manipülasyonu kategorisi olasılığı üzerinde etkili olan değişkenlerin marjinal etkilerinin hesaplanabilmesi amacıyla belirtilen yöntemler kullanılmaktadır. Bu bilgiler dahilinde makine öğrenme teknikleri yukarıda açıklanan analizlerin elde edilmesinde kullanılamayacağı için çalışmada Multinominal Logit ve Multinominal Probit modellerinin kullanılması uygun görülmüştür. Bu doğrultuda, Multinominal Logit ve Multinominal Probit yöntemleri kullanımı sayesinde değişkenlerin, finansal bilgi manipülasyonu olasılığının belirlenmesinde ortaya koydukları marjinal etkiler hesaplanmış ve Multinominal Logit ve Multinominal Probit modellerinin finansal bilgi manipülasyonu sınıflandırma başarıları elde edilmiştir. Çalışmada kullanılan modeller, araştırmanın yöntemi kısmında detaylıca tanıtılmıştır. Belirtilen modele ve yöntemlere göre analizler yapılarak, ulaşılan sonuçların yorumlarla desteklendiği çalışma giriş, literatür araştırması, analiz ve bulgular ile sonuç başlıklı dört bölümden oluşmaktadır.

Yapılan açıklamalar doğrultusunda çalışmanın amacı, BIST imalat sanayi sektöründe işlem gören işletmelerin finansal bilgi manipülasyonu yapma durumlarının tahmin edilmesidir. Bu amaç üzerine sektörde faaliyet gösteren 205 işletmenin, 2022-2023 yıllarına ait finansal bilgi manipülasyonu yapıp yapmadıkları, Beneish TR modeli kullanılarak belirlenmiştir. Ayrıca belirtilen modele ilave olarak çalışmada, Multinominal Logit ve Multinominal Probit analiz teknikleri kullanılmıştır. Belirtilen modele ve analiz tekniklerine göre gerekli analizler yapılarak, elde edilen sonuçlar yorumlarla desteklenmiştir. Türkiye de yapılan imalat sanayi sektörü finansal bilgi manipülasyonu çalışmaları incelendiğinde, belirtilen sektör üzerine çok sayıda çalışma yapılmadığı görülmektedir. Özellikle Türkiye literatüründe imalat sanayi sektörüne ait ilgili yıllar için finansal bilgi manipülasyonu konusuyla ilgili herhangi bir çalışmaya rastlanamamıştır. Yine Türkiye de yapılan ve imalat sanayi sektörü özelinde finansal bilgi manipülasyonu üzerine gerçekleştirilen çalışmalar araştırıldığında, Beneish TR modeli kullanılarak yapılan çalışma sayısı oldukça sınırlıdır. Özellikle belirtilen yıllarda imalat sanayi sektörü üzerine Beneish TR, Multinominal Logit ve Multinominal Probit modelleri kullanılarak yapılan herhangi bir çalışmaya rastlanamamıştır. Bu durum çalışmanın özgün yanını oluşturmaktadır. İmalat sanayi üzerine, Beneish TR modeli kullanılarak gerçekleştirilen ve bu çalışmayla benzerliği olduğu düşünülen çalışmalar; Ünver Kiracı ve Şengül Çelikay (2020) ile Peker (2023) tarafından yapılmıştır. Gerçekleştirilen çalışma, karşılaştırılanlara göre daha fazla model ve işletme içermektedir. Ünver Kiracı ve Şengül Çelikay (2020) çalışmalarında 2017-2018 yılları için 178 imalat sektörü

işletmesini Beneish TR modeli ile değerlendirilerek, bu işletmelerde yönetici değişikliği yapıldığı süreçlerde finansal manipülasyona başvurulduğunu belirtmiştir. Peker (2023) çalışmasında 2020-2021 yılları için 151 imalat sektörü işletmesinin finansal manipülasyon durumunu Beneish TR modeli aracılığıyla dört ayrı kategoride incelemiştir. Bu çalışmada ise sektörde faaliyet gösteren 205 işletmenin, 2022-2023 yıllarına ait finansal bilgi manipülasyonu yapıp yapmadıkları, Beneish TR modeli kullanılarak belirlenmiştir. Özellikle bu çalışmada Multinominal Logit ve Multinominal Probit modelleri ile değişkenlerin manipülasyona ait marjinal etkileri ve modellerin sınıflandırma başarıları değerlendirilmiştir. Bahsedilenlere ilaveten gerçekleştirilen çalışmanın güncel veri seti içermesi, belirtilen yıllarda ilgili sektörün ve kullanılan analiz yöntemlerinin daha önce çalışılmamış olması ve elde edilen sonuçlar doğrultusunda çalışmanın Türkiye literatürüne katkı sağlayacağı düşünülmektedir.

2. Literatür Araştırması

Bu kısımda, BIST imalat sanayi sektöründe ve diğer sektörlerde finansal bilgi manipülasyonu üzerine, uluslararası ve ulusal literatürde bulunan çalışmalara yer verilmiştir.

Tablo 1. Finansal Bilgi Manipülasyonu Üzerine Literatür Taraması

Yazar/Yazarlar	Analiz Sektörü ve Dönemi	Yöntem	Sonuç
Avşarlıgil (2010)	İMKB Tekstil İşletmeleri/2007-2008	Beneish ve Beneish TR Modeli	Beneish ve Beneish TR modellerinden elde edilen sonuçlar arasında farklılıklar olduğu belirtilmiştir.
Varıcı ve Er (2013)	İMKB 100/2010	Beneish Modeli	Değerlendirilen 39 işletmenin 20 tanesinde manipülasyon yapma ihtimali görülmüştür.
Kara vd. (2015)	BIST İmalat Sanayi/2010-2012	Beneish Modeli	İncelenen 66 işletmenin manipülasyon yapma ihtimali bulunmuştur.
Fındık ve Öztürk (2016)	BIST İmalat Sanayi/2014	Beneish Modeli	Tahakkuk esasına dayalı manipülasyon yapıldığı belirtilmiştir.
Tepeli ve Kayıhan (2016)	BIST Gıda Maddeleri Sanayi	Beneish TR Modeli	İşletmelerden 9 tanesinin manipülasyon yaptığına dair ciddi kanıtlar olduğu belirtilmiştir.
Kamal vd. (2016)	US SEC/1996-2014	Beneish Modeli	İncelenen 17 işletmeden 14'ünün kazanç manipülasyonu yaptığı açıklanmıştır.
Dölen (2016)	BIST Gıda Sektörü/2013-2014	Beneish TR Modeli	Değerlendirilen 13 işletmeden 4'ünün manipülasyon yapma olasılığının çok güçlü olduğu ifade edilmiştir.
Ramirez-Orellana vd. (2017)	Gıda Sektörü/Pescanova İşletmesi 2008-2011	Beneish Modeli	İlgili işletmenin manipülasyona başvurduğu gösterilmiştir.
Egbunike ve Igbinovia (2018)	Bankacılık Sektörü/2011-2015	Beneish M ve Altman Z Modelleri	İflas etme durumları olmayan işletmelerin kazanç manipülasyonuna başvurdukları belirtilmiştir.
Uzunoğlu ve Karacaer (2019).	BIST Sınai Endeksi/2013-2015	M-Skoru Modeli	Kullanılan 8 değişkenden 5'inin manipülasyonda kullanıldığı ifade edilmiştir.

Tablo 1. Devamı

Alfian ve Triani (2019)	55 İşletme/2012-2016	Beneish Modeli ve Logistic Regresyon Analizi	Benish modelinin manipülasyon tespitinde kullanılabilecek uygun bir model olduğu gösterilmiştir.
Öztürk ve Yılmaz (2019)	BIST Gelişen İşletmeler Piyasası	Beneish M ve Altman Z Modelleri	Finansal başarısızlık ve manipülasyon arasında kuvvetli bir ilişki olduğu belirtilmiştir.
Kara vd. (2019)	BIST İmalat Sanayi/2014-2017	Beneish Modeli ve Logistic Regresyon Analizi	İşletmelerde manipülasyona açık değişkenler açıklanmıştır.
Dereköy (2020)	Toshiba İşletmesi/2015	Örnek Olay Yöntemi	İlgili işletmede kullanılan manipülasyon yöntemleri tarif edilmiştir.
Holda (2020)	Varşova Menkul Kıymetler Borsası İşletmeleri	Beneish Modeli	Beneish modelinin finansal manipülasyon belirlemede etkili bir yöntem olduğu ifade edilmiştir.
Güner ve Kurnaz (2020)	BIST Kimya, Petrol, Plastik Endeksi/2017-2018	Beneish TR	Değerlendirilen 24 işletmeden 8'inin manipülasyon yapma olasılığının çok güçlü olduğu belirtilmiştir.
Ünver Kiracı ve Şengül Çelikay (2020)	BIST İmalat Sektörü/2017-2018	Beneish TR	Yönetici değiştiren işletmelerin büyük temizlik manipülasyonuna başvurdukları açıklanmıştır.
Kara ve Özcan (2020)	BIST İmalat Sektörü/2013-2017	Beneish Modeli ve Yapay Sinir Ağları	Beneish modelinin finansal manipülasyon belirlemede etkili bir yöntem olduğu gösterilmiştir.
Aksoy (2021)	BIST İşletmeleri/2000-2019	Makine Öğrenme Yöntemleri ve Lojistik Regresyon Analizi	Çalışmada kullanılan yöntemlerin manipülasyon tahmininde %100 sonuç verdiği ifade edilmiştir.
Elkhaldi vd. (2021)	Irak Borsası Turizm Sektörü/2017-2018	Beneish Modeli	İlgili 8 işletmeden 2'sinin manipülasyon yaptığı belirtilmiştir.
Özparlak (2021)	BIST İşletmeleri/2020	Beneish ve Altman Modelleri ve Yapay Sinir Ağları	264 işletmeden 113'ünün manipülasyon yapabileceği ifade edilmiştir.
Göktürk ve Yalçınkaya (2021)	BIST Toptan ve Perakende Ticaret, Lokantalar ve Oteller Sektörü/2017-2019	Beneish Modeli	Beneish aracılığıyla hazırlanan ölçüm modelinin, manipülasyon belirlemede %71.2 başarılı olduğu anlatılmıştır.
Erol Fidan (2021)	BIST Taş ve Toprağa Dayalı Sektör/2017-2019	Beneish TR Modeli	Değerlendirilen işletmelerden 2017'de 12'sinin, 2018'de 10'unun ve 2019'da 18'inin çok güçlü manipülasyon yapma ihtimalinin olduğu belirtilmiştir.
Toplu vd. (2021)	BIST İşletmeleri/2015	Beneish Modeli	İlgili 104 işletmeden %94'ünün manipülasyona başvurma ihtimalinin bulunduğu gösterilmiştir.
Benligiray ve Onay (2021)	Türkiye'de Faaliyet Gösteren İşletmeler/2013-2019	Beneish Modeli	Beneish TR modelinin, Beneish modelinden Türkiye'deki işletmeler üzerinde daha faydalı olduğu ifade edilmiştir.

Tablo 1. Devamı

Kara ve Toraman (2021)	BIST İmalat Sanayi/2015-2019	Beneish Modeli	Ekonomik kârlılık ve satış kârlılığı rasyolarının, manipülasyon için kullanılabilen oranlar olduğu açıklanmıştır.
Kara ve Sakarya (2021)	BIST İmalat Sanayi/2014-2019	Beneish Modeli	Değerlendirilen işletmelerde üzerinde manipülasyon yapılabilecek işletmeler gösterilmiştir.
Altınbay ve Ünal (2022)	Enron İşletmesi	Örnek Olay Analizi	Enron olayının sonuçları ve manipülasyonların azaltılması için gerekenler belirtilmiştir.
Richardson vd. (2022)	ABD'deki İşletmeler/2000-2014	Regresyon Analizi	Finansal manipülasyonların, gelecekteki hisse fiyatı çöküşleriyle doğrudan ilişkili olduğu ifade edilmiştir.
Erduru (2022)	BIST Kobi Sanayi Endeksi/2020	Mann Whitney U Testi ve Lineer Regresyon Analizi	İlgili işletmelerin %36'sının manipülasyona başvurma ihtimalinin yüksek olduğu açıklanmıştır.
Peker (2023)	İmalat Sektörü, Toptan ve Perakende Ticaret Sektörü/2020-2021	Beneish TR	Modelin imalat sektöründeki manipülasyonları belirlemede daha etkili olduğu belirtilmiştir.
Jain ve Bose (2023)	NSE 500 İşletmeleri/2009-2019	Beneish Modeli	NSE 500'deki işletmelerin finansal manipülasyona başvurdukları ve modelin güçlü sonuçlar verdiği ifade edilmiştir.
Uysal ve Kandil Göker (2023)	BIST Kurumsal Yönetim Endeksi/2012-2022	Beneish Modeli	Pay senedi kazançları ile manipüle yapılmış kâr oranları arasında anlamlı bir ilişki olduğu gösterilmiştir.
Can ve Özarı (2023)	BIST'te Bulunan Bir İşletme/5 Yıl	Benford Yasası ve Beneish Modeli	İlgili işletmede manipülasyon yapıldığı tespit edilmiştir. Modeller arasında benzerlik olduğu açıklanmıştır.
Yanya ve Kandil Göker (2023)	BIST Kurumsal Yönetim Endeksi/2012-2021	Beneish ve Panel Logit Modeli	CEO ikiliğinin manipülasyona başvurma ihtimalini %15 yükselttiği belirtilmiştir.
Zor ve Yanya (2023)	BIST Sınai Endeksi/2011-2021	Beneish ve Panel Logistik Regresyon Modeli	Finansal manipülasyon yapılmasıyla alacak devir hızı ile aktif büyüme oranı arasında olumlu bir ilişki bulunmuştur.
Soykan vd. (2023)	BIST Metal Sanayi/2018-2021	Beneish TR	İlgili 16 işletme arasından 2020'de 7 ve 2021'de 8 işletmenin manipülasyona başvurma ihtimali için çok ciddi kanıtlar olduğu ifade edilmiştir.
Günlük (2023)	BIST Gıda, İçecek ve Tütün Alt Sektörü/2017-2020	Beneish Modeli	Değerlendirilen 25 işletmeden tüm yıllarda manipülasyon yapma ihtimali olan 2 işletme bulunduğu gösterilmiştir.
Benligiray ve Onay (2023)	BIST'te Bulunan Bankacılık ve Finans Sektörü Dışındaki İşletmeler/2018-2021	Regresyon Analizi	Alacak karşılıklarının manipülasyon için kullanılma ihtimalinin yüksek olduğu belirtilmiştir.
Aslanoğlu ve Yanya (2023)	BIST Sınai Endeksi/2012-2021	Beneish Modeli	Hisse senedi kazançları üzerinde manipülasyonların etkisinin olduğu açıklanmıştır.
Çağlak ve Meder Çakır (2024)	Türkiye'de Faaliyet Gösteren İşletmeler/2009-2019	Beneish ve Logistik Regresyon Modeli	Geliştirilen modelin, Beneish'e göre manipülasyon tahmininde daha güçlü olduğu ifade edilmiştir.

Uluslararası ve ulusal literatürde finansal bilgi manipülasyonu konusunda imalat sanayi sektörü ve diğer sektörlerde gerçekleştirilmiş, çalışmayla benzer olduğu düşünülen seçili çalışmalar Tablo 1'de gösterilmiştir.

BIST imalat sanayi sektörü üzerine, Beneish TR modeli kullanılarak gerçekleştirilen ve bu çalışmayla doğrudan benzerliği olduğu düşünülen çalışmalar; Ünver Kiracı ve Şengül Çelikay (2020) ile Peker (2023) tarafından yapılmış olup yöntem benzerliği nedeniyle yalnızca bu çalışmaların tartışılması uygun görülmüştür.

Ünver Kiracı ve Şengül Çelikay (2020), çalışmalarında 2017-2018 dönemlerinde BIST imalat sanayi sektöründe işlem gören 178 işletmenin finansal bilgi manipülasyonu yapma durumlarını, Beneish TR modeli ile incelemiştir. Bu çalışmada ise aynı sektörde bulunan 205 işletme değerlendirilmiştir. Görüldüğü üzere bu çalışmada daha fazla işletme incelenmiştir. Bu çalışmada veri dönemi 2022-2023 olup bahsedilen çalışmaya göre oldukça güncel bir yapıdadır. Her iki çalışmada da Beneish TR modeli kullanılmıştır. Ayrıca bu çalışmada Multinominal logit ve probit analiz teknikleri de kullanılmıştır. Bahsedilen analizler kullanılarak, finansal bilgi manipülasyonu olasılığının belirlenmesinde gerekli olan marjinal etkiler ve işletmelerin finansal bilgi manipülasyonu sınıflandırma başarıları hesaplanarak, gerekli karşılaştırmalar yapılmıştır.

Gerçekleştirilen çalışmayla benzerliği olan diğer çalışma ise Peker (2023) tarafından yapılmıştır. Çalışmada, BIST imalat sanayi sektörü ile toptan ve perakende ticaret sektörü değerlendirilmiştir. Çalışmada 2020-2021 dönemi verileri ile Beneish TR modeli kullanılarak,151 işletme incelenmiştir. Bu çalışmada ise aynı yöntemle daha fazla sayıda işletme daha güncel verilerle değerlendirilmiştir.

3. Yöntem

Bu bölümde araştırmanın amacı, kapsamı, verisi ve değişkenleri, araştırma uygulamasında kullanılan yöntemler ile analiz ve bulgulara değinilmiştir.

3.1. Araştırmanın Amacı, Kapsamı ve Verisi

Çalışmanın amacı, BIST imalat sanayi sektöründe işlem gören işletmelerin finansal bilgi manipülasyonu yapma durumlarının tahmin edilmesidir. Bu amaç üzerine sektörde faaliyet gösteren 205 işletmenin, Kamuyu Aydınlatma Platformu (KAP, 2024) aracılığıyla 2022-2023 yıllarına ait finansal raporlarına ulaşılarak finansal bilgi manipülasyonu yapıp yapmadıkları, Beneish TR modeli kullanılarak belirlenmiştir. Model uygulamasıyla modelde bulunan birtakım endeksler hesaplanarak M_i ve Z_i değerleri ortaya konulmuştur. Ayrıca belirtilen modele ilave olarak çalışmada, Multinominal Logit ve Multinominal Probit analiz teknikleri kullanılmıştır. Multinominal Logit ve Multinominal Probit modellerinin kullanımı ile değişkenlerin finansal bilgi manipülasyonu olasılığının belirlenmesindeki marjinal etkilerinin ve modellerin finansal bilgi manipülasyonu sınıflandırma başarılarının hesaplanması amaçlanmıştır. Çalışma uygulaması yapıldığı tarihte, 2023 yılında 8 ve 2022 yılında 16 işletme özel durumları nedeniyle finansal tablolarını açıklamadığı için çalışma dışı bırakılmıştır.

3.2. Araştırmanın Yöntemi

Çalışmada Beneish TR, Multinominal Logit ve Multinominal Probit analiz modelleri kullanılmıştır. Bu bölümde kullanılan modeller ile ilgili bilgiler verilmiştir.

3.2.1. Beneish Türkiye (TR) Modeli

Beneish modeli, finansal tablo hesap kalemi tutarları aracılığıyla hesaplanan endeksler üzerinden Probit analiz tekniği kullanılması sonucunda finansal kazanç manipülasyonunun belirlenmesi amacıyla geliştirilen bir manipülasyon belirleme yöntemidir. Model, ihtiyari tahakkuklar üzerinden yapılan manipülasyonların belirlenmesinde kullanıldığı gibi kazanç manipülasyonlarının tahmin edilmesinde de kullanılmaktadır. Model aracılığıyla, değerlendirilen işletmelerin finansal bilgi manipülasyonu gerçekleştirme ihtimali ile bahsedilen işletmelerin finansal tablo hesapları arasında herhangi sistematik bir ilişkinin varlığına dair bulgular ortaya konulmaya çalışılmaktadır. Beneish modelinde, manipülasyona teşebbüs eden işletmeler ile kontrol işletmesi olarak tanımlanan işletmelerin, finansal tablolarında yer alan bilgiler esas alınarak Probit tekniğiyle değerlendirilmekte ve tüm değişkenler için katsayılar meydana getirilmektedir. Hesaplamalar sonucunda oluşturulan katsayılar, bir regresyon denklemi içerisine yerleştirilmektedir. Son olarak, ilgili finansal tablo hesapları kullanılarak oluşturulan endeksler modele aktarılmakta ve işletmelerin finansal manipülasyona başvurma olasılıklarını gösteren M_i değerleri elde edilmektedir (Güner ve Kurnaz, 2020: 202).

Beneish TR modeli, orijinal Benesih modeli üzerine Küçüksözen ve Küçükkocaoğlu (2004) tarafından geliştirilerek literatüre kazandırılmıştır. Yazar tarafından geliştirilen model, Beneish modelinin Türkiye'ye uyarlanması biçimindedir. Bahsedilen uyarlama, orijinal modele farklı iki değişkenin eklenmesi ve bir değişkenin modelden çıkarılması yoluyla yapılmıştır. Türkiye özelinde geliştirilen bu yeni model, satışların ve finansman giderlerinin brüt satışlara oranlanması şeklinde elde edilen iki değişkenin orijinal modele ilave edilmesi ile satışlardaki büyüme endeksinin modelden çıkarılması sonucunda oluşturulmuştur. Satışlardaki büyüme endeksinin, yüksek enflasyon yaşanan ekonomilerde manipülasyon tahmininde yanıltıcı sonuçlar meydana getireceği düşüncesi ile modelden çıkarıldığı belirtilmektedir. Beneish TR modeli aşağıda gösterilmiştir (Küçüksözen ve Küçükkocaoğlu, 2004: 48; Peker, 2023: 328).

$$M_i = -1.547 + (1.276 * TAE) + (-1.770 - BKM) + (0.082 * AKE) + (0.225 * AME) + (-0.488 * PSE) + (-0.514 * TVE) + (-0.341 * BYE) + (0.972 * SSE) + (0.060 * FSE) \quad (1)$$

Beneish TR modelinde yer alan değişkenler Tablo 2'de gösterilmiştir (Beneish, 1999: 27; Küçüksözen ve Küçükkocaoğlu, 2004: 39-42; Güner ve Kurnaz, 2020: 203; Erol Fidan, 2021: 5; Peker, 2023: 328; Soykan vd., 2023: 26).

Tablo 2. Beneish TR Modeli Değişkenler ve Formüller

Değişken	Formüller
Ticari Alacaklar Endeksi (TAE)	$\frac{\text{Ticari Alacaklar}_t/\text{Brüt Satışlar}_t}{\text{Ticari Alacaklar}_{t-1}/\text{Brüt Satışlar}_{t-1}}$
Brüt Kâr Marjı Endeksi (BKM)	$\frac{(\text{Brüt Satışlar}_{t-1}-\text{Satılan Mal Maliyeti}_{t-1})/\text{Brüt Satışlar}_{t-1}}{(\text{Brüt Satışlar}_t-\text{Satılan Mal Maliyeti}_t)/\text{Brüt Satışlar}_t}$
Aktif Kalitesi Endeksi (AKE)	$\frac{(1-\text{Dönen Varlıklar}_t+\text{Maddi Duran Varlıklar}_t)/\text{Toplam Varlıklar}_t}{(1-\text{Dönen Varlıklar}_{t-1}+\text{Maddi Duran Varlıklar}_{t-1})/\text{Toplam Varlıklar}_{t-1}}$
Amortisman Endeksi (AME)	$\frac{\Delta\text{Amortismanlar}_{t-1}/(\Delta\text{Amortismanlar}_{t-1}+\text{Maddi Duran Varlıklar}_{t-1})}{\Delta\text{Amortismanlar}_t/(\Delta\text{Amortismanlar}_t+\text{Maddi Duran Varlıklar}_t)}$
Pazarlama, Satış, Dağıtım ve Genel Yönetim Giderleri Endeksi (PSE)	$\frac{(\text{Pazarlama,Satış ve Dağıtım Giderleri}_t+\text{Genel Yönetim Giderleri}_t)/\text{Brüt Satışlar}_t}{(\text{Pazarlama,Satış ve Dağıtım Giderleri}_{t-1}+\text{Genel Yönetim Giderleri}_{t-1})/\text{Brüt Satışlar}_{t-1}}$
Borç Yapısındaki Değişim Endeksi (BYE)	$\frac{(\text{Uzun Vadeli Borçlar}_t+\text{Kısa Vadeli Borçlar}_t)/\text{Toplam Varlıklar}_t}{(\text{Uzun Vadeli Borçlar}_{t-1}+\text{Kısa Vadeli Borçlar}_{t-1})/\text{Toplam Varlıklar}_{t-1}}$
Toplam Tahakkukların Toplam Varlıklara Oranı Endeksi (TVE)	$\frac{\begin{array}{c}\Delta\text{Dönen Varlıklar}_t-\Delta\text{Hazır Değerler}_t-(\Delta\text{Kısa Vadeli Borçlar}_t-\\ \Delta\text{Uzun Vadeli Borçların Kısa Vadeli Kısımları}_t-\\ \Delta\text{Ödenecek Vergi ve Diğer Yasal Yükümlülükler Karşılığı}_t)-\\ \Delta\text{Amortismanlar}_t\end{array}}{\text{Toplam Varlıklar}_t}$
Stokların Brüt Satışlara Oranı Endeksi (SSE)	$\frac{\text{Stoklar}_t/\text{Brüt Satışlar}_t}{\text{Stoklar}_{t-1}/\text{Brüt Satışlar}_{t-1}}$
Finansman Giderlerinin Brüt Satışlara Oranı Endeksi (FSE)	$\frac{\text{Finansman Giderleri}_t/\text{Brüt Satışlar}_t}{\text{Finansman Giderleri}_{t-1}/\text{Brüt Satışlar}_{t-1}}$

İşletmeler tarafından gerçekleştirilen finansal bilgi manipülasyonunun normal dağılım gösterme olasılığını inceleyebilmek maksadıyla, model aracılığıyla oluşturulan M_i değerlerinin standartlaştırılarak normalize edilmesi neticesinde elde edilen Z_i değerleri kullanılmaktadır. Bahsi geçen Z_i değerlerinin hesaplanması amacıyla kullanılan formül aşağıdaki gibidir (Erol Fidan, 2021: 7).

$$Zi = \frac{Xi-\mu}{\sigma} \quad (2)$$

Eşitlik 2 denkleminin açıklayıcıları; $Zi = i'$inci değişkenin Z değeri, $Xi = i'$inci değişkenin değeri $\mu =$ Ortalama ve $\sigma =$ Standart sapma olarak açıklanabilir. Belirtilen formül aracılığıyla hesaplaması yapılan Z_i değerlerinin yorumlanması ve incelenen işletmeler tarafından finansal bilgi manipülasyonuna başvurulması durumu Tablo 3'e göre değerlendirilmektedir (Soykan vd., 2023: 26).

Tablo 3. Zi Değerinin Yorumlanması

Zi Değeri	Sonuç
$Zi < 0.15$	Manipülasyona başvurulduğuna ilişkin bir kanıt bulunmadığı, (1. Bölge)
$0.15 < Zi < 0.35$	Manipülasyon yapma olasılığının bulunduğu, (2. Bölge)
$0.35 < Zi < 0.82$	Manipülasyona ilişkin ciddi kanıtlar bulunduğu, (3. Bölge)
$0.82 < Zi$	Manipülasyona ilişkin çok önemli kanıtlar bulunduğu, (4. Bölge)

3.2.2. Multinominal Logit Modeli

Multinominal lojistik regresyon analizi, modelde yer alan bağımlı değişkenin ikili, üçlü ve çoklu yapılarda bulunduğu durumlarda, ilişkide olduğu açıklayıcı değişkenlerle arasındaki neden

sonuç birlikteliğini ortaya koyabilmek amacıyla başvurulan bir analiz tekniğidir (Özdamar, 2015: 475). Modelde bulunan bağımlı değişkenin ikiden çok sayıda olması halinde, çoklu lojistik regresyon modellerine başvurulmaktadır. Bahsedilen modelin kullanılması ile fazla sayıda parametreyle yapılan hesaplamalarda ve elde edilecek sonuçların karmaşık olduğu durumlarda analizciye oldukça kolaylık sağlanmaktadır (Long ve Freese, 2001: 174). Çoklu bağımlı değişkenin bulunduğu modellerde esas amaç, yapıların odds oranlarını ortak olan değişkenlerin birer fonksiyonu biçiminde modellemek ve elde edilecek sonuçları farklı yapıların ya da durumların tercihleri üzerinde bahis değerleri yönünden ortaya koyabilmektir (Hosmer ve Lemeshow, 2000: 260).

Değişkenlerin en düşük aralıklı ölçek kullanılarak ölçüldüğü kabul edilerek ve model bağımsız değişkenlerinin $x_1, x_2, x_3, \ldots . x_p$ biçiminde gösterildiği ve p sayıda bağımsız değişken olarak belirlendiğinde, var olan çıktı değerlerinin şartlı olasılığı $P(Y = 1 \mid x) = \pi(x)$ şeklinde gösterildiğinde, modelin Multinominal Logit değeri aşağıda gösterildiği gibidir.

$$g(x) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_p X_p \tag{3}$$

Bu eşitliğin Multinominal Logit modeli;

$$\pi(x) = \frac{e^{g(x)}}{1+e^{g(x)}} \tag{4}$$

Biçiminde gösterildiği gibi kullanılmaktadır. Belirtilen bağımsız değişkenlerin birkaç tanesinin kesikli değer olduğu görüldüğünde, bahsi geçen değişkenlerin modelde kullanılmaması ve aralıklı ölçekler ile belirtilmesi gerekmektedir. Bu tip bir yapı ile karşılaşıldığında kullanılması gerekli olan yöntem, sınıflama ölçeği aracılığıyla ölçülen bağımsız değişkenlerin gölge değişken şeklinde gösterilmesidir. Sınıflama ölçeği kullanılarak ölçülmüş bir değişken için k sayıda olası durum olduğunda, modelin sabit terime sahip olduğu süre boyunca, $k-1$ sayıda gölge değişken belirlenmelidir. Herhangi bir $x_j$değişkeni k_j sayıda olası değere sahip j'inci bağımsız değişken olmak koşuluyla, bahsedilen değişken için katsayılar β_{j1} olan ve D_{j1} biçiminde gösterilen k_{j-1} sayıda gölge değişken ortaya konulmalıdır ($\mathrm{I} = 1, 2, \ldots , k_{j-1}$). Bu şekilde j'inci bağımsız değişkeni kesikli değere sahip olan p değişkeni için Multinominal Logit modeli şöyledir (Hosmer ve Lemeshow, 2000: 31-33).

$$g(x) = \beta_0 + \beta_1 X_1 + \cdots + \sum_{l=1}^{k_j-1} \beta_{jl} D_{jl} + \beta_p X_p \tag{5}$$

Y çıktı değişkeninin kategorileri 0, 1, 2 ve 3 şeklinde kodlanarak, elde edilecek Multinominal Logit model aracılığıyla Y=0 üzerinden Y=1, Y=2 ve Y=3 için denklemler oluşturulmalıdır. 4 kategorili bir çıktı elde etmek için 3 Multinominal Logit fonksiyon meydana gelmektedir. Hangi çıktı kategorisinin karşılaştırılmak istendiğinin belirlenmesi gerekmektedir. Y=0 referans kategorisi seçerek, Y=1, Y=2 ve Y=3 için Multinominal Logit denklemler şöyledir (Hosmer ve Lemeshow, 2000: 261-262).

$$\begin{aligned} g_1(x) &= ln\left[\frac{P(Y=1|x)}{P(Y=0|x)}\right] \\ &= \beta_{10} + \beta_{11}x_1 + \beta_{12}x_2 + \cdots + \beta_{1p}x_p = x'\beta_1 \end{aligned} \tag{6}$$

$$\begin{aligned} g_2(x) &= ln\left[\frac{P(Y=2|x)}{P(Y=0|x)}\right] \\ &= \beta_{20} + \beta_{21}x_1 + \beta_{22}x_2 + \cdots + \beta_{2p}x_p \\ &= x'\beta_2 \end{aligned} \tag{7}$$

$$g_3(x) = ln\left[\frac{P(Y=3|x)}{P(Y=0|x)}\right] = \beta_{30} + \beta_{31}x_1 + \beta_{32}x_2 + \cdots + \beta_{3p}x_p = x'\beta_3 \quad (8)$$

Çıktı kategorilerinin şartlı olasılıkları aşağıdaki gibidir.

$$P(Y=0 \mid x) = \frac{1}{1 + e^{g_1(x)} + e^{g_2(x)} + e^{g_3(x)}} \quad (9)$$

$$P(Y=1 \mid x) = \frac{e^{g_1(x)}}{1 + e^{g_1(x)} + e^{g_2(x)} + e^{g_3(x)}} \quad (10)$$

$$P(Y=2 \mid x) = \frac{e^{g_2(x)}}{1 + e^{g_1(x)} + e^{g_2(x)} + e^{g_3(x)}} \quad (11)$$

$$P(Y=3 \mid x) = \frac{e^{g_3(x)}}{1 + e^{g_1(x)} + e^{g_2(x)} + e^{g_3(x)}} \quad (12)$$

3.2.3. Multinominal Probit Modeli

Bağımlı ve bağımsız değişkenlerin bulunduğu ilişki durumlarında, bağımlı değişken nitel bir yapı özelliği gösteriyorsa, gerekli seçimin yapılabilmesi için kesikli seçim modelleri tercih edilmelidir (Alpar, 2013: 703; Yakut, 2020: 3285). Bahsi geçen ilişki içerisinde bağımlı değişkenin ikiden fazla kategorisi bulunuyorsa Multinominal Logit ya da Multinominal Probit modelinin kullanılması uygun görülmektedir. Multinominal Probit modelinde, kategoriler için odds'lerin diğer kategorilerden farklı olmasını zorunlu kılan herhangi bir varsayım bulunmadığından, kesikli seçim modelleri için bahsedilen yöntem kolaylıkla uygulanabilmektedir (Greene, 2003: 724; Sigeze, 2017: 442). Yine Multinominal Probit modelinde hata terimleri normal dağılım gösterdiğinde birbirleri arasında korelasyon sağlanabilmektedir (Sigeze, 2017: 446; Alkan ve Yarbaşı, 2020: 141).

Multinominal Probit modeli, rassal fayda teorisi üzerine geliştirilmiş olan bir nitel tercih modelidir. Modelin temelinde faydanın maksimize edilmesi bulunmaktadır. Model üzerinde *m* seçim durumundan *j*. seçimin faydası aşağıdaki biçimde gösterilebilmektedir.

$$U_j = V_j + \varepsilon_j, \qquad J = 1, \ldots, m \quad (13)$$

Multinominal Probit modelinin seçim olasılıkları ise aşağıdaki gibi hesaplanabilmektedir.

$$P_n(i) = P\left(\varepsilon_{j,n} - \varepsilon_{i,n} < V_{i,n} - V_{j,n}, \forall j \neq i\right) = \int_{\varepsilon_n} I\left(\varepsilon_{j,n} - \varepsilon_{i,n} < V_{i,n} - V_{j,n}, \forall j \neq i\right) \emptyset(\varepsilon_n) d\varepsilon_n \quad (14)$$

Multinominal Probit modelinde seçim olasılıkları elde edilirken *I* boyutuna sahip integral hesaplanır. İntegral hesaplaması gerçekleştirilirken simülasyonlar aracılığı ile yaklaştırma işlemi yapılmaktadır. Bu doğrultuda Multinominal Probit modeli, en yüksek simülasyon işlemleri ile en fazla benzerlik tahmincisi uygulanarak elde edilmektedir (Cihangir vd., 2016: 136).

Multinominal Probit modellerinin sağlamış olduğu en önemli avantaj alternatifler arasında ilişki bulunmasını reddetmemesidir. Bahsi geçen modeller tahmin edilirken en fazla benzerlik yöntemine başvurulmaktadır. Bu yöntemin yanı sıra Monte Carlo yöntemi ve Faktör Analizi yaklaşımı da kullanılabilmektedir (Çağlayan ve Astar, 2011: 76).

3.3. Araştırmanın Analizi ve Bulguları

Çalışmanın bu kısmında 2022-2023 dönemleri için BIST imalat sanayi sektöründe işlem gören işletmelerin finansal bilgi manipülasyonu yapıp yapmadıklarının belirlenmesi amacıyla Beneish TR modeli, tanımlayıcı istatistikler, normallik testi, korelasyon analizi ile değişkenlerin finansal bilgi manipülasyonu olasılığının belirlenmesinde gerekli olan marjinal etkilerinin ve modellerin finansal bilgi manipülasyonu sınıflandırma başarılarının hesaplanması amacıyla Multinominal Logit ve Multinominal Probit modelleri analiz ve sonuçlarına yer verilmiştir.

3.3.1. Beneish TR Modeli Analizi ve Bulguları

2022-2023 yıllarına ait BIST imalat sanayi sektöründe işlem gören işletmeler, finansal bilgi manipülasyonu yapma durumlarının belirlenmesi amacıyla analiz edilerek bu kısımda gösterilmiştir. Sektörde işlem gören işletmelerden; 2023 yılında 8 işletmenin ve 2022 yılında 16 işletmenin finansal verilerine ulaşılamadığı için bu işletmeler analiz dışı bırakılmıştır. Geriye kalan işletmelerden; 2023 yılında 20 işletme ve 2022 yılında 16 işletme uç skorlara sahip olduğu için analize dahil edilmemiştir. Kalan işletmeler üzerinde Beneish TR modeli uygulanarak gerekli hesaplamalar yapılmıştır. Değerlendirilen işletmelerin 2023 yılına ait analiz sonuçları aşağıdaki gibidir. İşletmelerin 2023 yılı tanımlayıcı istatistiki bilgileri Tablo 4'te gösterilmiştir.

Tablo 4. İmalat Sanayi Sektörü 2023 Yılı Tanımlayıcı İstatistiki Bilgiler

M_i		İstatistik	Standart Hata
Ortalama		-1.1111	0.08017
Ortalama için %95 Güven Aralığı	Alt Sınır	-1.2692	
	Üst Sınır	-0.9531	
%5 Kesilmiş Ortalama		-1.1165	
Medyan		-1.0800	
Varyans		1.317	
Standart Sapma		1.14781	
En Düşük		-3.84	
En Yüksek		2.05	
Aralık		5.89	
Çeyrekler Arası Aralık		1.38	
Çarpıklık		0.081	0.170
Basıklık		0.146	0.338

Tablo 4 incelendiğinde analizi yapılan işletmelerin M_i değeri ortalamasının -1,1111 olduğu ve standart sapmasının ise 1,14781 olduğu belirlenmiştir. Bahsedilen M_i değeri ortalaması ve standart sapması Z_i değerinin hesaplanmasında kullanılmaktadır. Beneish TR modeline göre Z_i değerlerinin hesaplanabilmesi için değerlendirilen işletmelere ait veriler üzerinden belirlenen M_i değerlerinin normal dağılım göstermesi gerekmektedir. Bu doğrultuda Tablo 4'te gösterilen çarpıklık ve basıklık değerleri dikkate alınmaktadır. Literatürde çarpıklık ve basıklık değerlerinin

-2.00 ile +2.00 arasında olduğu durumda verilerin normal dağıldığı belirtilmektedir (Akay vd., 2023: 74). Tablo 4'te belirtilen çarpıklık değeri 0.081 ve basıklık değeri 0.146 olarak belirlenmiş ve verilerin normal dağılım gösterdiği anlaşılmıştır. Ancak normal dağılımın belirlenmesinde çarpıklık ve basıklık değerlerinin yanı sıra normallik testi de yapılması gerekmektedir. Bu doğrultuda Tablo 5'te normallik testi sonuçlarına yer verilmiştir. Kolmogorov-Smirnov ve Shapiro-Wilk normallik testine göre Sig. değerlerinin 0,05'den büyük çıkması durumunda verilerin normal dağıldığı kabul edilmektedir. Buradan hareketle Tablo 5 incelendiğinde Sig. değerlerinin 0,05'den büyük olduğu görülmüş olup verilerin normal dağıldığı sonucuna varılmıştır. Verilerin normal dağılması sonucu Beneish TR modeli kullanılarak ulaşılan M_i değerleri, standart normal dağılıma çevrilerek Z_i değerleri elde edilecektir.

Tablo 5. Normallik Testi

	Kolmogorov-Smirnov			Shapiro-Wilk		
	İstatistik	**df**	**Sig.**	**İstatistik**	**df**	**Sig.**
M_i	0.047	205	0.200	0.992	205	0.277

Değerlendirilen BIST imalat sanayi sektörü işletmelerinin finansal bilgi manipülasyonuna başvurup başvurmadıklarının belirlenmesi amacıyla hesaplanan Z_i değerleri ve manipülasyona başvurma durumları Tablo 6'da gösterilmiştir.

Tablo 6. İmalat Sanayi İşletmelerinin Z_i Değerleri ve Manipülasyon Yorumları

	TAE	BKM	AKE	AME	PSE	TVE	BYE	SSE	FSE	Mi	Zi	Bölge	Manipülasyon Yorumu
1	1.34	1.24	-0.46	2.93	1.48	0.02	1.19	1.16	5.52	**-1.09**	**0.02**	**1**	Bulgu yok
2	2.04	0.68	1.73	0.95	1.15	-0.08	0.91	1.03	0.78	**0.43**	**1.34**	**4**	Çok önemli bulgular var
3	1.40	0.94	1.14	1.28	1.04	-0.09	1.03	1.18	1.17	**-0.62**	**0.43**	**3**	Ciddi bulgular var
4	1.13	0.77	0.86	1.05	1.87	0.02	0.53	1.33	0.41	**-0.95**	**0.14**	**1**	Bulgu yok
5	1.19	0.45	1.20	1.11	1.40	-0.05	0.76	0.94	0.94	**-0.43**	**0.59**	**3**	Ciddi bulgular var
6	0.67	0.99	2.45	1.09	1.30	-0.03	0.90	1.40	1.22	**-1.48**	**-0.32**	**1**	Bulgu yok
7	1.43	0.93	0.75	1.81	1.08	0.15	1.25	1.05	1.60	**-0.82**	**0.25**	**2**	Yapma olasılığı var
8	0.32	1.24	0.75	1.62	2.12	0.17	1.05	0.96	0.75	**-3.42**	**-2.01**	**1**	Bulgu yok
9	0.42	1.28	0.71	1.22	1.35	0.18	0.87	1.23	1.14	**-2.72**	**-1.40**	**1**	Bulgu yok
10	1.26	1.01	1.35	0.98	1.13	0.02	1.03	2.04	1.16	**-0.26**	**0.75**	**3**	Ciddi bulgular var
11	2.94	0.86	0.71	0.59	0.83	0.29	0.88	0.48	0.72	**0.53**	**1.43**	**4**	Çok önemli bulgular var
12	0.52	1.07	0.53	1.13	2.49	0.24	1.07	1.74	2.03	**-2.38**	**-1.10**	**1**	Bulgu yok
13	1.37	0.91	1.04	1.06	1.05	-0.07	1.03	1.07	1.34	**-0.80**	**0.27**	**2**	Yapma olasılığı var
14	0.03	-1.45	-0.66	1.05	6.85	0.05	1.02	0.02	3.73	**-2.23**	**-0.98**	**1**	Bulgu yok
15	2.10	0.16	0.86	2.01	0.92	0.36	0.94	0.37	0.88	**0.84**	**1.70**	**4**	Çok önemli bulgular var
16	1.98	0.79	1.01	0.65	1.15	0.26	0.80	0.66	0.55	**-0.48**	**0.55**	**3**	Ciddi bulgular var
17	2.50	0.66	1.14	1.15	1.17	-0.07	0.99	1.19	1.23	**1.19**	**2.01**	**4**	Çok önemli bulgular var
18	1.00	1.08	5.54	1.06	2.29	0.13	0.53	1.17	1.61	**-1.61**	**-0.44**	**1**	Bulgu yok
19	1.05	0.03	2.58	1.26	1.07	-0.02	0.91	0.71	1.59	**0.19**	**1.14**	**4**	Çok önemli bulgular var
20	0.84	0.76	1.08	1.00	1.01	0.16	1.33	1.41	1.83	**-1.05**	**0.05**	**1**	Bulgu yok
21	1.11	1.00	1.30	0.71	1.37	0.04	1.15	0.96	0.99	**-1.72**	**-0.53**	**1**	Bulgu yok
22	1.04	0.72	0.73	1.37	1.30	-0.04	0.64	0.65	1.18	**-1.26**	**-0.13**	**1**	Bulgu yok
23	0.05	-0.90	1.80	1.06	3.33	-0.06	1.13	1.42	2.11	**0.03**	**1.00**	**4**	Çok önemli bulgular var
24	0.81	0.48	-0.43	1.35	1.26	0.15	0.84	1.09	2.24	**-0.88**	**0.21**	**2**	Yapma olasılığı var
25	1.21	0.10	1.25	1.24	0.76	-0.01	0.27	0.43	17.40	**1.20**	**2.01**	**4**	Çok önemli bulgular var

Tablo 6. Devamı

26	1.43	0.65	0.95	0.75	0.98	-0.14	0.89	0.79	1.32	**-0.49**	**0.54**	**3**	Ciddi bulgular var
27	0.62	1.13	-0.32	1.81	1.67	0.06	1.38	0.94	1.47	**-2.68**	**-1.37**	**1**	Bulgu yok
28	1.61	1.22	0.43	1.15	1.39	-0.05	1.07	0.95	1.09	**-1.39**	**-0.24**	**1**	Bulgu yok
29	0.71	1.28	1.14	1.10	1.65	0.36	0.60	1.93	1.70	**-1.78**	**-0.58**	**1**	Bulgu yok
30	0.35	0.85	0.51	0.95	2.59	0.11	1.16	3.51	2.60	**-0.50**	**0.53**	**3**	Ciddi bulgular var
31	2.56	0.83	-8.87	1.19	1.11	-0.04	0.90	0.98	2.63	**0.08**	**1.04**	**4**	Çok önemli bulgular var
32	1.66	1.23	-1.31	1.15	1.03	0.08	1.00	1.03	1.72	**-1.23**	**-0.10**	**1**	Bulgu yok
33	1.13	1.05	1.06	0.28	1.32	0.15	0.84	0.53	2.95	**-2.13**	**-0.89**	**1**	Bulgu yok
34	1.28	0.72	0.82	1.37	0.91	-0.08	1.00	0.69	5.25	**-0.58**	**0.46**	**3**	Ciddi bulgular var
35	1.44	1.52	0.86	1.40	1.11	0.46	0.42	0.70	1.87	**-2.13**	**-0.89**	**1**	Bulgu yok
36	1.37	0.69	3.29	0.96	1.20	0.09	0.69	0.99	1.01	**-0.37**	**0.64**	**3**	Ciddi bulgular var
37	1.11	0.90	1.76	1.12	1.14	-0.01	0.99	0.94	1.93	**-1.19**	**-0.07**	**1**	Bulgu yok
38	0.74	0.66	-15.67	0.00	0.35	0.01	0.62	0.41	0.04	**-3.04**	**-1.68**	**1**	Bulgu yok
39	1.04	0.71	-2.21	1.12	1.01	0.13	0.52	0.85	0.31	**-1.30**	**-0.16**	**1**	Bulgu yok
40	2.35	0.84	4.18	0.95	1.00	0.06	0.97	1.33	0.80	**1.02**	**1.85**	**4**	Çok önemli bulgular var
41	1.77	-0.28	1.01	1.20	1.72	-0.10	0.81	1.07	1.21	**1.61**	**2.37**	**4**	Çok önemli bulgular var
42	1.40	0.60	0.92	0.94	1.28	0.02	0.72	0.79	1.19	**-0.57**	**0.47**	**3**	Ciddi bulgular var
43	0.86	1.00	-0.91	1.33	1.26	0.19	0.70	0.91	0.98	**-2.00**	**-0.77**	**1**	Bulgu yok
44	1.83	1.10	0.61	0.91	1.00	-0.05	1.14	0.92	0.92	**-0.80**	**0.27**	**2**	Yapma olasılığı var
45	1.09	0.75	0.58	1.26	1.50	0.08	0.75	1.07	1.60	**-1.04**	**0.06**	**1**	Bulgu yok
46	1.79	0.94	0.99	1.27	1.06	-0.08	1.06	1.23	1.32	**-0.11**	**0.87**	**4**	Çok önemli bulgular var
47	0.42	0.99	-0.23	1.86	1.13	-0.38	0.97	1.14	2.43	**-1.81**	**-0.61**	**1**	Bulgu yok
48	1.08	2.03	-0.31	0.82	1.17	0.04	1.71	1.12	0.51	**-3.65**	**-2.21**	**1**	Bulgu yok
49	0.82	1.26	0.96	1.04	1.26	0.38	0.82	1.03	0.80	**-2.46**	**-1.17**	**1**	Bulgu yok
50	0.94	0.77	-2.25	1.20	1.22	-0.08	0.89	1.20	2.01	**-1.20**	**-0.08**	**1**	Bulgu yok
51	1.80	1.22	1.06	0.91	0.97	-0.20	0.95	1.77	0.77	**-0.05**	**0.93**	**4**	Çok önemli bulgular var
52	1.60	0.41	-0.79	1.02	1.03	0.01	0.83	0.98	0.41	**0.12**	**1.07**	**4**	Çok önemli bulgular var
53	1.90	1.01	1.47	0.87	1.07	0.10	0.98	1.09	1.34	**-0.36**	**0.66**	**3**	Ciddi bulgular var
54	1.66	0.98	0.98	0.82	1.03	0.09	0.99	0.79	0.55	**-0.98**	**0.11**	**1**	Bulgu yok
55	0.75	0.87	1.00	1.11	1.29	0.00	0.71	1.12	1.15	**-1.51**	**-0.35**	**1**	Bulgu yok
56	1.75	0.95	0.96	1.30	0.93	-0.04	0.94	0.93	0.72	**-0.43**	**0.59**	**3**	Ciddi bulgular var
57	0.28	0.25	0.93	7.67	1.57	0.06	0.46	0.00	0.00	**-0.78**	**0.29**	**2**	Yapma olasılığı var
58	1.03	1.28	1.81	0.95	1.47	0.09	1.00	1.37	1.24	**-1.85**	**-0.64**	**1**	Bulgu yok
59	1.74	1.35	1.40	1.05	2.14	0.08	0.63	1.58	1.97	**-1.02**	**0.08**	**1**	Bulgu yok
60	1.88	0.67	1.56	1.09	0.96	0.01	0.89	1.01	1.15	**0.33**	**1.25**	**4**	Çok önemli bulgular var
61	0.95	1.99	0.66	1.19	0.82	0.12	0.81	0.92	1.17	**-3.32**	**-1.92**	**1**	Bulgu yok
62	1.43	0.94	0.71	1.04	1.14	-0.05	1.06	0.90	3.68	**-0.88**	**0.20**	**2**	Yapma olasılığı var
63	0.69	0.92	0.42	3.29	1.20	0.14	0.94	1.07	2.42	**-1.32**	**-0.18**	**1**	Bulgu yok
64	1.12	0.94	0.88	1.07	1.34	0.00	0.83	1.13	0.63	**-1.27**	**-0.14**	**1**	Bulgu yok
65	1.01	0.70	0.57	1.33	1.15	0.02	0.94	1.07	0.80	**-0.96**	**0.13**	**1**	Bulgu yok
66	0.63	1.07	0.91	1.13	1.69	0.32	0.63	2.09	0.75	**-1.44**	**-0.29**	**1**	Bulgu yok
67	1.50	0.91	0.97	1.60	1.32	0.21	0.61	1.27	1.25	**-0.44**	**0.58**	**3**	Ciddi bulgular var
68	1.09	0.76	1.02	0.90	1.18	0.29	0.59	1.27	0.89	**-0.87**	**0.21**	**2**	Yapma olasılığı var
69	0.99	1.22	1.94	0.02	0.82	0.32	1.10	1.38	0.43	**-1.85**	**-0.64**	**1**	Bulgu yok
70	2.45	0.84	0.40	1.62	1.20	0.40	0.61	1.20	2.54	**0.80**	**1.66**	**4**	Çok önemli bulgular var
71	1.58	1.69	0.42	3.86	1.30	0.21	0.74	3.35	1.18	**0.71**	**1.58**	**4**	Çok önemli bulgular var
72	0.71	0.70	1.67	1.27	1.11	0.04	0.76	1.00	0.48	**-1.28**	**-0.14**	**1**	Bulgu yok
73	3.01	0.97	1.75	1.04	1.04	0.10	1.08	0.98	1.03	**1.05**	**1.88**	**4**	Çok önemli bulgular var
74	2.17	0.25	1.13	0.27	1.83	0.05	0.80	1.04	1.19	**0.82**	**1.69**	**4**	Çok önemli bulgular var
75	2.25	0.98	1.09	1.21	0.97	0.38	0.67	2.88	1.31	**1.93**	**2.65**	**4**	Çok önemli bulgular var
76	1.11	1.05	-0.50	1.83	1.31	0.21	0.90	1.15	1.00	**-1.49**	**-0.33**	**1**	Bulgu yok
77	2.05	1.56	-1.47	0.79	0.87	0.04	0.89	0.37	1.20	**-1.94**	**-0.72**	**1**	Bulgu yok
78	0.94	1.48	-4.71	1.06	1.23	0.07	0.74	1.32	0.83	**-2.66**	**-1.35**	**1**	Bulgu yok
79	1.08	0.73	0.09	1.19	1.67	0.21	0.75	1.93	0.76	**-0.44**	**0.59**	**3**	Ciddi bulgular var
80	0.55	1.11	0.87	1.25	1.21	0.30	1.01	0.97	1.02	**-2.53**	**-1.24**	**1**	Bulgu yok
81	1.58	0.84	0.85	1.55	1.16	0.01	0.94	1.13	1.09	**-0.33**	**0.68**	**3**	Ciddi bulgular var
82	1.34	0.87	1.29	1.04	1.40	0.24	1.06	1.08	0.30	**-1.13**	**-0.02**	**1**	Bulgu yok

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83	1.78	0.52	0.80	1.35	1.26	0.20	0.89	1.03	1.13	**0.21**	**1.15**	**4**	Çok önemli bulgular var
84	1.17	1.40	0.83	1.14	1.09	0.15	1.02	0.94	0.75	**-2.20**	**-0.95**	**1**	Bulgu yok
85	1.25	0.79	1.64	0.20	1.75	0.29	0.43	1.22	0.99	**-1.08**	**0.03**	**1**	Bulgu yok
86	1.01	1.16	0.84	1.10	0.69	0.29	0.67	1.05	0.61	**-1.66**	**-0.48**	**1**	Bulgu yok
87	1.02	0.81	1.81	1.44	1.18	0.05	0.56	0.89	0.93	**-1.09**	**0.02**	**1**	Bulgu yok
88	1.16	1.09	0.82	1.00	0.79	-0.04	1.00	0.70	1.04	**-1.67**	**-0.49**	**1**	Bulgu yok
89	1.29	1.32	0.14	0.92	1.47	-0.09	0.80	0.70	1.39	**-2.19**	**-0.94**	**1**	Bulgu yok
90	0.35	1.27	7.89	2.65	1.95	-0.04	1.06	1.34	1.30	**-2.01**	**-0.78**	**1**	Bulgu yok
91	0.33	1.45	0.98	0.60	2.57	-0.23	1.10	1.41	3.09	**-3.44**	**-2.03**	**1**	Bulgu yok
92	1.53	1.12	0.94	0.89	1.02	0.02	1.19	1.00	1.18	**-1.18**	**-0.06**	**1**	Bulgu yok
93	0.74	0.34	0.91	0.98	1.57	0.35	1.23	1.19	1.36	**-1.03**	**0.07**	**1**	Bulgu yok
94	2.59	0.74	-4.51	0.36	0.93	0.17	1.39	0.97	0.97	**0.15**	**1.10**	**4**	Çok önemli bulgular var
95	1.87	2.14	0.77	0.93	1.62	0.06	1.19	1.14	1.10	**-2.75**	**-1.42**	**1**	Bulgu yok
96	1.15	0.46	1.54	1.15	1.40	0.05	1.18	1.16	1.86	**-0.39**	**0.63**	**3**	Ciddi bulgular var
97	0.63	0.83	-0.44	1.04	1.47	0.15	0.69	1.24	0.99	**-1.79**	**-0.59**	**1**	Bulgu yok
98	1.16	1.07	0.62	1.69	1.16	0.32	1.10	0.61	0.51	**-2.02**	**-0.79**	**1**	Bulgu yok
99	0.55	2.42	4.11	1.98	1.70	-0.11	0.75	1.56	1.79	**-3.76**	**-2.31**	**1**	Bulgu yok
100	1.11	1.14	-1.31	1.60	0.89	0.02	0.86	0.62	0.77	**-1.99**	**-0.76**	**1**	Bulgu yok
101	0.65	1.33	-8.46	1.15	1.44	-0.05	0.92	0.92	2.50	**-3.45**	**-2.04**	**1**	Bulgu yok
102	1.42	0.77	1.20	1.46	0.95	-0.06	0.95	0.68	1.11	**-0.70**	**0.36**	**3**	Ciddi bulgular var
103	0.92	1.25	1.01	0.65	0.80	0.64	0.82	1.16	1.30	**-2.17**	**-0.92**	**1**	Bulgu yok
104	0.62	0.90	0.45	1.19	0.91	0.11	0.79	1.73	0.83	**-1.08**	**0.03**	**1**	Bulgu yok
105	1.12	0.89	0.62	1.09	1.02	0.04	0.79	0.80	0.89	**-1.36**	**-0.22**	**1**	Bulgu yok
106	0.82	0.80	0.57	1.24	1.45	0.10	0.95	1.50	2.41	**-1.08**	**0.03**	**1**	Bulgu yok
107	1.37	0.82	0.77	1.40	1.22	0.01	1.06	0.86	2.57	**-0.84**	**0.24**	**2**	Yapma olasılığı var
108	4.05	1.05	0.72	1.15	1.43	0.05	1.00	1.01	0.79	**2.05**	**2.76**	**4**	Çok önemli bulgular var
109	0.84	1.27	1.04	1.25	1.40	0.09	0.69	1.44	2.06	**-1.78**	**-0.59**	**1**	Bulgu yok
110	1.61	0.92	1.05	0.90	1.03	0.00	1.04	1.04	0.62	**-0.64**	**0.41**	**3**	Ciddi bulgular var
111	1.57	0.86	0.96	1.36	1.20	0.09	1.03	0.84	1.04	**-0.79**	**0.28**	**2**	Yapma olasılığı var
112	0.98	0.89	0.92	0.87	1.07	0.18	0.87	0.95	1.34	**-1.52**	**-0.36**	**1**	Bulgu yok
113	1.00	0.57	-0.78	0.94	1.16	-0.06	0.85	1.17	2.49	**-0.67**	**0.38**	**3**	Ciddi bulgular var
114	1.13	2.07	-0.11	1.38	1.67	0.17	0.49	1.08	0.70	**-3.44**	**-2.03**	**1**	Bulgu yok
115	0.88	1.09	-1.11	1.18	1.17	0.03	0.59	0.95	0.56	**-2.01**	**-0.78**	**1**	Bulgu yok
116	2.34	1.06	11.27	1.01	1.28	0.18	1.02	0.97	1.44	**0.68**	**1.56**	**4**	Çok önemli bulgular var
117	1.59	1.16	0.67	1.04	1.07	0.02	0.94	0.97	1.82	**-1.09**	**0.02**	**1**	Bulgu yok
118	0.83	1.01	2.61	1.06	1.08	0.03	0.87	0.88	0.33	**-1.79**	**-0.59**	**1**	Bulgu yok
119	0.83	1.00	2.61	1.06	1.08	0.03	0.87	0.88	0.33	**-1.78**	**-0.58**	**1**	Bulgu yok
120	0.83	1.05	2.61	1.06	1.08	0.03	0.87	0.88	0.33	**-1.86**	**-0.66**	**1**	Bulgu yok
121	0.81	0.88	0.80	0.92	1.58	0.15	1.44	0.97	0.82	**-2.15**	**-0.90**	**1**	Bulgu yok
122	1.87	0.46	0.47	1.00	0.73	0.16	1.16	0.86	0.24	**0.30**	**1.23**	**4**	Çok önemli bulgular var
123	0.97	1.70	-1.52	1.18	1.09	0.17	0.77	1.75	1.34	**-2.27**	**-1.01**	**1**	Bulgu yok
124	1.04	0.87	0.55	1.29	1.17	0.10	0.96	1.41	1.67	**-0.90**	**0.18**	**2**	Yapma olasılığı var
125	0.70	0.75	-1.44	1.09	0.85	0.11	0.74	0.96	1.73	**-1.54**	**-0.37**	**1**	Bulgu yok
126	0.59	1.16	0.42	0.95	0.96	0.15	0.82	0.84	1.59	**-2.51**	**-1.22**	**1**	Bulgu yok
127	1.08	0.59	0.08	1.65	1.48	0.20	0.63	1.50	2.03	**-0.28**	**0.72**	**3**	Ciddi bulgular var
128	1.04	1.04	1.67	1.38	1.31	0.07	0.66	0.97	1.57	**-1.46**	**-0.31**	**1**	Bulgu yok
129	2.74	0.83	1.06	1.02	0.99	0.34	1.54	1.00	5.47	**0.90**	**1.76**	**4**	Çok önemli bulgular var
130	1.96	1.02	0.51	1.12	0.84	0.13	1.02	0.87	0.27	**-0.51**	**0.52**	**3**	Ciddi bulgular var
131	2.30	0.98	1.14	1.16	1.12	0.13	0.62	1.17	1.03	**0.39**	**1.31**	**4**	Çok önemli bulgular var
132	1.98	0.84	1.02	1.08	0.98	0.11	0.94	1.48	1.30	**0.48**	**1.39**	**4**	Çok önemli bulgular var
133	1.89	0.83	1.53	0.91	1.49	-0.12	0.78	1.36	0.94	**0.17**	**1.12**	**4**	Çok önemli bulgular var
134	1.98	0.96	1.02	0.92	1.17	0.22	0.72	1.13	1.98	**-0.14**	**0.85**	**4**	Çok önemli bulgular var
135	1.09	1.20	0.51	1.91	1.21	0.07	1.06	0.86	1.85	**-1.83**	**-0.63**	**1**	Bulgu yok
136	0.88	2.02	1.44	0.88	1.40	0.08	0.73	1.10	1.12	**-3.52**	**-2.10**	**1**	Bulgu yok
137	0.50	1.17	0.29	0.80	1.39	0.03	0.95	0.81	1.18	**-2.93**	**-1.59**	**1**	Bulgu yok
138	0.78	0.84	0.69	1.10	0.85	-0.30	0.73	0.62	0.85	**-1.58**	**-0.41**	**1**	Bulgu yok
139	0.28	0.73	2.33	2.18	1.94	0.01	1.46	2.22	18.84	**0.04**	**1.01**	**4**	Çok önemli bulgular var

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140	1.07	0.85	0.17	1.22	1.25	0.02	0.97	0.86	1.81	**-1.42**	**-0.27**	**1**	Bulgu yok
141	1.20	0.99	0.70	1.21	0.55	0.15	0.73	0.96	2.10	**-0.98**	**0.12**	**1**	Bulgu yok
142	0.96	0.83	0.74	1.67	1.32	0.30	0.76	1.19	1.10	**-1.18**	**-0.06**	**1**	Bulgu yok
143	0.76	2.31	1.21	1.01	1.49	0.04	0.88	1.23	5.85	**-3.84**	**-2.38**	**1**	Bulgu yok
144	0.40	0.81	0.79	1.11	1.20	0.29	0.94	1.08	2.27	**-2.03**	**-0.80**	**1**	Bulgu yok
145	0.44	1.11	1.36	2.21	1.06	-0.10	0.83	1.16	0.00	**-1.95**	**-0.73**	**1**	Bulgu yok
146	2.19	0.99	1.09	1.08	0.92	-0.11	0.99	0.78	1.70	**-0.03**	**0.94**	**4**	Çok önemli bulgular var
147	1.29	0.81	0.41	1.16	0.96	0.05	0.51	1.07	1.88	**-0.55**	**0.49**	**3**	Ciddi bulgular var
148	1.07	0.41	0.55	1.86	1.00	0.23	0.84	0.92	1.57	**-0.35**	**0.67**	**3**	Ciddi bulgular var
149	1.27	0.85	0.74	1.33	1.00	0.25	0.39	1.33	0.68	**-0.49**	**0.54**	**3**	Ciddi bulgular var
150	0.79	1.01	0.64	0.82	0.90	0.05	0.88	1.08	1.51	**-1.71**	**-0.52**	**1**	Bulgu yok
151	2.27	0.95	1.12	1.53	0.95	-0.04	0.87	0.91	1.60	**0.34**	**1.27**	**4**	Çok önemli bulgular var
152	0.91	0.56	0.91	1.09	1.29	0.06	1.26	1.86	1.42	**-0.25**	**0.75**	**3**	Ciddi bulgular var
153	1.54	1.10	1.14	0.94	1.00	0.01	1.00	0.95	1.22	**-1.05**	**0.05**	**1**	Bulgu yok
154	1.35	0.91	1.07	1.10	0.97	-0.19	0.74	0.91	0.96	**-0.78**	**0.29**	**2**	Yapma olasılığı var
155	1.51	0.70	0.89	1.22	1.12	0.11	1.02	1.27	1.61	**-0.13**	**0.86**	**4**	Çok önemli bulgular var
156	1.13	1.07	0.98	1.06	1.09	-0.01	1.06	1.20	2.10	**-1.29**	**-0.15**	**1**	Bulgu yok
157	0.69	0.83	0.88	0.85	2.67	0.33	1.48	1.61	1.99	**-2.17**	**-0.92**	**1**	Bulgu yok
158	0.83	1.45	-0.70	1.10	1.95	0.17	0.72	2.04	1.17	**-2.11**	**-0.87**	**1**	Bulgu yok
159	1.16	1.50	0.80	0.64	0.89	0.07	0.92	1.33	1.26	**-1.94**	**-0.72**	**1**	Bulgu yok
160	0.85	0.76	0.64	1.46	1.43	0.38	1.01	1.00	2.08	**-1.58**	**-0.41**	**1**	Bulgu yok
161	0.02	0.98	0.77	0.67	1.11	0.06	0.80	1.25	1.05	**-2.61**	**-1.30**	**1**	Bulgu yok
162	0.27	2.06	0.32	1.69	1.26	0.10	0.82	2.39	1.56	**-2.98**	**-1.63**	**1**	Bulgu yok
163	1.26	0.95	6.43	0.47	0.94	0.20	1.07	1.11	0.83	**-0.78**	**0.29**	**2**	Yapma olasılığı var
164	0.21	2.16	5.67	8.01	1.18	-0.06	0.63	1.35	2.05	**-2.16**	**-0.91**	**1**	Bulgu yok
165	1.53	1.00	0.81	1.23	1.09	-0.04	0.99	1.15	1.59	**-0.65**	**0.40**	**3**	Ciddi bulgular var
166	0.83	0.65	0.92	1.08	1.33	0.18	0.91	1.49	2.83	**-0.77**	**0.30**	**2**	Yapma olasılığı var
167	1.56	1.12	1.31	1.77	1.03	-0.01	0.95	1.16	2.75	**-0.56**	**0.48**	**3**	Ciddi bulgular var
168	0.64	1.17	0.87	2.17	0.95	0.62	0.82	1.65	1.82	**-1.59**	**-0.42**	**1**	Bulgu yok
169	1.36	1.06	9.06	1.09	1.35	-0.05	0.96	0.93	0.97	**-0.72**	**0.34**	**2**	Yapma olasılığı var
170	0.57	0.69	5.77	0.64	1.10	0.11	1.50	1.83	1.23	**-0.68**	**0.38**	**3**	Ciddi bulgular var
171	1.81	1.16	1.21	0.86	1.40	-0.06	1.31	0.44	0.61	**-1.63**	**-0.45**	**1**	Bulgu yok
172	0.57	1.52	0.57	1.27	1.46	0.55	0.67	1.13	0.52	**-3.27**	**-1.88**	**1**	Bulgu yok
173	0.80	1.01	1.38	1.23	1.13	-0.11	0.88	1.02	1.00	**-1.67**	**-0.49**	**1**	Bulgu yok
174	0.60	0.85	0.70	1.39	1.33	0.46	0.71	2.37	0.46	**-0.71**	**0.35**	**2**	Yapma olasılığı var
175	1.35	2.09	-2.00	1.66	1.53	0.09	0.63	1.61	1.26	**-2.69**	**-1.37**	**1**	Bulgu yok
176	0.70	0.78	0.97	1.02	1.41	0.10	0.75	1.49	0.61	**-1.24**	**-0.12**	**1**	Bulgu yok
177	1.99	1.06	0.01	0.95	1.28	0.04	0.76	1.05	0.62	**-0.53**	**0.51**	**3**	Ciddi bulgular var
178	0.23	1.09	0.80	1.02	2.02	0.06	1.19	0.93	0.34	**-3.38**	**-1.98**	**1**	Bulgu yok
179	1.73	0.96	0.58	1.43	1.17	0.09	1.04	1.11	0.85	**-0.52**	**0.52**	**3**	Ciddi bulgular var
180	1.38	1.24	1.00	0.28	1.91	0.37	0.44	1.06	1.01	**-2.02**	**-0.79**	**1**	Bulgu yok
181	1.21	1.41	0.79	0.93	0.97	0.33	0.94	0.76	1.73	**-2.35**	**-1.08**	**1**	Bulgu yok
182	1.49	0.94	1.11	0.99	1.11	-0.22	1.04	0.88	1.19	**-0.86**	**0.22**	**2**	Yapma olasılığı var
183	0.73	0.51	3.38	0.79	0.96	0.44	0.53	0.35	1.32	**-1.51**	**-0.35**	**1**	Bulgu yok
184	0.56	0.84	0.11	1.17	1.31	0.20	0.93	1.56	1.02	**-1.52**	**-0.36**	**1**	Bulgu yok
185	1.90	0.18	1.30	1.00	1.31	0.22	1.08	1.13	2.47	**1.01**	**1.85**	**4**	Çok önemli bulgular var
186	2.59	0.69	2.26	0.98	0.87	0.18	1.00	1.27	1.35	**1.41**	**2.19**	**4**	Çok önemli bulgular var
187	0.88	0.69	1.05	1.58	1.39	0.03	0.82	1.96	0.67	**-0.23**	**0.77**	**3**	Ciddi bulgular var
188	1.52	1.02	-1.36	0.55	0.79	0.14	0.85	0.47	0.97	**-1.63**	**-0.46**	**1**	Bulgu yok
189	1.15	0.70	1.05	1.08	1.01	-0.11	0.82	1.10	0.87	**-0.58**	**0.46**	**3**	Ciddi bulgular var
190	1.30	1.09	1.07	0.53	1.15	0.00	0.96	1.11	1.16	**-1.35**	**-0.21**	**1**	Bulgu yok
191	0.66	1.19	-0.30	2.00	1.12	0.21	0.57	1.23	1.56	**-1.95**	**-0.73**	**1**	Bulgu yok
192	0.99	0.79	0.93	1.23	1.61	-0.08	0.92	1.15	1.23	**-1.20**	**-0.07**	**1**	Bulgu yok
193	1.25	0.86	0.82	1.24	1.06	0.21	0.89	1.04	1.01	**-1.00**	**0.10**	**1**	Bulgu yok
194	1.05	0.52	1.12	1.11	1.26	-0.08	1.21	1.07	0.70	**-0.68**	**0.37**	**3**	Ciddi bulgular var
195	1.65	1.46	0.81	1.07	1.26	0.05	0.98	1.07	1.13	**-1.59**	**-0.42**	**1**	Bulgu yok
196	1.39	0.95	0.40	0.86	1.34	0.04	0.92	1.13	1.97	**-0.99**	**0.11**	**1**	Bulgu yok

Tablo 6. Devamı

197	1.15	0.60	0.34	1.58	0.78	0.00	0.82	1.07	0.81	**-0.32**	**0.69**	**3**	Ciddi bulgular var
198	1.16	0.79	0.50	1.34	1.07	-0.27	0.92	1.17	0.93	**-0.63**	**0.42**	**3**	Ciddi bulgular var
199	0.38	1.73	1.59	1.02	1.71	-0.56	1.02	1.48	2.67	**-3.06**	**-1.70**	**1**	Bulgu yok
200	1.56	1.03	0.91	1.29	1.02	0.07	1.07	1.10	2.51	**-0.69**	**0.37**	**3**	Ciddi bulgular var
201	0.98	0.74	1.03	0.86	1.26	0.01	0.63	0.75	1.11	**-1.37**	**-0.22**	**1**	Bulgu yok
202	0.82	0.58	1.17	1.12	1.45	0.17	0.76	3.72	2.91	**1.56**	**2.33**	**4**	Çok önemli bulgular var
203	0.46	1.32	0.76	2.11	2.31	0.34	0.88	3.77	2.15	**-0.57**	**0.47**	**3**	Ciddi bulgular var
204	0.92	0.96	-0.32	5.72	0.99	0.04	0.55	1.22	0.87	**-0.27**	**0.73**	**3**	Ciddi bulgular var
205	0.99	1.00	0.72	1.35	1.24	0.35	1.18	1.49	1.88	**-1.31**	**-0.17**	**1**	Bulgu yok

Tablo 6'ya bakıldığında değerlendirilen işletmelerden 116 işletmenin herhangi bir finansal manipülasyona başvurduğuna ilişkin bulgunun olmadığı, 16 işletmenin finansal manipülasyon yapma olasılığının bulunduğu, 37 işletme için finansal manipülasyon yapmaya yönelik ciddi bulguların belirlendiği ve 36 işletmeye dair finansal manipülasyon yapmaya yönelik çok önemli bulguların var olduğu sonucuna ulaşılmıştır.

Manipülatör olarak belirlenen 89 işletmenin endeksler arasındaki ve Mi değerleriyle olan ilişkilerini belirleyebilmek amacıyla Pearson Korelasyon testi yapılmıştır. Çiftçi vd. (2021) çalışmalarında belirttiği üzere korelasyon katsayıları 0.30'dan küçük olduğunda düşük ilişki, 0,30 ile 0,60 arasında olduğunda orta düzey ilişki ve 0.60'tan büyük olduğunda güçlü ilişki olduğu biçiminde yorumlanabilmektedir. Gerçekleştirilen korelasyon analizi doğrultusunda elde edilen sonuçlar Tablo 7'de gösterilmiştir.

Tablo 7. İmalat Sanayi Manipülatör İşletme Endeksleri ve M_i Değeri Korelasyon Analizi

		TAE	**BKM**	**AKE**	**AME**	**PSE**	**TVE**	**BYE**	**SSE**	**FSE**	**Mi**
TAE	r	1	-0.055	0.004	**-0.209****	**-0.328****	-0.009	0.093	**-0.194****	-0.091	0.095
	p		0.432	0.949	**0.003**	**0.000**	0.899	0.185	**0.005**	0.192	0.175
BKM	r		1	0.019	0.098	**-0.264****	0.025	-0.038	**0.198****	-0.103	**-0.160***
	p			0.783	0.161	**0.000**	0.720	0.589	**0.004**	0.142	**0.022**
AKE	r			1	0.113	0.081	0.015	0.091	0.089	0.031	-0.070
	p				0.108	0.246	0.833	0.195	0.204	0.660	0.318
AME	r				1	0.020	-0.035	**-0.171***	0.072	0.071	-0.057
	p					0.772	0.622	**0.014**	0.305	0.315	0.420
PSE	r					1	-0.002	0.089	**0.162***	0.130	**0.143***
	p						0.980	0.206	**0.021**	0.062	**0.041**
TVE	r						1	**-0.144***	**0.177***	-0.068	-0.042
	p							**0.039**	**0.011**	0.333	0.553
BYE	r							1	0.023	0.086	0.026
	p								0.746	0.219	0.716
SSE	r								1	0.089	**-0.172***
	p									0.206	**0.014**
FSE	r									1	0.041
	p										0.559
Mi	r										1

Not: *Korelasyon 0,05 düzeyinde anlamlıdır. **Korelasyon 0,01 düzeyinde anlamlıdır.

Tablo 7'de verilen bilgiler doğrultusunda Ticari Alacaklar Endeksi (TAE) değişkeni ile Amortisman Endeksi (AME) değişkeni arasında 0.01 anlamlılık seviyesinde negatif yönlü düşük bir ilişki ve Pazarlama, Satış, Dağıtım ve Genel Yönetim Giderleri Endeksi (PSE) değişkeni arasında 0.01 anlamlılık seviyesinde negatif yönlü orta düzey bir ilişki ve Stokların Brüt Satışlara

Oranı Endeksi (SSE) değişkeni arasında 0.01 anlamlılık seviyesinde negatif yönlü düşük bir ilişki olduğu tespit edilmiştir. Brüt Kâr Marjı Endeksi (BKM) değişkeni ile Pazarlama, Satış, Dağıtım ve Genel Yönetim Giderleri Endeksi (PSE) değişkeni arasında 0.01 anlamlılık seviyesinde negatif yönlü düşük bir ilişki olduğu ve Stokların Brüt Satışlara Oranı Endeksi (SSE) değişkeni arasında 0.01 anlamlılık seviyesinde pozitif yönlü düşük bir ilişki olduğu ve Beneish M değeri arasında 0.05 anlamlılık seviyesinde negatif yönlü düşük bir ilişki olduğu belirlenmiştir. Amortisman Endeksi (AME) değişkeni ile Borç Yapısındaki Değişim Endeksi (BYE) değişkeni arasında 0.05 anlamlılık seviyesinde negatif yönlü düşük bir ilişki olduğu anlaşılmıştır. Pazarlama, Satış, Dağıtım ve Genel Yönetim Giderleri Endeksi (PSE) değişkeni ile Stokların Brüt Satışlara Oranı (SSE) değişkeni arasında 0.05 anlamlılık seviyesinde pozitif yönlü düşük bir ilişki olduğu ve Beneish M değeri arasında 0.05 anlamlılık seviyesinde pozitif yönlü düşük bir ilişki olduğu görülmüştür. Toplam Tahakkukların Toplam Varlıklara Oranı Endeksi (TVE) değişkeni ile Borç Yapısındaki Değişim Endeksi (BYE) değişkeni arasında 0.05 anlamlılık seviyesinde negatif yönlü düşük bir ilişki olduğu tespit edilmiş ve Stokların Brüt Satışlara Oranı (SSE) değişkeni arasında 0.05 anlamlılık seviyesinde pozitif yönlü düşük bir ilişki olduğu tespit edilmiştir. Stokların Brüt Satışlara Oranı Endeksi (SSE) değişkeni ile ve Beneish M değeri arasında 0.05 anlamlılık seviyesinde negatif yönlü düşük bir ilişki olduğu görülmüştür.

3.3.2. Multinominal Logit ve Multinominal Probit Modelleri Analizi ve Bulguları

Finansal bilgi manipülasyonu üzerinde etkisi olan değişkenlerin etkilerini belirlemek amacıyla Multinominal Logit ve Multinominal Probit regresyon modelleri uygulanmıştır. Multinominal Logit ve Multinominal Probit analizinden önce değişkenler arasında çoklu doğrusal bağlantı analizi gerçekleştirilmiş, değişkenlerin VIF değerlerinin eşik değer olduğu kabul edilen 5'in altında olduğu anlaşılmıştır. Multinominal Logit ve Multinominal Probit modelinin anlamlılığı ki-kare testiyle belirlenerek modellerin olabilirlik oran değerleri (log likelihood) -115.39 ile -120.78 olarak hesaplanmış ($p < 0.001$) olup bağımsız değişkenlerin yer aldığı modellerin istatistiksel açıdan anlamlı olduğu belirlenmiştir. Böylece çalışmada Multinominal Logit ve Multinominal Probit modeli sonrasında değişkenlerin finansal bilgi manipülasyonu üzerinde marjinal etki analizi sonuçları Tablo 8'de değerlendirilmiştir. Tablo 8'de işletmelerin finansal bilgi manipülasyonunu etkileyen faktörleri belirlemek için uygulanan Multinominal Logit ve Multinominal Probit regresyon analizinin sonuçları verilmiştir. Tablo 8'de ilk sütunda uygulanan analizlerin β katsayıları yer almaktadır. Manipülasyona ilişkin kanıt yok referans kategorisi dikkate alındığında; bağımsız değişkenlerden Ticari Alacaklar Endeksi (TAE), Brüt Kâr Marjı Endeksi (BKM), Aktif Kalitesi Endeksi (AKE), Amortisman Endeksi (AME), Pazarlama, Satış, Dağıtım ve Genel Yönetim Giderleri Endeksi (PSE), Stokların Brüt Satışlara Oranı Endeksi (SSE) ile Finansman Giderlerinin Brüt Satışlara Oranı Endeksinin (FSE) istatistiksel olarak anlamlı olduğu belirlenmiştir. Çalışmada bağımsız değişkenlerin işletmelerin finansal bilgi manipülasyonu uygulama olasılığı üzerindeki etkilerini belirlemek için bir sonraki analizde marjinal etkiler hesaplanmıştır.

Tablo 8. İşletmelerin Finansal Bilgi Manipülasyonunu Etkileyen Faktörlerin Multinominal Logit-Multinominal Probit Analizi

	Değişkenler	Multinominal Logit Analizi			Multinominal Probit Analizi		
		β	Std.Hata	Z	β	Std.Hata	Z
Manipülasyona İlişkin Kanıt Yok		**Referans Kategorisi**					
Manipülasyon yapma olasılığı var	**TAE**	**4.122*** **	**1.176**	**3.51**	**2.559*** **	**0.731**	**3.50**
	BKM	-6.407***	1.535	-4.17	-4.001***	0.927	-4.32
	AKE	0.637**	0.223	2.85	0.417**	0.153	2.73
	AME	1.424**	0.433	3.29	0.910**	0.282	3.22
	PSE	-2.212*	1.079	-2.05	-1.477	0.770	-1.92
	TVE	0.354	2.298	0.15	0.615	1.459	0.42
	BYE	0.804	1.562	0.51	0.724	1.124	0.64
	FSE	0.312	0.343	0.91	0.239	0.244	0.98
	SSE	-0.178	0.665	-0.27	0.023	0.394	0.06
Manipülasyona ilişkin ciddi kanıtlar bulunmakta	TAE	4.746***	0.998	4.76	2.852***	0.579	4.93
	BKM	-6.721***	1.348	-4.99	-3.819***	0.713	0.71
	AKE	0.423*	0.212	1.99	0.267	0.140	1.91
	AME	1.263**	0.422	2.99	0.798**	0.267	2.99
	PSE	-1.840**	0.634	-2.90	-0.862*	0.374	-2.31
	TVE	-0.713	1.831	-0.39	-0.153	1.285	-0.12
	BYE	-0.168	1.276	-0.13	0.240	0.915	0.26
	FSE	0.263	0.312	0.84	0.204	0.229	0.89
	SSE	0.756*	0.357	2.12	0.604*	0.282	2.14
Manipülasyona ilişkin çok önemli bulunmakta	TAE	11.169***	1.830	6.10	6.975***	1.035	6.74
	BKM	-12.466***	2.120	-5.88	-7.196***	1.119	-6.43
	AKE	0.760**	0.323	2.35	0.474**	0.201	2.36
	AME	2.213***	0.591	3.74	1.408***	0.357	3.94
	PSE	-2.243**	0.782	-2.87	-1.093**	0.489	-2.24
	TVE	-2.023	3.644	-0.56	-0.032	2.228	-0.01
	BYE	-0.891	2.581	-0.35	-0.818	1.660	-0.49
	FSE	0.935**	0.357	2.62	0.662**	0.258	2.57
	SSE	0.667	0.367	1.82	0.519	0.280	1.85

Not: ***p<0.001; **p<0.01; *p<0.05.

Tablo 9'a göre finansal bilgi manipülasyonuna ilişkin kanıt olmadığı kategorisinde Ticari Alacaklar Endeksi (TAE), Brüt Kâr Marjı Endeksi (BKM), Aktif Kalitesi Endeksi (AKE), Amortisman Endeksi (AME) ve Pazarlama, Satış, Dağıtım ve Genel Yönetim Giderleri Endeksi (PSE) değişkenlerinin marjinal etkilerinin %1 önem seviyesinde istatistiksel açıdan anlamlı olduğu tespit edilmiştir. Marjinal etkiler, bağımsız değişkendeki bir birimlik değişim karşısında, tahmin edilen işletmelerin finansal manipülasyon yapma olasılığındaki değişimi göstermektedir. Multinominal Logit ve Multinominal Probit model analizleri incelendiğinde; işletmelerin Ticari Alacaklar Endeksi (TAE) değişkenindeki bir birimlik artışın %97 ile %80.9, Aktif Kalitesi Endeksi (AKE) değişkenindeki bir birimlik artışın %10.2 ile %8.9, Amortisman Endeksi (AME) değişkenindeki bir birimlik artışın %27.5 ile %23.8 oranında finansal manipülasyon yapma kanıtının olma olasılığını arttırırken, Brüt Kâr Marjı Endeksi (BKM) değişkenindeki bir birimlik artışın %80.1 ile %55.3 ve Pazarlama, Satış, Dağıtım ve Genel Yönetim Giderleri Endeksi (PSE) değişkenindeki bir birimlik artışın %40.6 ile %29.4 oranında finansal manipülasyon yapma kanıtının olma olasılığını azalttığı belirlenmiştir. İşletmelerin manipülasyon yapma olasılığının var olduğu kategori değerlendirildiğinde; Ticari Alacaklar Endeksi (TAE) değişkenindeki bir birimlik artışın %23.1 ile %18.3, Aktif Kalitesi Endeksi (AKE) değişkenindeki bir birimlik artışın %4.1 ile %4 ve Amortisman Endeksi (AME) değişkenindeki bir birimlik artışın %8.7 ile %7.63

oranında finansal manipülasyon yapma olasılığını artırdığı, buna karşın Brüt Kâr Marjı Endeksi (BKM) değişkenindeki bir birimlik artışın %37.2 ile %32 oranında finansal manipülasyon yapma olasılığını azalttığı anlaşılmıştır.

Tablo 9. Değişkenlerin Finansal Bilgi Manipülasyonu Uygulaması Üzerindeki Marjinal Etkileri

Modeller		**Multinominal Logit Marjinal Etkiler**			**Multinominal Probit Marjinal Etkiler**		
Değişkenler		**dy/dx**	**Std. hata**	**Z**	**dy/dx**	**Std. hata**	**Z**
Manipülasyona ilişkin kanıt yok	TAE	-0.970***	0.207	-4.68	-0.809***	0.164	-4.94
	BKM	0.801***	0.153	5.25	0.553***	0.097	5.70
	AKE	-0.102*	0.041	-2.47	-0.089*	0.036	-2.43
	AME	-0.275**	0.080	-3.40	-0.238**	0.070	-3.39
	PSE	0.406**	0.119	3.41	0.294*	0.103	2.84
	TVE	0.089	0.345	0.26	-0.018	0.322	-0.06
	BYE	-0.020	0.240	-0.09	-0.099	0.235	-0.42
	FSE	-0.059	0.062	-0.97	-0.063	0.061	-1.03
	SSE	-0.135	0.074	-1.83	-0.142	0.073	-1.92
Manipülasyon yapma olasılığı var	TAE	0.231*	0.103	2.24	0.183*	0.092	1.97
	BKM	-0.372**	0.117	-3.17	-0.320**	0.097	-3.30
	AKE	0.041*	0.017	2.43	0.040*	0.017	2.35
	AME	0.087**	0.033	2.64	0.763*	0.030	2.53
	PSE	-0.138	0.072	-1.90	-0.144	0.082	-1.75
	TVE	0.040	0.169	0.24	0.083	0.168	0.49
	BYE	0.651	0.112	0.58	0.811	0.127	0.64
	FSE	0.019	0.024	0.79	0.020	0.025	0.78
	SSE	-0.032	0.045	-0.71	-0.028	0.043	-0.66
Manipülasyona ilişkin ciddi kanıtlar bulunmakta	TAE	0.696***	0.172	4.04	0.560***	0.141	3.96
	BKM	-0.979***	0.196	-5.00	-0.733***	0.156	-4.69
	AKE	0.058	0.033	1.74	0.046	0.031	1.48
	AME	0.180**	0.066	2.72	0.150**	0.058	2.58
	PSE	-0.261**	0.094	-2.77	-0.143	0.087	-1.64
	TVE	-0.121	0.284	-0.43	-0.063	0.292	-0.22
	BYE	-0.041	0.199	-0.20	0.030	0.206	0.15
	FSE	0.037	0.048	0.76	0.037	0.049	0.75
	SSE	0.092*	0.047	1.96	0.097	0.050	1.91
Manipülasyona ilişkin çok önemli kanıtlar bulunmakta	TAE	0.043	0.036	1.19	0.066	0.059	1.11
	BKM	-0.046	0.039	-1.18	-0.619	0.056	-1.10
	AKE	0.003	0.003	1.06	0.003	0.004	0.98
	AME	0.008	0.007	1.15	0.117	0.011	1.10
	PSE	-0.007	0.007	-1.04	-0.007	0.008	-0.83
	TVE	-0.008	0.014	-0.58	-0.001	0.237	-0.04
	BYE	-0.004	0.012	-0.35	-0.116	0.020	-0.58
	FSE	0.004	0.003	1.08	0.006	0.006	1.04
	SSE	0.075	0.047	1.57	0.074	0.050	1.48

Not: ***p<0,001; **p<0,01; *p<0,05

Manipülasyona ilişkin ciddi kanıtlar bulunduğu kategoriye göre, Ticari Alacaklar Endeksi (TAE) değişkenindeki bir birimlik artışın %69.6 ile %56, Amortisman Endeksi (AME) değişkenindeki bir birimlik artışın %18 ile %15, Stokların Brüt Satışlara Oranı Endeksi (SSE) değişkenindeki bir birimlik artışın %9.2 oranında işletmelerin finansal manipülasyonuna ilişkin ciddi kanıtların olma olasılığını artırdığı ve Brüt Kâr Marjı Endeksi (BKM) değişkenindeki bir birimlik artışın %97.9 ile %73.3, Pazarlama, Satış, Dağıtım ve Genel Yönetim Giderleri Endeksi

(PSE) değişkenindeki bir birimlik artışın %26.1 oranında finansal manipülasyona ilişkin ciddi kanıtların olma olasılığını azalttığı görülmüştür. Manipülasyona ilişkin çok önemli kanıtlar bulunma kategorisinde ise değişkenlerin marjinal etkilerinin istatistiksel olarak anlamlı olmadığı belirlenmiştir.

3.3.3. Analiz Sonuçlarının Karşılaştırılması

Bu kısımda, Multinominal Logit ve Multinominal Probit analizleri kullanılarak elde edilen sonuçlar arasında karşılaştırmalar yapılmıştır. Tablo 10'da işletmelerin finansal manipülasyon yapma kategorisine göre Multinominal Logit ve Multinominal Probit modeli analizlerinin sınıflandırma başarıları belirlenmiştir. Tablo 10'a göre 2022-2023 dönemine göre 205 işletmenin Multinominal Logit ve Multinominal Probit modelleri analiz sonuçlarının sınıflandırma başarıları karşılaştırıldığında manipülasyonun olmadığı kategoride %98,28 ile %96,55, manipülasyon yapma olasılığı var kategorisinde %75 ile %62,50, manipülasyona ilişkin ciddi kanıtların bulunduğu kategoride %70,27 ile %86,11 ve manipülasyona ilişkin çok önemli kanıtların olduğu kategoride ise %86,11'lik sınıflandırma başarısı tespit edilmiştir. Toplam sınıflandırma başarıları karşılaştırıldığında Multinominal Logit modeli analizinde %89,27'lik ve Multinominal Probit modeli analizinde %85,5'lik sınıflandırma başarısı elde edilmiştir. Bununla birlikte analizlerin yanlış sınıflandırma sonuçları için gerçekte doğru olan sıfır hipotezinin reddedilme olasılığı I.Tip hata ve gerçekte yanlış olan sıfır hipotezinin reddedilmeme olasılığı II.Tip hata olasılığı olarak hesaplanmıştır (Barboza vd., 2017: 412).

Tablo 10. Multinominal Logit ve Multinominal Probit Modellerinin Sınıflandırma Başarıları

Multinominal Logit Analizi	**Gözlenen Grup**				
Tahmin Edilen Grup	**A.**	**B.**	**C.**	**D.**	**Doğruluk Yüzdesi**
A. Manipülasyon yok	114		2		%98,28
B. Manipülasyon yapma olasılığı var	1	12	3		%75,00
C. Manipülasyona ilişkin ciddi kanıtlar var	7	1	26	3	%70,27
D. Manipülasyona ilişkin çok önemli kanıtlar var	2		3	31	%86,11
Toplam	124	13	34	34	%89,27
Multinominal Probit Analizi	**Gözlenen Grup**				
Tahmin Edilen Grup	**A.**	**B.**	**C.**	**D.**	**Doğruluk Yüzdesi**
A. Manipülasyon yok	112	1	2	1	%96,55
B. Manipülasyon yapma olasılığı var	4	10	2		%62,50
C. Manipülasyona ilişkin ciddi kanıtlar var	9	1	23	4	%62,16
D. Manipülasyona ilişkin çok önemli kanıtlar var	3		2	31	%86,11
Toplam	128	12	29	36	%85,85

Multinominal Logit ve Multinominal Probit model analizleri I. Tip hata sonuçları sırasıyla manipülasyon yok kategorisi için %11,5 (10/87) ile %18,8 (16/85), manipülasyon yapma olasılığı var kategorisi için %0.54 (1/185) ile %1.09 (2/183), manipülasyona ilişkin ciddi kanıtlar var kategorisi için %5.09 (8/157) ile %3.9 (6/154) ve manipülasyona ilişkin çok önemli kanıtlar var kategorisi için % 1.8 (3/164) ile %3.05 (5/164) olarak gerçekleşmiş ve genel ortalaması %3.7 (22/593) ile %4,9 (29/586) olarak hesaplanmıştır. II. Tip hata sonuçları sırasıyla manipülasyon yok kategorisi için %1,7 (2/116) ile %3,4 (4/116), manipülasyon yapma olasılığı var kategorisi için %25 (4/16) ile %37,5 (6/16), manipülasyona ilişkin ciddi kanıtlar var kategorisi için %29,7 (11/37) ile %37,8 (14/37) ve manipülasyona ilişkin çok önemli kanıtlar var kategorisi için %13,9

(5/36) ile %13,9 (5/36) olarak hesaplanmış ve genel ortalaması %10,7 (22/205) ile %14,1 (29/205) olarak belirlenmiştir. Bu doğrultuda testin gücünü gösteren $(1-\beta)$ ölçütü %89,3 (1-0.107=0.893) ile %85,9 (1-0.141=0.859) gerçekleşmiş ve testin güvenirlik düzeyini gösteren $(1-\alpha)$ ölçütü %96,3 (1-0.037=0.963) ile %95,1(1-0.049=0.951) olarak hesaplanmıştır.

Ayrıca analiz yöntemlerinin, işletmelerin finansal manipülasyon uygulaması kategorisine ait duyarlılık ve belirleyicilik istatistikleri de hesaplanmıştır. Duyarlılık istatistiği bir sınıflandırma tablosunda gerçekte pozitif olarak gözlenen değerlerin toplam pozitif örneklere olan oranını gösterirken belirleyicilik istatistiği, gerçekte negatif olarak gözlenen değerlerin toplam negatif örneklere olan oranını ifade etmektedir (Jahangiri vd., 2020; Monaghan vd., 2021). Araştırmada işletmelere uygulanan Multinominal Logit ve Multinominal Probit analizlerinde duyarlılık istatistiklerine göre sırasıyla manipülasyon yok kategorisinde %98,30 ile %96,60, manipülasyon yapma olasılığı var kategorisinde %75 ile %62,5, manipülasyona ilişkin ciddi kanıtlar var kategorisinde %70,30 ile %62,20 ve manipülasyona ilişkin çok önemli kanıtlar var kategorisinde %86,10'luk sınıflandırma başarısına ulaşılmıştır. Analiz yöntemlerini karşılaştırmada kullanılan bir diğer gösterge ölçütü olan belirleyicilik istatistiğine göre uygulanan yöntemlerin sınıflandırma başarıları sırasıyla manipülasyon yok kategorisi için %88,80 ile %82, manipülasyon yapma olasılığı var kategorisi için %99,50 ile %98,90, manipülasyona ilişkin ciddi kanıtlar var kategorisi için %95,20 ile %96,40 ve manipülasyona ilişkin çok önemli kanıtlar var kategorisi için %98,20 ile %97 olarak elde edilmiştir. Analiz yöntemleri hesaplanan bu istatistiki gösterge değerlerine göre kıyaslandığında, Multinominal Logit modelinin Multinominal Probit modelinden daha başarılı sınıflandırma performansı gösterdiği ortaya çıkmıştır.

4. Sonuç

Günümüz ekonomilerinde finansal piyasalar arasındaki etkileşimin artması sonucunda, yurt içi ve yurt dışı piyasalarda faaliyet gösteren işletmelerin kaynak bulmaları, şirket birleşmesi uygulamaları, yeni yatırım gerçekleştirebilmeleri ve yatırımcıların dikkatini çekebilmeleri konularında açıklamış oldukları finansal bilgiler oldukça önemli bir yere sahip olmuştur (Yanya ve Kandil Göker, 2023: 1211). Manipülasyon yapılarak yayınlanan finansal bilgiler yatırımcılar, kredi verenler, tedarikçiler ve benzeri işletmeyle ilgili tüm paydaşların zarar görmesine sebebiyet vermektedir (Soykan vd., 2023: 27). Özellikle yatırımcıların tutum ve davranışlarını etkilemek ve değiştirmek finansal bilgi manipülasyonunun başlıca hedeflerindendir. Bu doğrultuda en fazla başvurulan manipülasyon tekniği ise işletmenin kârlılığı üzerinde yapılan yanıltıcı işlemlerdir. İşletme kârının yüksek gösterilmesi sonuncunda finansal performansın da yüksek olarak algılanması amaçlanmaktadır (Kara ve Sakarya, 2021: 133). Bir diğer önemli manipülasyon amacı ise yöneticilerin kendi çıkarlarını düşünmeleri ve finansal bilgiler üzerinde manipülasyon yapmalarıdır. (Aslanoğlu ve Yanya, 2023: 263). Yine hukuki mevzuatta yer alan boşluklardan yararlanarak manipülasyon yapıldığı ve özellikle denetlenebilirliği oldukça fazla olan borsa işletmeleri tarafından dahi finansal manipülasyona başvurulduğu bilinmektedir. Bu durum potansiyel yatırımcıların ve yatırım yapmayı düşünen tasarruf sahiplerinin, finansal piyasalara olan güven duygularını olumsuz bir şekilde etkilemektedir. Bu doğrultuda yatırımcıların, yatırım işlemi esnasında, manipülasyon yapılabilme durumuna dikkat ederek yatırım kararlarını vermeleri gerekmektedir (Güner ve Kurnaz, 2020: 212; Erol Fidan, 2021: 24).

Yapılan açıklamalar doğrultusunda bu çalışmanın amacı, BIST imalat sanayi sektöründe bulunan işletmelerin finansal bilgi manipülasyonuna başvurma durumlarının tahmin edilmesidir.

Bu amaç üzerine sektörde faaliyet gösteren 205 işletmenin, 2022-2023 yıllarına ait finansal bilgi manipülasyonu yapıp yapmadıkları, Beneish TR modeli kullanılarak incelenmiştir. Ayrıca Beneish TR modeline ilave olarak çalışmada, Multinominal Logit ve Multinominal Probit analiz teknikleri uygulanmıştır. Multinominal Logit ve Multinominal Probit analizleri aracılığıyla finansal bilgi manipülasyonu olasılığının belirlenmesinde gerekli olan marjinal etkiler hesaplanmıştır. Yine Multinominal Logit ve Multinominal Probit analizleri sonucunda, işletmelerin finansal bilgi manipülasyonu sınıflandırma başarıları değerlendirilerek, gerekli karşılaştırmalar yapılmış ve ulaşılan sonuçlar yorumlarla desteklenmiştir.

Türkiye literatüründe gerçekleştirilen imalat sanayi sektörü finansal bilgi manipülasyonu çalışmaları incelendiğinde, belirtilen sektör üzerine çok sayıda çalışma yapılmadığı anlaşılmaktadır. İmalat sanayi üzerine, Beneish TR modeli kullanılarak gerçekleştirilen ve bu çalışmayla benzer olduğu düşünülen çalışmalar; Ünver Kiracı ve Şengül Çelikay (2020) ile Peker (2023) tarafından yapılmıştır. Gerçekleştirilen çalışma, karşılaştırılanlara göre daha fazla model ve işletme sayısı içermektedir. Ünver Kiracı ve Şengül Çelikay (2020) çalışmalarında 2017-2018 yılları için 178 imalat sektörü işletmesini Beneish TR modeli ile değerlendirilerek, bu işletmelerde yönetici değişikliği yapıldığı süreçlerde finansal manipülasyona başvurulduğunu belirtmiştir. Peker (2023) çalışmasında 2020-2021 yılları için 151 imalat sektörü işletmesinin finansal manipülasyon durumunu Beneish TR modeli aracılığıyla dört ayrı kategoride incelemiştir. Bu çalışmada ise sektörde faaliyet gösteren 205 işletmenin, 2022-2023 yıllarına ait finansal bilgi manipülasyonu yapıp yapmadıkları, Beneish TR modeli kullanılarak belirlenmiştir. Özellikle bu çalışmada Multinominal Logit ve Multinominal Probit modelleri ile değişkenlerin manipülasyona ait marjinal etkileri ve modellerin sınıflandırma başarıları değerlendirilmiştir. Bahsedilenlere ilaveten gerçekleştirilen çalışmanın güncel veri seti içermesi, belirtilen yıllarda ilgili sektörün ve kullanılan analiz yöntemlerinin daha önce çalışılmamış olması ve elde edilen sonuçlar doğrultusunda çalışmanın Türkiye literatürüne katkı sağlayacağı düşünülmektedir.

Çalışma sonucunda, Beneish TR modeli kullanılarak değerlendirilen 205 işletme arasından 116 işletmenin herhangi bir finansal manipülasyona başvurduğuna ilişkin bulgunun olmadığı, 16 işletmenin finansal manipülasyon yapma olasılığının bulunduğu, 37 işletme için finansal manipülasyon yapmaya yönelik ciddi bulguların belirlendiği ve 36 işletmeye dair finansal manipülasyon yapmaya yönelik çok önemli bulguların var olduğu belirlenmiştir.

Multinominal Logit ve Multinominal Probit analiz bulgularına göre Ticari Alacaklar Endeksi (TAE), Brüt Kâr Marjı Endeksi (BKM), Aktif Kalitesi Endeksi (AKE), Amortisman Endeksi (AME), Pazarlama, Satış, Dağıtım ve Genel Yönetim Giderleri Endeksi (PSE) ile Stokların Brüt Satışlara Oranı Endeksi (SSE) değişkenlerinin işletmelerin finansal manipülasyon uygulama olasılığı üzerinde istatistiksel açıdan anlamlı olduğu belirlenmiştir. Özellikle Brüt Kâr Marjı Endeksi (BKM) değişkeni finansal manipülasyon yapma olasılığını azaltıcı ve Ticari Alacaklar Endeksi (TAE) değişkeni finansal manipülasyon yapma olasılığını arttırıcı en önemli değişkenler olarak belirlenmiştir.

İmalat sanayi üzerine, Beneish TR modeli kullanılarak gerçekleştirilen ve bu çalışmayla doğrudan benzerliği olduğu düşünülen çalışma Peker (2023) tarafından yapılmıştır. Gerçekleştirilen bu çalışma ile Peker (2023) tarafından yapılan çalışma karşılaştırıldığında; her iki çalışmanın da imalat sanayi üzerine farklı zaman dilimleri için yapıldığı görülmektedir. Çalışmalar da finansal bilgi manipülasyon durumu Beneish TR modeli aracılığıyla dört ayrı kategoride incelenmiştir. Çalışmalar sonuçları dahilinde incelendiğinde, değerlendirilen

işletmelerin manipülasyona başvurma durumlarının kategorilere göre dağılımı ele alındığında bu çalışma ile Peker (2023) tarafından yapılan çalışmanın benzer sonuçlara ulaştığı belirlenmiştir.

Çalışma sonucunda borsada işlem gören ve sürekli gözetim altında olan işletmelerin dahi finansal manipülasyona başvurabileceklerine yönelik çok önemli bulgular olduğu belirlenmiştir. Bu doğrultuda yatırımcıların BIST imalat sanayi sektörü işletmelerine yatırım yapacakları esnada, sektör işletmeleri hakkında daha detaylı araştırma yapmaları, finansal manipülasyona başvurulması yönünden bilgi edinmeye çalışmaları ve buna göre yatırımlarını yönlendirmeleri önerilmektedir. Ayrıca işletme denetimi yapan bağımsız denetçilerin, çalışmadan elde edilen sonuçları dikkate alarak denetimlerini bu yönde derinlemesine yapmaları önerilmektedir. Yine çalışma sonuçları doğrultusunda, sektör işletme yöneticilerinin finansal bilgi manipülasyonuna yönelik daha dikkatli olmaları ve işletmelerini bu doğrultuda kontrol altında tutmaları önerilmektedir. Buradan hareketle çalışma sonucu ulaşılan, işletmelerin finansal manipülasyon yapma olasılığı üzerinde istatistiksel açıdan anlamlı bulunan değişkenlerin yatırımcılar, denetçiler ve ilgili kişiler tarafından manipülasyon yapılma durumunun anlaşılması açısından dikkate alınması gerektiği, özellikle finansal manipülasyon yapma olasılığını azaltıcı Brüt Kâr Marjı Endeksi (BKM) değişkeninin ve finansal manipülasyon yapma olasılığını arttırıcı Ticari Alacaklar Endeksi (TAE) değişkeninin üzerinde önemle durulması gerektiği önerilmektedir. Bahsedilen sonuçlara ulaşılması için kullanılan Multinominal Logit modelde %89,27'lik ve Multinominal Probit modelde %85,5'lik yüksek düzeyli sınıflandırma başarısı elde edilmiş olması nedeniyle çalışmanın, ilgili taraflarca referans kabul edilebileceği ve finansal manipülasyonun varlığına ilişkin ön bilgi vermesi açısından taraflara katkı sağlayabileceği düşünülmektedir. Son olarak kanun koyucuların ya da politika yapıcıların devletin, yatırımcıların ve ilgili çevrelerin korunması adına bu çalışmayı dikkate alarak finansal bilgi manipülasyonunun belirlenmesine ve engellenmesine dair hukuki düzenlemeler yaparak daha ciddi önlemler almaları gerektiği önerilmektedir. Gelecekte yapılacak çalışmalar için bu çalışma referans alınarak farklı sektör ve dönemler için araştırma yapılabileceği, farklı sektör ve modeller kullanılarak modellerin sektörlere göre başarılarının belirlenebileceği, farklı değişkenlerle aynı modellerin kullanılabileceği, denetim şirketlerince yüksek manipülasyon olasılığının belirtildiği işletmelerin değerlendirilebileceği ve literatürde bulunan diğer modeller için belirlenen değişkenler kullanılarak farklı analiz yöntemleriyle finansal manipülasyon çalışmaları yapılarak ulaşılacak bulguların bu çalışmanın sonuçlarıyla karşılaştırılarak hangi yöntemin daha başarılı sonuçlar verdiğinin incelenebileceği önerilmektedir.

Araştırma ve Yayın Etiği Beyanı
Etik kurul izni ve/veya yasal/özel izin alınmasına gerek olmayan bu çalışmada araştırma ve yayın etiğine uyulmuştur.

Araştırmacıların Katkı Oranı Beyanı
Yazar, makalenin tamamına yalnız kendisinin katkı sağlamış olduğunu beyan eder.

Araştırmacıların Çıkar Çatışması Beyanı
Bu çalışmada herhangi bir potansiyel çıkar çatışması bulunmamaktadır.

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ESTIMATION OF FINANCIAL INFORMATION MANIPULATION USING BENEISH TR MODEL: AN APPLICATION ON BIST MANUFACTURING INDUSTRY

EXTENDED SUMMARY

Purpose of the Study

The aim of the study is to estimate the financial information manipulation of the enterprises traded in the BIST manufacturing industry sector. For this purpose, the financial reports of 205 enterprises operating in the sector for the years 2022-2023 were accessed through the Public Disclosure Platform (PDP) and it was determined whether they engaged in financial information manipulation using the Beneish TR model.

Literature Research

Studies on the BIST manufacturing industry sector using the Beneish TR model, which is considered to be directly similar to this study, were conducted by Ünver Kiracı and Şengül Çelikay (2020) and Peker (2023). Among these studies, Ünver Kiracı and Şengül Çelikay (2020) examined the financial information manipulation of 178 enterprises traded in the BIST manufacturing industry sector in the 2017-2018 periods. Beneish TR model was used in the research application. Another study was introduced to the literature by Peker (2023). In his study, the author investigated whether the BIST manufacturing industry sector and wholesale and retail trade sector enterprises engage in financial information manipulation. Due to its relevance to the subject of the study, the application to the BIST manufacturing industry sector is taken into consideration. Data for the 2020-2021 period were used in the study. Within the scope of the study application, 151 manufacturing industry enterprises were examined. Beneish TR model was used to identify enterprises that resort to financial information manipulation.

Methodology

Whether 205 enterprises operating in the BIST manufacturing industry sector have engaged in financial information manipulation for the years 2022-2023 is determined using the Beneish TR model. With the model application, some indices in the model were calculated and Mi and Zi values were revealed. In addition to the mentioned model, Multinominal Logit and Multinominal Probit analysis techniques were used in the study. With the use of Multinominal Logit and Multinominal Probit models, it is aimed to calculate the marginal effects of variables in determining the probability of financial information manipulation and the success of the models in classifying financial information manipulation.

Findings

As a result of the Beneish TR analysis, it has been concluded that there is no evidence that 116 enterprises have resorted to any financial manipulation, 16 enterprises are likely to engage in

financial manipulation, 37 enterprises have serious findings for financial manipulation and 36 enterprises have very important findings for financial manipulation. In addition, the Multinominal Logit and Multinominal Probit models were used to determine the marginal effects of variables on financial information manipulation.

Conclusion

Among the 205 enterprises evaluated using the Beneish TR model, 116 enterprises have no evidence of any financial manipulation, 16 enterprises are likely to engage in financial manipulation, 37 enterprises have serious findings for financial manipulation and 36 enterprises have very important findings for financial manipulation.

According to Multinominal Logit and Multinominal Probit findings, Trade Receivables Index (TRI), Gross Profit Margin Index (GPM), Asset Quality Index (AQI), Depreciation Index (AMI), Marketing, Selling, Distribution and General Administrative Expenses Index (PSE) and Stocks to Gross Sales Index (SSI) variables are statistically significant on the probability of financial manipulation. In particular, the Gross Profit Margin Index (GPM) and Trade Receivables Index (TRA) are the most important variables that decrease and increase the probability of financial manipulation, respectively.

There is no study examining the manufacturing industry sector in Turkish in 2022-2023 using Beneish TR, Multinominal Logit, and Multinominal Probit models. This situation constitutes the originality of the study. The study includes more models and more businesses than similar ones. In particular, the marginal effects of the manipulation of variables and the classification success of the models were evaluated with the Multinominal Logit and Multinominal Probit models in this study. In addition to those mentioned above, the current data set, the relevant sector, and the analysis methods used in the specified years have not been examined before and it is thought that the study will contribute to the Turkish literature in line with the results obtained.

It is suggested that the variables found to be statistically significant on the probability of financial manipulation should be taken into consideration by investors, auditors, and related persons in order to understand the manipulation situation, especially the Gross Profit Margin Index (GPM) variable that reduces the probability of financial manipulation and the Trade Receivables Index (TRAI) variable that increases the probability of financial manipulation should be emphasized.

Ekonomi, Politika & Finans Araştırmaları Dergisi, 2025, 10(1): 389-411
Journal of Research in Economics, Politics & Finance, 2025, 10(1): 389-411
Araştırma Makalesi / Research Article, https://doi.org/10.30784/epfad.1616780

TÜRKİYE'DE ÇALIŞANLARDAKİ MADDİ YOKSUNLUĞUN ÇOK BOYUTLU ANALİZİ*

Multidimensional Analysis of Material Deprivation among Employees in Turkey

Tülin TURGUT** & **İsmail ÇAKMAK*****

Öz

Maddi yoksunluk, yaşanılan ülkenin ekonomik şartlarına göre temel ihtiyaçların yeterli düzeyde karşılanamaması ve arzu edilen yaşam koşullarından uzak kalınması olarak değerlendirilir. Bu doğrultuda, çalışan bireylerin maddi yoksunluklarının diğerlerine kıyasla daha az olduğu düşünülebilir fakat çalışan bireylerdeki maddi yoksunluk riski de oldukça yüksektir. Sebepleri ve belirleyicileri araştırılarak çalışan bireylerdeki maddi yoksunluğa sebep olan faktörler tespit edilip, riskler azaltılabilir. Bu bağlamda çalışmada TÜİK 2013-2018 ve 2022 Gelir ve Yaşam Koşulları Araştırması mikro veri setleri kullanılarak Türkiye'de çalışan bireylerdeki maddi yoksunluk olgusu çok yönlü olarak analiz edilmiştir. Çalışmanın ilk fazında çalışanların sosyo-ekonomik, demografik ve çevresel faktörlerinin maddi yoksunlukta ayrıştırıcı bir etkisinin olup olmadığına odaklanılmıştır. İkinci fazda çalışılan sektörlere, üçüncü fazda ise mesleklere ve çalışılan pozisyonlara odaklanılarak maddi yoksunluk yaşama olasılığında sektörel ve mesleki bir ayrışmanın olup olmadığı tespit edilmeye çalışılmıştır. Yapılan logit ve marjinal etkiler analizler sonuçları, Türkiye'de çalışan bireylerin maddi yoksunluk yaşama olasılıklarının yaş, cinsiyet, medeni hal, eğitim durumu, sağlık durumu ve gelir gibi sosyo-ekonomik ve demografik faktörler, çalışılan sektörler ve meslekler özelinde farklılaştığını ortaya koymuştur. Çalışmanın sonuçları ayrıca, pandemi ve son dönem ekonomik görünümün çalışan maddi yoksunluğunda etkili olduğunu göstermiştir. Çalışmanın sonucunda, üç fazda incelenen çalışan maddi yoksunluğuna ilişkin analiz sonuçları tartışılmış ve çeşitli öneriler sunulmuştur.

Anahtar Kelimeler: Maddi Yoksunluk, Logit Model, Gelir ve Yaşam Koşulları Araştırması

JEL Kodları: I32, C51, D31, J21.

Abstract

Material deprivation is assessed as the inability to meet basic needs at an adequate level and staying away from desired living conditions according to the economic conditions of the country in which one lives. In this context, it may be presumed that the material deprivation of working individuals is less than others, but the risk of material deprivation in working individuals is also quite high. These risks can be reduced by investigating the reasons and determinants and identifying the factors that cause material deprivation in working individuals. In this context, this study analyzed the phenomenon of material deprivation in working individuals in Turkey in a multi dimensions using the micro data sets of the TURKSTAT 2013-2018 and 2022 Income and Living Conditions Survey. The first phase of the study focused on whether the socio-economic, demographic, and environmental factors of employees had a differentiating effect on material deprivation. The second phase examined the sectors in which these individuals work, while the third phase investigates professions and positions held, aiming to identify any sectoral and occupational disparities in the likelihood of experiencing material deprivation. The results of the logit and marginal effects analyses revealed that the probability of individuals working in Turkey experiencing material deprivation varies according to socio-economic and demographic factors such as age, gender, marital status, education status, health status, and income, as well as the sectors and professions in which they work. The results of the study also showed that the pandemic and the recent economic conditions were a significant impact on employee material deprivation. The study is concluded with a discussion of the results concerning material deprivation among workers across the three phases, alongside various recommendations.

Keywords: Material Deprivation, Logit Model, İncome and Living Conditions Research

JEL Codes: I32, C51, D31, J21.

* Bu makale "Türkiye'de Çalışan Bireylerdeki Maddi Yoksunluğun Belirleyicileri: Mikro Veri Analizi" adlı yüksek lisans tez çalışmasından türetilmiştir.

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Makale Geliş Tarihi (Received Date): 09.01.2025 Makale Kabul Tarihi (Accepted Date): 17.03.2025

1. Giriş

Yoksulluk, geçmişten günümüze en önemli toplumsal olgulardan birisidir. Bireylerin yüksek refah seviyesi, huzurlu ve yaşanabilir bir hayata sahip olabilmesi için, özellikle bazı ülkelerde ve bazı zamanlarda yoksullukla mücadele etmesi gerekmektedir. Yaşanılan ülkenin ekonomik düzeyine bağlı olarak yoksulluk ile mücadele etme düzeyi de değişmektedir. Uzun yıllardır varlığını sürdüren yoksulluk, küresel bir tehdit haline gelmiştir. Yoksulluk insanlığı fiziksel, psikolojik ve kültürel açıdan da olumsuz yönde etkilemektedir. Yoksulluk kavramı temelde gelire dayalı algılansa da bunun çok daha ötesinde farklı boyutlara dayanmaktadır. Yoksulluk, yalnızca ekonomik durumu ifade etmemekte, aynı zamanda insan onuruna saygı gösterilmemesi, insani hak ve özgürlüklerden yoksun olma ve fırsatların sınırlı olduğu durumları da ifade etmektedir.

Yoksulluğun mutlak, göreli, insani ve çok boyutlu yoksulluk gibi çeşitli türleri bulunmaktadır. Bu tanımlamalardan mutlak yoksulluk, insanların en temel ihtiyaçlarını karşılayabilmesi için sahip olması gereken en düşük gelir seviyesine ulaşamama durumu olarak tanımlanmaktadır. (Erdem, 2006). Göreli yoksulluk ise bireylerin bulunduğu topluma kıyasla belli bir yoksulluk oranının altında kalması şeklinde kısaca ifade edilebilir (Altan, 2004) Çok boyutlu yoksulluk ise geliri doğrudan denklemin dışına çıkarmakta ve yoksulluğu eğitim, sağlık ve yaşam koşulları boyutlarında analiz etmektedir. Alkire ve Foster (2011) tarafından geliştirilen çok boyutlu yoksulluk endeksi, yukarıda açıklanan üç temel boyutu eşit ağırlıklandırmakta ve böylece endekse konu olan hiçbir boyutun bir diğerinden ne daha önemli ne de daha önemsiz olduğunu vurgulamaktadır.

Yukarıda açıklanan yoksulluk tanımlamalarının dışında, bu çalışma çalışanların maddi yoksunluğa odaklanmaktadır. Maddi yoksunluk Stankovičová vd. (2013) tarafından gelişmiş ve gelişmekte olan ülke şartları ele alınarak arzu edilen yaşam standardına ve refah düzeyine sahip olabilmek için gerekli mal ve hizmetleri satın alabilmeye dayanan bir kavram olarak tanımlanmıştır. Bunun yanında, toplumda en basit ve/veya gündelik faaliyetlerde yer alamama, arzu edilen tüketime ulaşamama gibi durumlar da maddi yoksunluk olarak tanımlanmaktadır (Fusco vd., 2010).

Maddi yoksunluk bireyin makul refah düzeyini devam ettirebilmek için önceliklerinin ne olduğu ve bireyin durumu el verdiğinde karşılayabileceği ancak günümüz şartlarında karşılayamadıkları şeklinde ele alınmaktadır (Kaygısız, 2023). Maddi yoksunluk kavramına yönelik yapılan çalışmalar yirminci yüzyılın sonlarına doğru artmıştır. Özellikle Avrupa ülkelerinin maddi yoksunluk ölçümleri için yoksulluk ve sosyal dışlanmadan faydalandığı görülmektedir (Ünver ve Alkan, 2020). Türkiye İstatistik Kurumu (TÜİK, 2021) Gelir ve Yaşam Koşulları Araştırması (GYKA) tanımına göre; "çamaşır makinesi, renkli televizyon, araba sahipliği, beklenmedik harcamalar, evden uzakta bir hafta tatil, kira ödemesi, konut kredisi, borç ödemeleri, iki günde bir et yiyebilme, balık içeren yiyecek ve evin ısınma" ihtiyaçlarının yeterince karşılayamayan haneler, "maddi yoksun" olarak belirtilmektedir. Söz konusu dokuz maddeden en az dördünü karşılayamayan haneler "ciddi maddi yoksun", en az üçünü karşılayamayan haneler "maddi yoksun" şeklinde ifade edilmektedir (TÜİK, 2021). 2021 yılından sonra maddi yoksunluk revize edilerek yanına sosyal yoksunluk da dahil edilmiştir. Maddi ve sosyal yoksunluk hane düzeyinde sorulan 7 madde ile "otomobil sahipliği, ekonomik olarak beklenmedik harcamaları yapabilme, evden uzakta bir haftalık tatil masrafını karşılayabilme, kira, konut kredisi ve faizli borçları ödeyebilme, iki günde bir et, tavuk, balık içeren yemek yiyebilme, evin ısınma ihtiyacını

karşılayabilme ve yeni eklenen mobilyaları eskidiğinde değiştirebilme" takip edilmektedir. Daha önceleri sorulan çamaşır makinesi, renkli televizyon ve telefon sahipliği seçenekleri tanımlamadan çıkarılmıştır. Söz konusu fert düzeyinde yeni eklenen 6 madde ile birlikte TÜİK on üç maddeden en az yedisini karşılayamayanları yoksun olarak sınıflandırmaktadır. Fert düzeyinde yeni eklenenler ise Tablo 1'de sunulmuştur (TÜİK, 2022).

Tablo 1. Maddi Yoksunluk (Fert) Anket Soruları

Maddi Yoksunluk
- Eskimiş giysilerinizin yerine yeni giysiler alabilir misiniz? (ikinci el olmayan)
- Biri günlük kullanıma uygun olmak üzere; düzgün iki çift ayakkabınız var mı?
- Ayda en az bir kere arkadaşlarınız, aileniz/akrabalarınızla yemek yemek veya bir şeyler içmek için evde veya dışarıda (lokanta, pastane, kafe vb. yerlerde) bir araya gelir misiniz?
- Spor, sinema, konser gibi boş zaman faaliyetlerine (ücret ödeyerek) düzenli olarak katılır mısınız?
- Çoğu hafta küçük bir miktar parayı kendinizi iyi hissettirmek için (kendiniz için bir şey almak/yapmak gibi) harcar mısınız?
- Evde kişisel amaçlı kullanımınız için internet erişiminiz var mı? (Cep telefonu, wireless, video oyun konsolu, dizüstü/masaüstü bilgisayar, TV vb. aracılığıyla)

Bireylerin satın alma potansiyeline sahip olsa da sosyal dışlanmalara maruz kalarak istedikleri hayattan mahrum kalmaları da maddi yoksunluk riskini arttırmaktadır (Hick, 2013). Dışlanmanın en bilinen nedenlerinin yoksulluk ve maddi yoksunluk olduğu vurgulanmaktadır (Şahin, 2009). Çok boyutlu yoksulluk, sosyal yaşamdan kopukluk ve toplum dışına itilme sosyal dışlanmayı doğurmaktadır. Maddi yoksunluk ile ilgili yapılan araştırmaların başında yoksulluk ve finansal yetersizlik gelmektedir. İşsizlik, ekonomik büyüme, düzensiz ve hızlı yükselen vergiler, krizler ve enflasyon gibi parametreler, maddi yoksunluğun ekonomik nedenlerinden bazılarıdır (Addabbo vd., 2015; Giugni ve Grasso, 2016; Özdamar vd., 2021).

Yukarıda da açıklandığı üzere çalışmada esas üzerinde durulan grup çalışanlardır ve çalışanların maddi yoksulluk yaşayıp yaşamadığının analizidir. Çalışmayanlara kıyasla maddi olarak refah seviyesi daha yüksek olarak algılanan çalışan bireylerin ilk bakışta maddi yoksunluk yaşamadığı ve/veya daha az yaşadığı düşünülebilir. Fakat çalışan bireylerin de maddi yoksunluk yaşayıp yaşamadığı, çalışanların sosyo-ekonomik ve demografik özelliklerinin maddi yoksunlukta belirleyici olup olmadığı, çalışılan sektörün ve meslek grubunun maddi yoksunluktaki etkisi de ayrıca incelenmelidir. Bu bağlamda, çalışmada çalışanların maddi yoksunlukları üç ayrı fazda analiz edilmiştir. İlk olarak sosyo-ekonomik ve demografik özelliklere odaklanılarak çalışan bireylerin eğitim, yaş, medeni durum, cinsiyet gibi özelliklerinin maddi yoksunlukta belirleyici olup olmadığı analiz edilmiştir. İkinci olarak, çalışılan sektörlerin maddi yoksunlukta ayrıştırıcı bir etkisinin olup olmadığına odaklanılmıştır. Son olarak ise çalışan bireylerin çalıştıkları pozisyonların ve/veya meslek gruplarının maddi yoksunluk yaşayıp yaşamamada anlamlı bir ayrıştırıcı gücünün olup olmadığı analiz edilmiştir. Böylece çalışma, çalışan bireylerin maddi yoksunluğunu çok boyutlu ve her yönüyle analiz etmeye odaklanmıştır. Ayrıca çalışmada birden fazla yıla odaklanılarak, yukarıda açıklanan boyutlarda incelenen maddi yoksunluğun, yıllar içindeki seyri de takip edilebilmiştir. Bu çalışma altı bölümden oluşmaktadır. Çalışmanın ikinci bölümünde ilgili literatür sunulmuştur. Çalışmanın üçüncü bölümünde veri, dördüncü bölümünde yönteme dair bilgilere yer verilmiştir. Çalışmanın beşinci bölümünde ise yapılan analizlerinin bulguları sunulmuş, son bölümde ise elde edilen bulgular tartışılmıştır.

2. Literatür İncelemesi

Alan yazınında Türkiye'de ve dünyada maddi yoksunluğunun belirleyicilerini araştıran çalışmalar mevcuttur. Literatürde, hanelerin maddi yoksunluğunu inceleyen çalışmaların bireylere kıyasla daha fazla olduğu görülmüştür. Çalışmada, bireylerin maddi yoksunluğu ile ilgili literatürün yanında hane ve birey bazlı maddi yoksunluk literatürü de incelenmiştir.

Canbay ve Selim (2010), Türkiye'de kent ve kırsal hanehalkının yoksulluk düzeyini ve işsiz bireylerin maddi yoksunluklarını logit model ile incelemişlerdir. Çalışma sonucunda gelir ve eğitim düzeyindeki artışın maddi yoksunluğu ve gelirden yoksunluğu azaltıcı yönde önemli derecede etkisi olduğu sonucuna ulaşmışlardır. Karadağ ve Saraçoğlu (2015), eğitim düzeyinde meydana gelen düşüşün maddi yoksunluk çekme riskini artırdığını tespit etmişlerdir. Karcı ve Arlı (2018), hanehalkı düzeyinde maddi yoksunluğu etkileyen demografik faktörleri inceledikleri çalışmanın sonucunda, hanede sağlık problemlerin fazla olması, düşük eğitim düzeyini ve yeterli ısıya ulaşabilmek için daha az odaya sahip olanların maddi yoksunluk yaşama olasılıklarının daha yüksek olduğunu ve maddi yoksunlukta en yoğun bölgenin Güneydoğu Anadolu Bölgesi olduğu sonucuna ulaşmıştır. Ünlü (2020), çalışmasında Türkiye'de batıdan doğuya gidildikçe ekonomik kalkınmada farklılık yaşandığını belirtmiştir. Bodur ve Kumaş (2021) ise çalışmada emeklilik ile işgücü piyasasına yeniden katılmanın maddi yoksunluk yaşama olasılığını üzerindeki etkilerini analiz etmişlerdir. Lojistik regresyon analizi sonucuna göre erkeklerin kadınlara kıyasla emeklilikten sonra işgücü piyasasına dönme olasılıklarının yüksek olduğunu, emeklilikten önce de maddi yoksunluk çeken bireylerin emeklilikten sonra çalışma olasılığı düşük iken, emeklilikte yüksek gelire sahip bireylerin çalışma olasılığının daha yüksek olduğu sonucuna varmışlardır. Kapar (2023), yoksulluk ve maddi yoksunlukla mücadele için istihdam sağlanarak, çalışan bireylerin sayısının arttırılması gerektiğini vurgulamıştır.

Literatür incelendiğinde, eğitim düzeyinin maddi yoksunluk üzerindeki etkisini ortaya koyan çalışmalar mevcuttur. Örneğin Uğur (2023), eğitim düzeyinin düşük olmasının maddi yoksunluk yaşam olasılığını arttırdığını ve eğitim düzeyinin yüksek olmasının maddi yoksunluk riskini azalttığını tespit etmiştir. Ünver ve Alkan (2020), ise çalışmalarında çok değişkenli probit regresyon modeli kullanmışlar ve çalışmanın sonucunda bireylerin eğitim ve gelir düzeyi arttıkça maddi yoksun olma olasılıklarının azaldığı sonucuna varmışlardır. Eğitimin yanı sıra cinsiyet faktörünün de maddi yoksunluğu azaltıcı veya arttırıcı etkileri görülebilmektedir. Örneğin Hick (2013), çalışmasında hanehalkı reisinin kadın olduğu durumlarda maddi yoksunluğun azaldığını vurgulamaktadır.

Whelan ve Maitre (2012), maddi yoksunluğun sadece gelir düzeyi ile belirlenmemesi gerektiğini savunmuşlardır. Nelson (2012), sosyal yardımlar ile maddi yoksunluk arasındaki ilişkiyi incelemiştir. Çok düzeyli lojistik regresyon modeli kullanılan çalışmanın sonucunda, sosyal yardımlar ile maddi yoksunluk arasındaki ilişkinin negatif yönlü olduğu tespit edilmiştir. Diğer önemli bir faktör olan eğitimde ise Nelson (2012), Avrupa ülkelerinde yapılan araştırmalar sonucunda eğitim düzeyinin artmasının maddi yoksunluk riskini önemli ölçüde azalttığını vurgulamıştır. Soltes ve Ulman (2015), çalışmalarında lojistik regresyon modeli ile Slovakya ve Polonya'yı karşılaştırmışlardır. Çalışmada, işsiz hane reisinin işi olana kıyasla daha fazla maddi yoksunluk çektiğini tespit etmişlerdir. Ayrıca çalışmada, Slovakya'ya kıyasla Polonya'da işsiz hane reisinin daha fazla olduğu tespit edilmiştir. Bu nedenle Polonya'daki hanelerin Slovakya'ya oranla maddi yoksunluk riskinin daha yüksek olduğu tespit edilmiştir. Deutsch vd. (2015) çalışmalarında AB ülkelerinin yaşamış olduğu maddi yoksunluğu ve maddi yoksunluğun

kısıtladığı harcamaların neler olduğunu araştırmıştır. Çalışma sonucunda Avrupa Birliği ülkeleri bir bütün olarak ele alındığında hanelerin ilk önce yıllık tatillerini, yeni mobilyalarını, eğlence ve sosyal aktivitelerini azalttığı sonucuna ulaşılmıştır. Dudek (2019), maddi yoksunluğu AB ülkeleri düzeyinde inceleyerek, hanehalkının gelir durumunun, maddi yoksunluk oranını tespit etmede önemli rol oynadığı belirtmiştir. Çalışmanın sonuncunda hanehalkı gelirinin artmasının maddi yoksunluğu azaltabileceği sonucuna ulaşmıştır.

Toge ve Bell (2016) sağlık durumu kötü veya çok kötü olan bireylerin maddi yoksunluk çekme riskinin fazla olduğu sabit etkiler logit analizi ile ortaya koymuşlardır. Guio vd. (2016), sağlık ile maddi yoksunluk arasında güçlü bir ilişkinin söz konusu olduğunu, Beck vd. (2019) ise, sağlık hizmetlerinin iyileştirilmesinin maddi yoksunluğu azalttığını ortaya koymuşlardır.

Nikoloski, (2021) çalışmasında 2015 yılında Makedonya'daki maddi yoksunluğa neden olan etkenleri araştırmıştır. Çalışmanın sonucunda asgari ücretin arttırılması, gerekli sosyal yardımların yapılması ve eğitim düzeyinin yükselmesinin maddi yoksunluğu azaltıcı etkisini tespit edilmiştir. Önceki çalışmalara benzer olarak söz konusu çalışma da eğitim düzeyinin düşük olmasının maddi yoksunluk çekme olasılığını arttırdığını vurgulamaktadır. Tüm bu bilgilerin ışığında, mevcut çalışmalar, bireyin eğitim düzeyinin, istihdamda olma durumunun, sağlık durumunun ve demografik özelliklerinin maddi yoksunluk üzerinde etkili olduğunu göstermektedir. Bu çalışma da Türkiye'deki sosyo-ekonomik ve demografik faktörlerin, çalışan bireylerin maddi yoksunlukları üzerinde anlamlı bir farklılaşma yaratıp yaratmadığına odaklanmaktır. Fakat mevcut literatüre ek olarak çalışma, çalışan maddi yoksunluğuna sadece sosyo-ekonomik ve demografik faktörler özelinde yoğunlaşmamakta, bunun yanında çalışılan sektörlerin ve mevcut işteki çalışılan pozisyonun da maddi yoksunluktaki etkilerini araştırmaktadır. Çalışma böylece çalışan maddi yoksunluğunun belirleyicilerini bütüncül ve çok boyutta ele almayı amaçlamaktadır. Tüm bunlara ek olarak çalışma, Türkiye'deki çalışanların maddi yoksunluklarını geniş bir yıl skalası içinde inceleyerek, yıllar içinde maddi yoksunluğun belirleyicilerinin dramatik olarak değişip değişmediğini tespit etmeye de çalışmaktadır.

3. Veri

Çalışmada, TÜİK'in 2013, 2018 ve 2022 yıllarına ait GYKA Fert Kayıt ve Fert veri setleri kullanılmıştır. Çalışmanın bağımlı değişkenini elde etmek için, ilgili veri setlerindeki "maddi yoksunluk" bölümlerinden faydalanılmıştır. Tablo 1'de bulunan sorulara, bireylerin evet, hayır (maddi yetersizlik) ve hayır (diğer nedenler) olmak üzere üç farklı kategoride cevap vermeleri beklenmektedir. Çalışmada "hayır-diğer nedenler" cevabı çıkarılmış ve sorulara "evet" veya "hayır (maddi yetersizlik)" cevaplarını veren bireylere ilişkin veriler kullanılmıştır. Çalışmanın bağımlı değişkeni "maddi yoksunluk" oluşturulurken, Tablo 1'deki sorulardan en az dört tanesine hayır (maddi yetersizlik) cevabını verenler "maddi yoksun" olarak değerlendirilerek 1 değeri verilmiştir. Çalışmanın giriş bölümünde ifade edildiği üzere TÜİK (2022), Türkiye'de maddi yoksunluğu bütüncül bir şekilde analiz ederken fert ve hane düzeyinde olmak üzere toplam on üç soru yöneltmekte ve bu sorulardan en az yedi tanesine olumsuz cevap verenleri maddi yoksun olarak belirtmektedir. Buradan TÜİK'in maddi yoksunluktaki kıstasının, belirtilen sorulardan yarıdan fazlasına -bir başka değişle çoğunluğuna- olumsuz cevap verilmesi olduğu görülmektedir. Mevcut çalışma, çalışanlara ve çalışanların bireysel parametrelerine odaklandığından ve ilgili veri setlerinde fert bazlı maddi yoksunluğu tespit etmeye yönelik altı soru sorulduğundan, ilgili soruların en az dört tanesine olumsuz cevap verenler çalışmada maddi yoksun olarak kabul

edilmiştir. Böylece çalışma, TÜİK'in (2022) belirlediği yarıdan fazlasına olumsuz cevap verme sistematiğini de takip etmeyi amaçlamıştır.

Daha önceki bölümlerde de ifade edildiği üzere bu çalışma, çalışan bireylerdeki maddi yoksunluğu üç fazda analiz etmektedir. Bahsedildiği üzere, çalışmada sadece çalışan bireylere odaklanıldığından, ilgili veri setlerindeki ferdin şu anki istihdam durumlarına ilişkin sorularda sadece ücretli, maaşlı veya yevmiyeli (tam ve yarı zamanlı) çalıştığını beyan eden bireyler çalışma kapsamına dahil edilmiştir. Böylelikle çalışmada, 2013 yılı için 6317, 2018 yılı için 7049 ve 2022 yılı için 6213 çalışan bireye ait veriler analiz edilmiştir.

Maddi yoksunluk analizlerindeki birinci basamak sosyo-ekonomik ve demografik farklılıkların analizidir. Bu bağlamda ilgili fazın bağımsız değişkenleri yaş, cinsiyet, medeni durumu, eğitim durumu, sağlık durumu, kronik hastalığın olup olmaması ve gelir düzeyi olarak belirlenmiştir. Bağımsız değişkenlerden biri olan cinsiyet değişkeninde kadınlara 1, erkeklere ise 0 değeri verilmiştir. Çalışmada yaş iki ayrı aralıkta ele alınmıştır. Yaş aralığı belirlenmesinde Santrock'un (2001) gelişim dönemleri dikkate alınmıştır. Buna göre çalışmada 45 yaş ve üzerindeki bireylere 1, 18-44 yaş arasındaki genç yetişkinlere ise 0 değeri verilmiştir. Medeni hal değişkeni ise bekar, evli, eşi öldü veya boşandı kategorilerinden oluşmaktadır. Çalışmanın bağımsız değişkenlerinden biri olan sağlık durumu "çok iyi/iyi, orta ve çok kötü/ kötü" olarak üç kategoride ele alınmıştır. Bir diğer bağımsız değişken olan "kronik", bireylere yöneltilen "kronik bir hastalığının olup olmaması" sorusundan türetilmiştir. Kronik değişkeninde "kronik bir hastalığının olup olmaması" sorusuna "evet" cevabını verenlere 1, "hayır" cevabını verenlere ise 0 değeri verilmiştir. Bir başka bağımsız değişken olan eğitim düzeyi değişkeninde ise okur-yazar olmayan ve bir okul bitirmedi cevaplarını tek bir başlık altında toplanarak "okur-yazar olmayan" olarak belirtilmiştir. Yine benzer bir şekilde ilkokul, ilköğretim, ortaokul ve dengi olanlar "ilköğretim" olarak, genel lise ve mesleki lise "lise", yüksekokul, fakülte, yüksek lisans ve doktora ise "lisans ve üzeri" adı altında toplanmıştır.

Bağımlı ve bağımsız değişkenlerin değerlerine ilişkin gözlem ve yüzdeler Tablo 2'de verilmiştir. Araştırmaya katılan çalışanların sosyo-ekonomik ve demografik özelliklerine ilişkin gözlem ve yüzde dağılımı incelendiğinde, çalışmada analiz edilen yılların tamamında ücretli maaşlı veya yevmiyeli çalışan bireylerin daha çok 18-44 yaş aralığında olduğu göze çarpmaktadır. İncelenen yıllar cinsiyet özelinde değerlendirildiğinde, yıllar içinde aradaki fark azalsa da erkek çalışan oranın kadınlara nazaran oldukça yüksek olduğu görülebilmektedir. Medeni durumlarına göre evlilerin, sağlık durumlarına göre ise iyi olduğunu beyan edenlerin sayısının diğerlerine kıyasla fazladır. Ancak çalışan bireylerin eğitim durumları incelendiğinde okur-yazar olmayan ve ilköğretim mezunu olan çalışan bireylerin oranı yıllar içinde azalmış, buna karşın lise ve en az üniversite mezunu olan çalışan bireylerin oranı ise artmıştır. Cinsiyet ve eğitim düzeyi beraber değerlendirildiğinde, incelenen tüm yıllarda en çok kadın çalışanın lisans ve üzeri mezunu seviyesinde olduğu görülmektedir (sırasıyla %46, %60 ve %64). Öte yandan erkeklerde ise eğitim durumuna göre en çok çalışanın 2013 yılında ilköğretim seviyesinde iken (%40), 2018'de %46 ve 2022'de yaklaşık %49 olmak üzere lisans ve üzerin mezuniyet seviyesindedir. Kronik hastalığı olan bireylerin yıllar içinde çalışanlar içindeki oranı gerilemiştir. 2013 yılından 2018 yılına kadar bireylerin maddi yoksun olma durumunda ciddi oranda düşüş meydana geldiği görülebilmektedir.

Tablo 2. Sosyo-Ekonomik ve Demografik Özelliklerine İlişkin Gözlem ve Yüzde Bilgileri

	2013		2018		2022	
Değişkenler	**Gözlem**	**Yüzde**	**Gözlem**	**Yüzde**	**Gözlem**	**Yüzde**
Maddi Yoksunluk						
Evet	1990	31.50	514	7.29	641	10.32
Hayır	4327	68.50	6535	92.71	5572	89.68
Cinsiyet						
Kadın	1718	27.20	2361	33.49	2112	33.99
Erkek	4599	72.80	4688	66.51	4101	66.01
Yaş						
44 ve altı	5285	83.66	5973	84.74	5151	82.91
45+	1032	16.34	1076	15.26	1062	17.09
Medeni Durum						
Evli	4358	68.99	4500	63.84	3935	63.33
Bekar	1693	26.80	2195	31.14	1959	31.53
Eşi öldü / Boşandı	266	4.21	354	5.02	319	5.13
Eğitim Durumu						
Okur-yazar olmayan/Okul bitirmeyen	380	6.02	188	2.67	159	2.56
İlköğretim	2519	39.88	1958	27.78	1463	23.55
Lise	1456	23.05	1693	24.02	1568	25.24
Lisans ve üzeri	1962	31.06	3210	45.54	3023	48.66
Sağlık Durumu						
Kötü	267	4.23	152	2.16	105	1.69
Orta	888	14.06	813	11.53	823	13.25
İyi	5162	81.72	6084	86.31	5285	85.06
Kronik Hastalık						
Evet	1192	18.87	1240	17.59	1037	16.69
Hayır	5125	81.13	5809	82.41	5176	83.31
Toplam Gözlem	6317		7049		6213	

Çalışmanın ikinci fazında çalışılan sektörün maddi yoksunlukta bir ayrıştırıcı etkisinin olup olmadığı analiz edilmiştir. Bu bağlamda çalışmada, ilgili veri setlerinde NACE REV-2 sınıflandırma sistemine göre esas iş bilgileri kullanılmıştır. Çalışma kapsamındaki analizler, imalat, inşaat, eğitim, sağlık ve hizmet sektörleri odağında gerçekleştirilmiştir. Hizmet sektörü, ulaştırma ve depolama, konaklama ve yiyecek hizmeti faaliyetleri, bilgi ve işlem, finans ve sigorta faaliyetleri, insan sağlığı ve sosyal hizmet faaliyetleri, kültür, sanat, eğlence, dinlence ve spor ve diğer faaliyetlerin toplulaştırılmasından oluşmaktadır. Çalışmada analiz edilen sektörlere ilişkin gözlem ve yüzde bilgileri Tablo 3'te sunulmuştur.

Tablo 3. Bireylerin Çalıştıkları Sektörlere İlişkin Gözlem ve Yüzde Bilgileri

	2013		2018		2022	
Değişkenler	**Gözlem**	**Yüzde**	**Gözlem**	**Yüzde**	**Gözlem**	**Yüzde**
İmalat	1275	20.18	1463	20.75	1249	20.10
İnşaat	658	10.42	471	6.68	361	5.81
Eğitim	716	11.33	904	12.82	864	13.91
Sağlık	404	6.40	584	8.28	539	8.68
Hizmet	1485	23.51	1716	24.34	1478	23.79

Sektörlere ilişkin gözlem ve yüzde oranı sonuçlarına göre 2013, 2018 ve 2022 yıllarında en çok çalışanın olduğu sektörün hizmetler sektörü olduğu görülebilmektedir. İncelenen sektörler

arasında en az çalışan ise sağlık hizmetleri alanındadır. Cinsiyet ve çalışılan sektör beraber değerlendirildiğinde 2013 yılında hizmetler sektöründe çalışanların yaklaşık yüzde 37'si kadınlardan oluşmakta iken bu oran 2022 yılına gelindiğinde yaklaşık yüzde 43'e yükselmiştir. Öte yandan, sağlık sektöründe 2013 yılında çalışanların yüzde 68'i kadınlardan oluşmak iken, 2022 yılına gelindiğinde oran yüzde 66'ya gerilemiştir.

Çalışma kapsamında en son olarak, maddi yoksunluğun çalışanların profesyonel meslekleri özelinde farklılaşıp farklılaşmadığı analiz edilmek istenmiştir. Bu bağlamda ilgili veri setlerinde ISCO-08 meslek sınıflandırılmasına göre meslek grupları esas alınmıştır. Buna göre, yöneticiler, hizmet ve satış elemanları, profesyonel meslek mensupları, sanatkârlar ve nitelik gerektirmeyen işlerde çalışanlar çalışma kapsamında analiz edilmiştir. Mesleklere ilişkin gözlem ve yüzde bilgileri Tablo 4'te verilmiştir.

Tablo 4. Çalışılan işteki Meslek ve Pozisyonlara İlişkin Gözlem ve Yüzde Bilgileri

	2013		2018		2022	
Değişkenler	**Gözlem**	**Yüzde**	**Gözlem**	**Yüzde**	**Gözlem**	**Yüzde**
Yönetici	304	4.81	489	6.94	361	5.81
Profesyonel	1117	17.68	1696	24.06	1650	26.56
Hizmet. satış	1222	19.34	1329	18.85	1160	18.67
Sanatkârlar	978	15.48	829	11.76	656	10.56
Nitelik Gerektirmeyen	946	14.98	642	9.11	643	10.35

Çalışmada kapsamındaki verilerden hareketle gözlem ve yüzde oranlarına göre, 2013, 2018 ve 2022 yıllarında en çok çalışanın olduğu meslek grubunun hizmetler ve satış elemanları olduğu görülebilmektedir. Meslekler arasında en az katılımcıya sahip grubun ise yöneticiler olduğu tespit edilmiştir. Yıllar içerisinde diğerlerine oranla en fazla yükseliş yaşayan meslek grubu ise profesyonel meslek mensupları olmuştur. Çalışılan pozisyon ve cinsiyet beraber değerlendirildiğinde ise herhangi bir işyerinde yönetici olarak çalışanlar içinde kadınların oranı 2013 yılında yüzde 16 iken, 2022 yılına gelindiğinde yaklaşık yüzde 22'ye yükselse de yönetici pozisyonunda çalışan kadınların oranının erkeklere kıyasla oldukça düşük seyrettiği görülmektedir.

4. Yöntem

Çalışmanın baz yöntemi olarak logit model belirlenmiş ve Türkiye'de çalışan bireylerin sosyo-ekonomik ve demografik özellikleri, çalıştıkları sektör ve mesleklerin maddi yoksunluk üzerindeki etkisi tespit edebilmek amacıyla logit yöntemi kullanılmıştır

Logit modelinin basit ekonometrik gösterimi aşağıdaki gibi yapılabilir.

$$y^* = x'\beta + e \tag{1}$$

Denklem (1)'de y^* bağımlı değişkeni ifade etmektedir. β açıklayıcı değişken için tahmin edilecek parametreler, x ise bağımsız değişken olduğunu göstermektedir.

$$P_i = F(Z_i) = F(\alpha + \beta X_i) = \frac{1}{(1 + exp^{-(Z_i)})} = \frac{1}{1 + exp^{-(\alpha+\beta X_i)}} \tag{2}$$

Denklem (2)'de F birikimli olasılık fonksiyonu, a ise sabit katsayısını ve i bağımsız değişkeni ifade etmektedir.

$$L_i = L_n\left[\frac{P_i}{(1-P_i)}\right]=Z_i = \alpha + \beta_1 X_1 + \beta_2 + X_2 + \ldots. + \beta_n + X_n + e_i \quad (3)$$

Denklem (3)'teki L_i , bağımsız değişkenlerin bağımlı değişkenini etki etmesinin herhangi bir etki etmemesine bölümünün logaritmasıdır (Gujarati, 2004).

Marjinal etkilerinin hesaplanması ve analiz edilmesi logit analizinde oldukça önemlidir. Marjinal etkiler analizinin ifade edilmesinde sürekli ve kesikli değişkenler yardımıyla hesaplanmaktadır (Williams, 2018).

Sürekli değişken

$$(\partial P_i/\partial X_{ij})=[\beta_j \exp(-\beta X_{ij})]/[1+\exp(-\beta X_{ij})]^2 \quad (4)$$

Kesikli değişken

$$(\partial P_i/\partial X_{ij}) = P_i(Y_i{:}\, X_{ij}=1) - P_i\big(Y_i{:}\, X_{ij}=0\big) \quad (5)$$

Logit analizlerinin sağlamlığı ve tutarlılığını kontrol etmek amacıyla çalışmada Probit yöntemi de kullanılmıştır. Probit modelin denklemi aşağıdaki denklemde verilmiştir.

$$y^* = x'\beta + e \quad (6)$$

$$\Pr(y=1|x) = \Phi(x'\beta) \quad (7)$$

Denklem (6)'da $\boldsymbol{y}$ kukla değişkeni olasılıklarını vermektedir. Birikimli normal dağılım Φ olasılığını 0 ve 1 arasında belirlenmektedir. Probit modelde logit model yönteminde olduğu gibi katsayıların hesaplanması kadar marjinal etkilerin yorumlanmasının yeri önemlidir.

Marjinal etkiler analizinde, değişkende meydana gelen değişimin $\Pr(y=1|x)$ olarak ifade edilen olasılığı ne yönde etkilediğini gösterirken, diğer tüm değişkenler sabittir şeklindedir. Kısaca bir olayın gerçekleşme olasılığını vermektedir. Böylece probit model denklemi elde edilmiş olur.

5. Bulgular

Çalışmanın bu bölümünde Türkiye'de tam-yarı zamanlı ücretli, maaşlı veya yevmiyeli çalışan bireylerin maddi yoksunluklarını analiz etmek için yapılan logit ve marjinal etkiler analizleri sonuçlarına yer verilmiştir. Çalışma kapsamında kullanılan tüm veriler ve kurulan modeller STATA 14 programı kullanılarak analiz edilmiştir. Türkiye'deki çalışanların maddi yoksunluklarında etkili sosyo-ekonomik ve demografik faktörlerin tespitine yönelik yapılan logit model ve marjinal etkiler analizleri sonuçları Tablo 5'te sunulmuştur. Sonuçlar, incelenen tüm yıllarda cinsiyetin, yaşın, eğitim-sağlık durumunun ve gelirin maddi yoksunluk üzerinde istatistiksel olarak anlamlı düzeyde etkili olduğunu ortaya koymaktadır. Analiz sonucuna göre çalışan kadınların erkeklere, bekarların evlilere ve sağlık durumu iyi olanların kötü olanlara kıyasla maddi yoksunluk yaşama olasılıklarının düştüğü tespit edilmiştir. 45 yaş ve üstündeki çalışan bireylerin ise genç yetişkinlere kıyasla maddi yoksunluk yaşama olasılıklarının arttığı görülmüştür.

Logit analizini takiben yapılan marjinal etkiler analizleri sonuçlarına göre, eğitim düzeyi, medeni hal ve sağlık durumunun çalışan bireylerin maddi yoksunluklarında en etkili parametreler olarak öne çıkmaktadır. Buna göre en az lisans düzeyindeki bir çalışanın bir okul bitirmeyenlere kıyasla maddi yoksunluk yaşama olasılığı 2013 yılında %35, 2018 yılında %13, 2022 yılı %20

oranında azalmaktadır. Medeni hale göre bekar çalışanların evlilere kıyasla maddi yoksunluk yaşama olasılıkları ise 2013 yılında %16, 2018 yılında yaklaşık %5 ve 2022 yılında %7 azalmaktadır. Çalışan bireylerin sağlık durumlarına bakıldığında ise marjinal etkiler analizleri, sağlık durumunun kötü olduğunu beyan eden bireylere kıyasla sağlık durumunu iyi olarak nitelendiren çalışanların maddi yoksunluk yaşama olasılıklarının 2013 yılında %20, 2018 yılında %7 ve 2022 yılında %11 oranında azaldığını ortaya koymaktadır.

Tablo 5. Sosyo-Ekonomik ve Demografik Farklılıkların Maddi Yoksunluğa Olan Etkisinin Logit ve Marjinal Etkiler Analiz Sonuçları

Değişkenler	**2013**		**2018**		**2022**	
Maddi Yoksunluk	**Logit Model**	**Marjinal Etkiler**	**Logit Model**	**Marjinal Etkiler**	**Logit Model**	**Marjinal Etkiler**
Cinsiyet						
Kadın	-0.701***	-0.096***	-0.904***	-0.042***	-.76***	-0.047***
	(0.087)	(0.011)	(0.139)	(0.006)	(0.126)	(0.007)
Yaş: 45+	0.21**	0.030**	0.621***	0.037***	0.118	0.008
	(0.097)	(0.014)	(0.131)	(0.009)	(0.119)	(0.008)
Medeni Durumu						
Bekar	-1.181***	-0.164***	-1.046***	-0.049***	-1.193***	-0.073***
	(0.088)	(0.011)	(0.143)	(0.006)	(0.136)	(0.007)
Eşi ölmüş, boşandı	-0.26	-0.036	0.292	0.016	-0.166	-0.011
	(0.166)	(0.023)	(0.218)	(0.013)	(0.208)	(0.013)
Eğitim Durumu						
İlköğretim	-1.103***	-0.136***	-1.334***	-0.078***	-1.442***	-0.095***
	(0.142)	(0.015)	(0.176)	(0.011)	(0.189)	(0.012)
Lise	-1.955***	-0.262***	-2.564***	-0.114***	-2.28***	-0.148***
	(0.153)	(0.016)	(0.213)	(0.009)	(0.204)	(0.013)
Lisans ve üzeri	-2.862***	-0.345***	-3.291***	-0.125***	-3.377***	-0.198***
	(0.187)	(0.016)	(0.269)	(0.010)	(0.243)	(0.017)
Sağlık Durumu						
Orta	-0.94***	-0.120***	-.677***	-0.031***	-.583**	-0.036**
	(0.187)	(0.021)	(0.242)	(0.010)	(0.259)	(0.014)
İyi	-1.341***	-0.201***	-1.095***	-0.070***	-1.343***	-0.114***
	(0.187)	(0.028)	(0.26)	(0.020)	(0.287)	(0.029)
Kronik	-0.01	-0.001	0.07	0.004	0.128	0.009
	(0.103)	(0.015)	(0.16)	(0.009)	(0.165)	(0.012)
Gelir	-.0001***	-0.00001***	-.0001***	-3.93e-06***	-.00004***	-2.39e-06***
	(5.66e-06)	(7.12e-07)	(6.04e-06)	(3.01e-07)	(2.84e-06)	(1.78e-07)
cons	3.819***		2.452***		3.129***	
	(0.239)		(0.322)		(0.351)	
Gözlem	6317		7049		6213	

Not: Standart hatalar parantez içinde verilmiştir. *, **, *** sırasıyla katsayıların, %1, %5, %10 düzeylerinde istatistiksel olarak anlamlı olduğunu ifade etmektedir.

Tablo 6'da çalışılan sektörlere ilişkin logit model ve marjnal etkileri analizi sonuçlarına yer verilmiştir. 2013 yılı özelindeki logit analizi sonucunda imalat, inşaat, eğitim ve sağlık sektörlerinde çalışmanın maddi yoksunluk üzerinde istatistiksel olarak anlamlı bir etkisinin olduğu görülürken hizmet sektöründe çalışmanın ise maddi yoksunluk üzerinde anlamlı bir

etkisinin olmadığı tespit edilmiştir. 2018 yılında ise imalat ve sağlık alanında çalışmanın maddi yoksunluk üzerinde istatistiksel olarak anlamlı bir etkisi görülmemiştir. Fakat 2022 yılı özelinde tüm sektörlerde çalışan bireylerin maddi yoksunlukta istatistiksel olarak anlamlı bir etkisinin olduğu tespit edilmiştir

Tablo 6. Sektör Farklılıkların Maddi Yoksunluğa Olan Etkisinin Logit ve Marjinal Etkiler Analiz Sonuçları

	2013		2018		2022	
Değişkenler (Sektörler)	**Logit Model**	**Marjinal Etkiler**	**Logit Model**	**Marjinal Etkiler**	**Logit Model**	**Marjinal Etkiler**
İmalat	0.229***	0.048***	0.204	0.014	0.233**	0.022**
	(0.075)	(0.016)	(0.125)	(0.009)	(0.114)	(0.011)
İnşaat	0.973***	0.221***	1.129***	0.110***	1.464***	0.203***
	(0.091)	(0.021)	(0.144)	(0.019)	(0.135)	(0.025)
Eğitim	-1.383***	-0.222***	-1.865***	-0.067***	-1.645***	-0.089***
	(0.133)	(0.015)	(0.328)	(0.006)	(0.255)	(0.008)
Sağlık	-0.42***	-0.080***	-0.292	-0.018	-.582***	-0.043***
	(0.135)	(0.024)	(0.201)	(0.011)	(0.194)	(0.012)
Hizmet	0.02	0.004	0.227*	0.016*	0.294**	0.028**
	(0.08)	(0.017)	(0.134)	(0.010)	(0.123)	(0.012)
cons	-0.808***		-2.628***		-2.263***	
	(0.046)		(0.08)		(0.072)	
Gözlem	6317		7049		6213	

Not: Standart hatalar parantez içinde verilmiştir. *, **, *** sırasıyla katsayıların, %1, %5, %10 düzeylerinde istatistiksel olarak anlamlı olduğunu ifade etmektedir.

Logit analizi sonuçlarına göre, imalat, inşaat ve hizmetler sektöründe çalışan bireylerin diğerlerine kıyasla maddi yoksunluk yaşama olasılıkları yükselmektedir. Yapılan analizler ayrıca, eğitim ve sağlık sektörlerinde çalışan bireylerin diğer sektörlerde çalışanlara kıyasla ise maddi yoksunluk riskinin azaldığını ortaya koymaktadır.

Marjinal etkiler analizlerine bakıldığında, inşaat, eğitim ve sağlık sektörlerinde çalışmanın maddi yoksunluk yaşama olasılığında öne çıkan sektörler olarak dikkat çekmektedir. Sonuçlara göre, inşaat sektöründe çalışan bireylerin diğer sektörlerde çalışanlara kıyasla maddi yoksunluk yaşama olasılıkları 2013 yılında %22, 2018 yılında %11 ve 2022 yılında %20 oranında artmaktadır. Eğitimde çalışanların ise diğer sektörlerde çalışanlara kıyasla maddi yaşama olasılıkları 2013 yılında %22, 2018 yılında %7 ve 2022 yılında %9 oranında azalmaktadır. Sağlık sektöründe çalışan bireylerin diğer sektörlere kıyasla maddi yoksunluk yaşama olasılıkları 2013 yılında %8, 2022 yılında ise %4 oranında azaldığı yapılan analizler neticesinde ortaya konmuştur.

Tablo 7'de çalışılan mesleklere ilişkin logit model ve marjnal etkileri analizi sonuçlarına yer verilmiştir. Tablo 7, yöneticilerin ve profesyonel meslek mensuplarının diğer mesleklere kıyasla maddi yoksunluk yaşama olasılıklarının azaldığını göstermektedir. Nitelik gerektirmeyen işlerde çalışan elemanların diğer mesleklerde çalışanlara kıyasla maddi yoksunluk yaşama olasılıkları ise artmaktadır. Mesleklere ilişkin marjinal etkileri analizi incelendiğinde, yöneticilerin diğer mesleklerde çalışan elemanlara kıyasla 2013 yılında %26, 2018 yılında %7 ve 2022 yılında %8 oranında maddi yoksunluk yaşama olasılığı azalmaktadır. Böylece maddi yoksunluk yaşama olasılığı diğer mesleklere kıyasla en düşük olan mesleğin profesyonel meslek

mensupları olduğu analizler neticesinde ortaya konmuştur. Nitelik gerektirmeyen işlerde çalışan bireylerin diğer mesleklerde çalışanlara kıyasla maddi yoksunluk yaşama olasılıkları 2013 yılında %30, 2018 yılında %17 ve 2022 yılında %20 oranında artmaktadır.

Tablo 7. Meslek Farklılıkların Maddi Yoksunluğa Olan Etkisinin Logit ve Marjinal Etkiler Analiz Sonuçları

	2013		2018		2022	
Değişkenler (Meslekler)	**Logit Model**	**Marjinal Etkiler**	**Logit Model**	**Marjinal Etkiler**	**Logit Model**	**Marjinal Etkiler**
Yönetici	-2.048***	-0.255***	-3.342***	-0.073***	-1.642***	-0.082***
	(0.289)	(0.019)	(1.006)	(0.005)	(0.421)	(0.011)
Profesyonel Meslek	-2.463***	-0.303 ***	-2.503***	-0.077***	-2.323***	-0.108***
	(0.188)	(0.011)	(0.367)	(0.005)	(0.283)	(0.006)
Hizmet ve Satış	0.489***	0.088***	0.557***	0.039***	0.523***	0.048***
	(0.081)	(0.014)	(0.136)	(0.0103)	(0.124)	(0.012)
Sanatkârlar	0.954***	0.177***	1.023***	0.082***	1.069***	0.112***
	(0.084)	(0.016)	(0.139)	(0.0134)	(0.131)	(0.016)
Nitelik Gerektirmeyen	1.571***	0.304***	1.704***	0.166***	1.635***	0.195***
	(0.087)	(0.016)	(0.134)	(0.017)	(0.123)	(0.018)
cons	-1.061***		-2.849***		-2.438***	
	(0.055)		(0.097)		(0.088)	
Gözlem	6317		7049		6213	

Not: Standart hatalar parantez içinde verilmiştir. *, **, *** sırasıyla katsayıların, %1, %5, %10 düzeylerinde istatistiksel olarak anlamlı olduğunu ifade etmektedir

Çalışmada, logit analizleri sonuçlarının sağlamlığını ve tutarlığını kontrol edebilmek maksadı ile her bir boyut özelinde probit analizleri yapılmıştır. Probit analizleri sonuçları, çalışmanın ekler bölümünde sunulmuştur. Probit analizleri sonuçları, logit ve marjinal etkiler analizleri benzeştiğinden, yapılan logit ve marjinal etkiler analiz sonuçlarının çalışan bireylerin sosyo-ekonomik ve demografik özellikleri, çalışılan sektörler ve meslek grupları bağlamında sağlam ve tutarlı sonuçlar verdiğini göstermektedir.

6. Tartışma ve Sonuç

Geçmişten günümüze yoksulluk, ülkelerin ekonomik gelişimine engel olan ve insanlığın yaşamını olumsuz yönde etkileyen önemli bir sorundur. Gelişmişlik seviyesinden bağımsız olarak ülkeler, çeşitli sosyal ve ekonomik politikalar izleyerek yoksullukla mücadele etmektedir. Ancak yoksulluk sınırının altında kalan bölgelere yeterli desteğin sağlanamaması yoksulluk ile mücadelede eksik kalmaktadır. Coğrafi dezavantaj, yetersiz eğitim düzeyi, artan sağlık problemleri ve işsizliğin yüksek olması toplumdaki yoksulluğu arttırabilmektedir (Ünlü, 2020). Özellikle kırsal alanlarda yaşayanlar, kentte yaşayanlara kıyasla yeterli derecede sağlık ve eğitim imkanlarından faydalanamamakta ve bu alanlardan yoksun kalmaktadırlar (Karcı ve Arlı, 2018; Tatlı vd., 2020). Sağlık ve eğitimde yapılacak iyileştirmeler ile bireylerin ihtiyaçlarını yeterli şekilde karşılamaları halinde yoksulluk oranları büyük ölçüde azaltılabilir (İncedal, 2013). Maddi durum, yoksullukta takip edilen parametrelerden birisi olmakla birlikte, yoksullukla mücadele eden bireyin yaşadığı maddi yetersizlik, maddi yoksunluk ve sosyal dışlanmayı da beraberinde getirmektedir.

Türkiye'deki çalışanların yapısı incelendiğinde çoğunluğun tam ve yarı zamanlı ücretli çalışanlardan oluştuğu görülmektedir. Örneğin 2017 yılında Türkiye'deki toplam istihdamın %67,3'ü ücretli ve yevmiyeli çalışanlardan oluşmakta iken (TCMB, 2018), 2017-2019 yılları arasında tarım dışında çalışan ücretlilerin yaklaşık %49'u asgari ücretlidir. Asgari ücretli çalışanların sektörler arasındaki ağırlığı da ayrıca farklılaşmakta ve oranlar imalat için %50, inşaat için yaklaşık %54'lere kadar çıkmaktadır (TCMB, 2021). Türkiye'deki istihdamın genelde ücretli çalışanlar eksenine yoğunlaşması dolayısı ile mevcut çalışma da özellikle tam ve yarı zamanlı olarak ücretli, maaşlı ve yevmiyeli çalışanların maddi yoksunluklarına odaklanmıştır. Böylece çalışmada söz konusu gruplarda maddi yoksunluk yaşama olasılığını arttıran faktörlerin neler olduğu, çalışılan sektörlerin ve işteki pozisyonların maddi yoksunluktaki etkisi tespit edilmeye çalışılmıştır.

Çalışmada, çalışanların maddi yoksunlukları üç ayrı fazda analiz edilmiştir. İlk olarak sosyo-ekonomik ve demografik özelliklere odaklanılarak çalışan bireylerin eğitim, yaş, medeni durum, cinsiyet gibi özelliklerinin maddi yoksunlukta belirleyici olup olmadığı analiz edilmiştir. İkinci olarak, çalışılan sektörlerin maddi yoksunlukta ayrıştırıcı bir etkisinin olup olmadığına odaklanılmıştır. Son olarak ise çalışan bireylerin çalıştıkları pozisyonların ve/veya meslek gruplarının maddi yoksunluk yaşayıp yaşamamada anlamlı bir etkisinin olup olmadığı analiz edilmiştir. Böylece çalışma, çalışan bireylerin maddi yoksunluğunu çok boyutlu ve her yönüyle analiz etmeye odaklanmıştır. Ayrıca çalışmada birden fazla yıla odaklanılarak, yukarıda açıklanan boyutlarda incelenen maddi yoksunluğun, yıllar içindeki seyri de takip edilebilmiştir. Çalışmada TÜİK 2013, 2018 ve 2022 GYKA mikro veri setleri kullanılmış ve veriler logit yöntemi ile analiz edilmiştir. Ayrıca analizlerin sağlamlığını da test edebilmek maksadı ile veriler probit yöntemi ile de analiz edilmiştir. İncelenen dönemin, COVID 19 pandemi dönemi öncesi ve sonrasını da içermesi dolayısı ile çalışan bireylerdeki maddi yoksunluğun pandemi öncesi ve sonrası arasında anlamlı bir fark yaratıp yaratmadığını da gösterir nitelikte olduğu düşünülmektedir.

Çalışmanın ilk fazında incelenen sosyo-ekonomik ve demografik özelliklerine ilişkin logit analiz sonuçları, kadınların erkeklere kıyasla maddi yoksunluk yaşama olasılığının azaldığını göstermektedir. İlgili alan yazınında da benzer bulgular elde eden çalışmalar mevcuttur (Örneğin, Özdamar vd., 2021; Uğur, 2023). İlgili alan yazını, toplumsal cinsiyet kalıp yargıları bağlamında işgücü piyasasında kadınların erkeklere kıyasla daha düşük kazanç elde etmelerine rağmen daha fazla tasarruf yapabildiklerini vurgulamakta ve ayrıca hanehalkı reisi kadın olduğunda daha bilinçli harcamalar ve etkili tasarrufların yapılabildiğini vurgulamaktadır (Hick, 2013). Çalışmanın cinsiyet temelli sonuçları, yukarıda verilen bilgiler eşliğinde değerlendirildiğinde çalışan kadınların daha fazla sosyal dışlanmaya rağmen (İnak ve Kesgin, 2023) tasarruf yapabildikleri ve bu bağlamda görece maddi yoksunluk yaşama olasılıklarının azaldığı şeklinde yorumlanabilir.

Bu çalışmanın sonuçları, bekarların evlilere kıyasla maddi yoksunluk yaşama olasılıklarının azaldığını göstermektedir. Ünver ve Alkan (2020) ve Uğur'un (2023) sonuçları ile bu çalışmanın bulguları, medeni hale ilişkin benzer doğrultudadır. Kalabalık hane nüfusuna sahip evlilerin barınma, yeme-içme gibi temel ihtiyaçları dışında sosyal aktivitelere yeterince bütçe ayıramadıkları ve/veya zamanlarının kısıtlı olması nedeniyle maddi yoksunluk riski ve olasılığı da artış göstermiş olabilir.

Yaşa bağlı sonuçlar incelendiğinde benzer birçok çalışmanın (Örneğin, Erdoğan, 2002; Aydın ve Güloğlu, 2011; Karcı ve Arlı, 2018; Uğur, 2023) aksine bu çalışmada yaş arttıkça

çalışan bireylerin maddi yoksunluk yaşama riskinin arttığı tespit edilmiştir. Orta yaş ve üzeri bireylerin genç yetişkinlere kıyasla sosyal dışlanmaya daha fazla maruz kaldığı, bunun da maddi yoksunluk riskini arttırdığı öne sürülmektedir (Aydın ve Sayılan, 2022). Bireylerin yaşı ilerledikçe maddi yükümlülüklerini arttıran ve sosyal hayattan uzaklaşmasına neden olan çeşitli faktörlerin maddi yoksunluk yaşama riskini arttırmış olabilir (İnak ve Kesgin, 2023).

Logit analizi sonuçları eğitim bağlamında incelendiğinde ise incelenen tüm yıllarda geçerli olmak üzere eğitim düzeyi arttıkça çalışan bireylerin maddi yoksunluklarının azaldığına işaret etmektedir. Alan yazınında da söz konusu örüntüyü destekler çok sayıda çalışma mevcuttur (Örneğin, Moreno vd., 2014; Soltes ve Ulman, 2015; Blatna, 2017; Nikoloski, 2021). Ayrıca, bu çalışmanın birinci fazında incelenen tüm bağımsız değişkenler arasında eğitimin marjinal etkisi oldukça öne çıkmaktadır. Lisans düzeyindeki bu yüksek marjinal etki, tüm bağımsız değişkenler arasındaki en majör etkidir. Böylece bu çalışma, iş hayatında eğitimin önemini ve yüksek eğitim düzeyine ulaşmış çalışan bir bireyin, diğerlerine nazaran sosyal ve maddi olarak farkındalık yaratabileceğini vurgulamaktadır. Lisans ve üzeri mezun olan çalışan bireylerin tasarruf yapmaları, mali durumlarını daha planlı ve hesaplı kullanmaları (Uğur, 2023), bilinçli harcama ve yatırım vb. gibi durumların maddi yoksunluğu azaltıcı etkisinin olduğu söylenebilir. Az gelişmiş ve gelişmekte olan ülkelerin daha fazla yoksulluk ve maddi yoksunluk yaşamalarındaki temel sorunlardan birisi de bireylerin eğitim düzeylerinin gelişmiş ülkelere kıyasla daha düşük seviyede olması olabilir. Cinsiyet ayrımcılığının daha yoğun olarak yaşandığı coğrafyalarda eğitim alma hakkından mahrum bırakılan bireylerin arzu ettikleri yaşama ulaşamamaları, maddi yoksunluk yaşamalarına da neden olabilmektedir.

Çalışmada, sağlık durumları iyi olanların kötü olanlara kıyasla daha az maddi yoksunluk yaşadığı tespit edilmiştir. Öznel sağlık durumu beyanı "iyi" olarak adlandıran bireylerin diğerlerine kıyasla maddi yoksunluk yaşama olasılığının daha düşük olabileceğini Toge ve Bell (2016) ve Beck ve diğerlerinde (2019) vurgulamışlardır.

Maddi yoksunlukta gelir elbette ki önemli bir parametredir. Bu çalışmanın sonuçları da literatürdeki birçok çalışmada olduğu gibi (Örneğin, Aslan, 2020; Ünver ve Alkan, 2020; Turgut, 2021; Aydemir ve Dilsiz, 2021), gelirin maddi yoksunluğu azaltıcı etkisini ortaya koymaktadır. Fakat bu çalışmanın birinci fazının sonuçları, gelirin maddi yoksunluğu azaltıcı etkisinin olduğunu göstermekle birlikte, gelirin doğrudan etkisinden daha marjinal etkili parametrelerin de olduğunu ortaya koymuştur. Fakat maddi yoksunluk yaşama olasılığını düşürmede eğitim ve sağlık durumu gibi sosyo-ekonomik diğer parametrelerin etkisi de oldukça önemlidir.

Çalışmanın ikinci fazında maddi yoksunluğun çalışılan sektör özelinde farklılaşıp farklılaşmadığının tespitine odaklanılmıştır. Yapılan analizler sağlık ve eğitim sektöründe çalışmanın maddi yoksunluğu azaltıcı, imalat ve inşaat sektöründe çalışmanın ise maddi yoksunluğu arttırıcı etkisini vurgulamaktadır.

Sektörel ayrışmalar derinlemesine incelendiğinde, eğitim sektöründe çalışan bireylerin diğer sektörde çalışanlara kıyasla maddi yoksunluk yaşama olasılıklarının azaldığı göstermektedir. Fakat ortaya konan sonuçlar yıllar özelinde karşılaştırıldığında, eğitim sektöründe çalışmanın maddi yoksunluk yaşama olasılığındaki düşürücü etkisinin yıllar içinde azaldığı görülebilmektedir. Bir başka deyişle, eğitim sektöründe çalışanların maddi yoksunluk yaşama riski diğer çalışanlara kıyasla daima düşük olsa da yıllar içinde etki gücünü kaybetmiştir.

Sağlık sektörüne ilişkin sonuçlar değerlendirildiğinde, eğitim sektöründekine benzer bir örüntünün olduğu görülmüştür. Buna göre sağlık sektöründe çalışan bireylerin diğer sektörlerde çalışanlara kıyasla maddi yoksunluk yaşama olasılıkları azalmaktadır. Sağlık sektöründe çalışmanın da maddi yoksunluk yaşama olasılığını diğerlerine kıyasla azaltıcı etkisi görülebilir. Buna rağmen, çalışmaya konu olan sektörler arasındaki en pozitif ayrıştırıcı sektörün eğitim olduğu analiz sonuçlarından takip edilebilmektedir.

Maddi yoksunlukta diğerlerine göre negatif ayrışan sektörlere odaklanıldığında, bu çalışmaya konu edilen sektörler arasında özellikle inşaat sektörünün öne çıktığı görülmüştür. İnşaat sektöründe çalışanların diğerlerine kıyasla maddi yoksunluk yaşama olasılığının arttığı tespit edilmiştir. Kayalıdere ve Şahin (2014), eğitim düzeyine önem verilmeyen inşaat sektörü çalışanlarının maddi yoksunluk yaşama riskinin diğer sektörlerde çalışanlara nazaran oldukça yüksek olduğunu vurgulamaktadır. Gözüak ve Ceylan (2021) ise bir başka perspektiften yaklaşarak inşaat sektöründe çalışanların çoğunun iş kazası sonucu sağlık problemleri nedeniyle yeterince çalışamamaları dolayısı ile maddi yoksunluklarının artabileceğini öngörmüşlerdir. İnşaat sektörü özelindeki sonuçlar, yıllar özelinde analiz edildiğinde başka bir noktayı daha aydınlatmaktadır. Özellikle 2013 ile 2018 yılları arasında inşaat sektöründe çalışanların maddi yoksunlukta hala dezavantajlı olduğu görülmekle birlikte etki gücünün görece azaldığı, fakat 2018'den 2022 yılına geçen sürede etki gücünün tekrar yükseldiği görülebilmektedir. Bir başka deyişle, ilk periyotta Türkiye'deki inşaat sektöründeki gelişme ile birlikte, sektör çalışanlarının ekonomik gücünün görece yükseldiği, fakat 2018 yılından sonra hem Türkiye'deki genel ekonomik görünümün hem de pandeminin etkisi ile inşaat sektörünün tekrar negatif ayrışarak sektör çalışanlarının maddi yoksunluk yaşama olasılığı yükselmiş olabilir. İnşaat sektörü ile birlikte imalat sanayinde çalışan bireylerin de diğer sektörlere kıyasla maddi yoksunluk yaşama olasılıklarının yükseldiği çalışma bulguları ile ortaya konmuştur. Marjinal etkiler göz önüne alındığında, her ne kadar etkisi inşaat sektörü kadar dramatik olmasa da imalat sektöründe çalışmanın da maddi yoksunluktaki negatif durumu görülebilmektedir.

Çalışmanın üçüncü fazında maddi yoksunluk, işteki pozisyon boyutunda analiz edilmiş ve meslek grupları arasında maddi yoksunluk yaşama olasılıklarının dramatik biçimde ayrıştığını ortaya koymuştur. Çalışma kapsamındaki logit ve marjinal etkiler analiz sonuçları, profesyonel meslek mensubu olan bireylerin ve yöneticilerin diğer mesleklerde çalışan bireylere nazaran maddi yoksunluk yaşama riskinin düşük olduğunu göstermektedir. Buna benzer bulgular elde eden Aydın (2012), çalışmasında yöneticilerin ve profesyonel meslek mensuplarının gelir dağılımındaki yerlerinin diğer meslek gruplarında çalışanlara kıyasla yüksek olduğunu belirtmektedir. İncelenen meslek grupları arasında profesyonel meslek grubuna mensup çalışanların (Örneğin, bilim, mühendislik, sağlık, eğitim, bilgi, iletişim, iş ve yönetimi, hukuk, sosyal ve kültür ile ilgili tüm profesyonel meslek mensupları) maddi yoksunluk yaşama olasılıklarının diğerlerine nazaran daha az olduğu görülmüştür (Örneğin, Aydın, 2012; Selim ve Çomuk, 2017; Van, 2022). Buna göre, söz konusu gruptaki çalışanların maddi yoksunluk yaşama olasılıkları azalmaktadır. Benzer şekilde yöneticilik pozisyonunda çalışan bireylerin maddi yoksunluk yaşama olasılıkları ise diğerlerine kıyasla azalmaktadır. Bu iki meslek grubuna ait sonuçlar şu önemli sonucu göstermektedir. Çalışmanın ikinci fazındaki eğitim ve sağlık sektörlerindeki senaryoya benzer şekilde profesyonel meslek grubu ile yönetici olarak çalışan bireylerin maddi yoksunluk yaşama olasılıkları incelenen her dönemde diğerlerine kıyasla düşüktür fakat söz konusu iş pozisyonlarının maddi yoksunluktan uzak tutma potansiyeli yıllar içinde dramatik ölçüde azalmıştır.

Logit analiz sonuçlarına göre nitelik gerektirmeyen işlerde çalışanların (Örneğin, temizlikçi, yardımcı, balıkçı, inşaat işçisi ve sokaklarda satış yapanlar gibi nitelik gerektirmeyen işlerde çalışanlar) daha fazla olmak üzere sanatkarların da diğerlerine nazaran maddi yoksunluk yaşama olasılıklarının arttığı benzer çalışmalarla aynı sonuçlara ulaşılmıştır (Örneğin, Aydın, 2012; Aslan, 2020; Van, 2022). Bu iki meslek grubunun diğer mesleklere nazaran 2018 sonrasında pandeminin ve genel ekonomik görünümün olumsuz etkilerini daha fazla hissettiği görülmektedir.

Eğitim düzeyi düşük olan nitelik gerektirmeyen işlerde çalışanlar daha fazla maddi yoksunluk yaşamaktadırlar. Literatürde bu bulguları destekleyen benzer çalışmalar olduğu gibi (Örneğin, Aydın, 2012; Aslan, 2020) nitelik gerektirmeyen işlerde çalışanlar yoksullukla mücadele etmekte zorlanmakta, maddi yoksunluk yaşama olasılıkları yükselmektedir.

Toparlanacak olursa, çalışmada Türkiye'deki çalışan bireylerin maddi yoksunluklarının sosyo-ekonomik ve demografik belirleyicileri analiz edilmiş, çalışılan sektör özelinde maddi yoksunluğun farklılaşıp farklılaşmadığı tespit edilmiş ve maddi yoksunluğun işteki pozisyon ve meslek gruplarına göre değişip değişmediği yapılan analizler ile ortaya konmuştur. Ayrıca çalışmada sosyo-ekonomik ve demografik faktörlerin, sektör ve çalışılan pozisyonların maddi yoksunluktaki etkilerinin yıllar içinde değişip değişmediği de bu çalışma ile tespit edilmiştir. Yukarıda açıklanan yönleri ile maddi yoksunluğu üç fazda ve çok boyutlu olarak ele alan çalışma ile alan yazınına ve ilgili alandaki politika yapıcılara katkı sunacağı düşünülmektedir. Çalışan bireylerdeki maddi yoksunluğu analiz edecek sonraki çalışmalar, analizlerine yeni değişkenler ekleyebilir, daha geniş bir yıl skalası seçilerek analizler genişletilebilir. Ayrıca yeni ülkeler de analizlere dahil edilerek Türkiye ve diğer ülkelerdeki maddi yoksunluklar karşılaştırılabilir.

Araştırma ve Yayın Etiği Beyanı
Etik kurul izni ve/veya yasal/özel izin alınmasına gerek olmayan bu çalışmada araştırma ve yayın etiğine uyulmuştur.

Araştırmacıların Katkı Oranı Beyanı
Yazarlar makaleye eşit oranda katkı sağlamış olduklarını beyan eder.

Araştırmacıların Çıkar Çatışması Beyanı
Bu çalışmada herhangi bir potansiyel çıkar çatışması bulunmamaktadır.

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EKLER

Ek 1. Sosyo-ekonomik ve Demografik Farklılıkların Maddi Yoksunluğa Olan Etkisinin Probit Model ve Marjinal Etkiler Analiz Sonuçları

Değişkenler	**2013**		**2018**		**2022**	
Maddi Yoksunluk	**Probit Model**	**Marjinal Etkiler**	**Probit Model**	**Marjinal Etkiler**	**Probit Model**	**Marjinal Etkiler**
Cinsiyet						
Kadın	-0.381*** (0.05)	-0.091 ***(0.011)	-0.43*** (0.071)	-0.039*** (0.006)	-0.37*** (0.066)	-0.043*** (0.007)
Yaş: 45+	0.123** (0.056)	0.030** (0.014)	0.336*** (0.072)	0.038*** (0.009)	0.073 (0.066)	0.009 (0.009)
Medeni Durumu						
Bekar	-0.667*** (0.05)	-0.160*** (0.011)	-0.514*** (0.071)	-0.047*** (0.006)	-0.619*** (0.07)	-0.071*** (0.007)
Eşi ölmüş, boşandı	-0.157 (0.097)	-0.037 (0.023)	0.129 (0.118)	0.0136 (0.013)	-0.082 (0.113)	-0.010 (0.013)
Eğitim Durumu						
İlköğretim	-0.644*** (0.08)	-0.138 *** (0.0144)	-0.797*** (0.103)	-.084*** (0.011)	-0.871*** (0.112)	-0.010*** (0.012)
Lise	-1.174*** (0.087)	-0.268*** (0.016)	-1.404*** (0.116)	-*.122*** (0.010)	-1.357*** (0.118)	-0.157*** (0.013)
Lisans ve üzeri	-1.615*** (0.101)	-0.352*** (0.017)	-1.684*** (0.13)	-0.137*** (0.012)	-1.828*** (0.129)	-0.214*** (0.018)
Sağlık Durumu						
Orta	-0.537*** (0.105)	-0.119*** (0.021)	-0.409*** (0.138)	-0.035*** (0.010)	-0.37** (0.146)	-0.041** (0.014)
İyi	-0.786*** (0.106)	-0.206*** (0.028)	-0.646*** (0.147)	-0.081*** (0.022)	-0.817*** (0.161)	-0.130*** (0.031)
Kronik	-0.007 (0.06)	-0.002 (0.015)	0.028 (0.086)	0.003 (0.009)	0.064 (0.091)	0.008 (0.012)
Gelir	0*** (0)	-0.000013*** (6.76e-07)	0*** (0)	-3.58e-06*** (2.72e-07)	0*** (0.00)	-2.24e-06*** (1.61e-07)
cons	2.168*** (0.132)		1.266*** (0.179)		1.752*** (0.197)	
Gözlem	6317		7049		6213	

Not: Standart hatalar parantez içinde verilmiştir, *, **, *** sırasıyla katsayıların, %1, %5, %10 düzeylerinde istatistiksel olarak anlamlı olduğunu ifade etmektedir.

Ek 2. Meslek Farklılıkların Maddi Yoksunluğa Olan Etkisinin Probit Model ve Marjinal Etkiler Analiz Sonuçları

	2013		2018		2022	
Değişkenler (Sektörler)	**Probit Model**	**Marjinal Etkiler**	**Probit Model**	**Marjinal Etkiler**	**Probit Model**	**Marjinal Etkiler**
İmalat	0.14*** (0.046)	0.0483*** (0.016)	0.1 (0.061)	0.014 (0.009)	0.121** (0.059)	0.021** (0.011)
İnşaat	0.604*** (0.056)	0.223*** (0.022)	0.59*** (0.077)	0.110*** (0.019)	0.82*** (0.078)	0.204*** (0.025)
Eğitim	-0.778*** (0.07)	-0.219*** (0.015)	-0.792*** (0.126)	-.066*** (0.006)	-0.745*** (0.105)	-.087*** (0.008)
Sağlık	-0.25*** (0.08)	-0.080*** (0.024)	-0.142 (0.097)	-0.018 (0.0110)	-0.296*** (0.097)	-.043*** (0.012)
Hizmet	0.012 (0.049)	0.004 (0.017)	0.111* (0.066)	0.015 (0.010)	0.153** (0.064)	0.027** (0.0119)
_cons	-0.501*** (0.028)		-1.496*** (0.039)		-1.315*** (0.037)	
Gözlem	6317		7049		6213	

Not: Standart hatalar parantez içinde verilmiştir. *, **, *** sırasıyla katsayıların, %1, %5, %10 düzeylerinde istatistiksel olarak anlamlı olduğunu ifade etmektedir

Ek 3. Meslek Farklılıkların Maddi Yoksunluğa Olan Etkisinin Probit Model ve Marjinal Etkiler Analiz Sonuçları

	2013		2018		2022	
Değişkenler (Meslekler)	**Probit Model**	**Marjinal Etkiler**	**Probit Model**	**Marjinal Etkiler**	**Probit Model**	**Marjinal Etkiler**
Yönetici	-1.067*** (0.132)	-0.242*** (0.019)	-1.271*** (0.319)	-0.072*** (0.005)	-.726*** (0.168)	-.078*** (0.011)
Profesyonel Meslek	-1.249*** (0.083)	-0.29*** (0.012)	-0.995*** (0.129)	-0.074*** (0.005)	-0.984*** (0.107)	-.104*** (0.007)
Hizmet ve Satış	0.296*** (0.049)	0.089*** (0.015)	0.271*** (0.066)	0.036*** (0.009)	0.269*** (0.064)	0.045*** (0.011)
Sanatkarlar	0.585*** (0.052)	0.182*** (0.016)	0.514*** (0.071)	0.077*** (0.013)	0.571*** (0.071)	0.109*** (0.016)
Nitelik Gerektirmeyen	0.97*** (0.053)	0.316*** (0.017)	0.899*** (0.071)	0.162*** (0.017)	0.906*** (0.068)	0.197*** (0.018)
_cons	-0.652*** (0.032)		-1.6*** (0.045)		-1.403*** (0.044)	
Gözlem	6317		7049		6213	

Not: Standart hatalar parantez içinde verilmiştir. *, **, *** sırasıyla katsayıların, %1, %5, %10 düzeylerinde istatistiksel olarak anlamlı olduğunu ifade etmektedir

MULTIDIMENSIONAL ANALYSIS OF MATERIAL DEPRIVATION AMONG EMPLOYEES IN TURKEY

EXTENDED SUMMARY

Purpose

The main objective of this study is to analyze the factors affecting the material deprivation of employees in Turkey. In this context, the study approaches material deprivation among employees in Turkey in three phases. Firstly, the study aims to identify the material deprivation of individuals in employment by examining various socio-economic, demographic, and environmental factors such as age, gender, marital status, education level, income level, health status, and the presence of chronic diseases. Secondly, given that the main focus of the study is on employees, the research investigates whether material deprivation varies across different sectors of employment. Finally, the study seeks to determine whether occupational differences have a distinguishing effect on material deprivation, taking into account the positions held by employees in their current jobs. In this way, the study addresses material deprivation among employees in a multidimensional manner.

Literature Review

Related literature reveals that studies generally highlight the impact of education level on material deprivation (e.g., Ünver and Alkan, 2020; Uğur, 2023). In addition, studies identified the distinguishing effects of factors such as health status (Toge and Bell, 2016), gender, age, and marital status on material deprivation. Furthermore, the literature emphasizes that sectoral differences (e.g., Aydın, 2012; Selim and Çomuk, 2017; Van, 2022) and job positions (e.g., Aydın, 2012; Aslan, 2020; Van, 2022) have a significant impact on the likelihood of experiencing material deprivation.

Methodology

TURKSTAT's 2013, 2018, and 2022 Income and Living Conditions data sets are used in this study. To obtain the dependent variable of the study, the "material deprivation" sections of the relevant datasets are used. In the study, responses of "no-other reasons" are excluded from the analysis and data from individuals who answered "yes" or "no (material insufficiency)" are considered. Individuals who responded "no (material insufficiency)" to at least four out of the six relevant questions in the datasets are classified as "materially deprived" for the purposes of this study. The data are analyzed using the logit method, and additionally, probit analysis is conducted to verify the robustness and consistency of the results obtained.

Findings

The results reveal that gender, age, education, and health status, as well as income, have a statistically significant effect on material deprivation across all the years examined. Logit analysis results show that female employees have a lower likelihood of experiencing material deprivation

compared to their male counterparts, and single individuals have a lower probability than married individuals. It was also found that employees aged 45 and older have a higher likelihood of experiencing material deprivation compared to younger adults. Furthermore, the logit analysis indicates that as employees' income increases, the probability of experiencing material deprivation decreases, and individuals who report poor health have a higher likelihood of experiencing material deprivation compared to those in better health. The results of the marginal effects analysis show that among all the factors examined, education is the most decisive factor in material deprivation. Specifically, as education level increases, employees' likelihood of experiencing material deprivation decreases dramatically.

The analyses conducted in the second phase of the study to determine whether material deprivation varies across different sectors revealed that certain sectors reduce the likelihood of experiencing material deprivation compared to others while working in some sectors has an increasing effect on material deprivation. In this context, the study emphasizes that employment in the health and education sectors reduces material deprivation, whereas working in the manufacturing and construction sectors increases the likelihood of material deprivation.

In the third phase of the study, material deprivation was analyzed within the context of the sector, revealing a dramatic divergence in the likelihood of experiencing material deprivation among different occupational groups. The results of the logit, probit, and marginal effects analyses within the scope of the study show that individuals in professional occupations and managerial positions have a lower risk of experiencing material deprivation compared to those in other occupations.

Results

The study is expected to make a significant contribution to the literature due to its multidimensional approach, which includes the effects of socio-economic, demographic, and environmental factors, sectors of employment, and the position of employment on the material deprivation of employees. Furthermore, since the study examines employee material deprivation specifically for the years 2013, 2018, and 2022, it highlights the changes in deprivation over time and investigates whether the pandemic had a dramatic effect on material deprivation. The findings of the study, particularly emphasizing the importance of sectoral and occupational differences in material deprivation, suggest that policymakers should implement specific policies both at the sectoral level and with respect to the nature of the work to reduce material deprivation.

Ekonomi, Politika & Finans Araştırmaları Dergisi, 2025, 10(1): 412-428
Journal of Research in Economics, Politics & Finance, 2025, 10(1): 412-428
Araştırma Makalesi / Research Article, https://doi.org/10.30784/epfad.1621302

BORSA İSTANBUL'DA HİSSE GERİ ALIM KARARLARINA İLİŞKİN AMPİRİK BİR ANALİZ

An Empirical Analysis of Share Buyback Decisions in Borsa Istanbul

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Anahtar Kelimeler:
BİST**,** Hisse Geri Alımı, Hisse Değeri, Kümülatif Getiri, Sermaye Piyasaları

JEL Kodları:
G10, G14, G15

Öz

Bu çalışma, hisse geri alım kararlarının 2022-2023 yıllarında Borsa İstanbul'da işlem gören 95 şirketin hisse değerleri üzerindeki etkisini analiz etmektedir. Çalışmanın amacı, hisse geri alım kararlarının hisse fiyatları ve piyasa performansı üzerindeki etkilerini değerlendirmektir. Analizlerde hisse geri alım duyuruları öncesi ve sonrası 5, 10 ve 21 günlük kümülatif getiriler incelenmiştir. Veriler normal dağılmadığı için çalışmada öncelikli olarak parametrik olmayan testler kullanılmıştır. Hisse geri alım duyuruları öncesi ve sonrası getiri farklılıklarını değerlendirmek için Wilcoxon İşaretli Sıralar Testi, hisse geri alım kararları ile BIST-100 endeks getirileri arasındaki ilişkiyi incelemek için Spearman Korelasyon Testi uygulanmıştır. Örneklem büyüklüğünün fazla olması (n=95) nedeniyle bağımlı örneklem t-testi de destekleyici bir yöntem olarak kullanılmıştır. Sonuçlar, hisse geri alım kararlarının hisse değerleri üzerinde istatistiksel olarak anlamlı ve pozitif bir etkiye sahip olduğunu göstermektedir. Özellikle 10 ve 21 günlük dönemlerde hisse getirilerinde önemli bir artış gözlenmektedir. Ayrıca, hisse geri alım kararları ile BIST-100 endeks getirileri arasında pozitif bir korelasyon bulunmaktadır.

Keywords:
BIST, Capital Markets, Cumulative Return, Repurchase, Stock Value

JEL Codes:
G10, G14, G15

Abstract

This study analyses the impact of share buyback decisions on the share values of 95 companies traded on Borsa Istanbul in 2022-2023. The aim of the study is to evaluate the effects of share buyback decisions on share prices and market performance. In the analysis, 5, 10, and 21-day cumulative returns before and after the share buyback announcements are examined. Since the data are not normally distributed, nonparametric tests are primarily used in the study. The Wilcoxon Signed Rank Test was applied to evaluate the return differences before and after the share buyback announcements, and the Spearman Correlation Test was applied to examine the relationship between share buyback decisions and BIST-100 index returns. Due to the large sample size (n = 95), the dependent sample t-test was also used as a supporting method. The results show that share buyback decisions have a statistically significant and positive effect on share values. Especially in the 10 and 21-day periods, a significant increase in share returns is observed. Moreover, there is a positive correlation between share buyback decisions and BIST-100 index returns.

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Makale Geliş Tarihi (Received Date): 16.01.2025 Makale Kabul Tarihi (Accepted Date): 13.03.2025

1. Giriş

Günümüz finansal dünyasının dinamik ve karmaşık yapısı içerisinde, şirketlerin sermaye yönetimi ve benimsedikleri finansal stratejiler, yatırımcılar, analistler ve piyasa katılımcıları açısından büyük bir öneme sahiptir. Bu stratejiler arasında yer alan hisse geri alımları, halka açık şirketlerin hisse senedi fiyatları üzerinde doğrudan etkili olabilen ve hem şirketler hem de yatırımcılar için stratejik bir araç niteliği taşıyan önemli bir karar mekanizmasıdır. Bu çalışma, 2022-2023 yıllarında Borsa İstanbul'da (BIST) işlem gören 95 şirketin hisse geri alım kararlarının hisse senedi fiyatları üzerindeki etkilerini incelemeyi amaçlamaktadır.

Sermaye piyasaları, modern ekonomilerin temel taşlarından biridir ve hisse senetleri, başlıca yatırım araçları arasında yer alır. Bu nedenle, şirket hisse performansı büyük önem taşımaktadır. Hisse geri alımı, bir şirketin piyasadan kendi çıkarılmış hisselerini tekrar satın almasını ifade eden bir stratejidir. Bu faaliyet genellikle şirketin sermaye yapısını yeniden düzenlemek amacıyla gerçekleştirilir ve temel hedefi hisse değerini artırarak hissedarların refahını yükseltmektir.

Çalışmanın temel amacı, hisse geri alım kararlarının hisse fiyatları ve piyasa performansı üzerindeki etkilerini değerlendirmektir. Kümülatif al ve tut getiri oranlarının analizi ve tek örneklem t-testi yöntemiyle, geri alım duyurularından önce ve sonraki getiri oranlarındaki değişimlerin BIST-100 endeksine göre karşılaştırılması amaçlanmaktadır. Araştırma dönemi, seçilen 95 şirketin hisse geri alım duyurularına odaklanmakta ve bu kararların piyasa trendleri ve sektör dinamikleri bağlamında ele alınmasını sağlamaktadır.

Çalışmayı diğerlerinden ayıran özellik, farklı zaman dilimlerini kapsayan kapsamlı bir analiz sunmasıdır. Hisse geri alım duyurularından hem önce hem de sonra getiriler üzerindeki kısa vadeli etkilerin incelenmesi, literatürde genellikle göz ardı edilen bir alanı derinlemesine ele almaktadır. Daha önce yapılan çalışmalarda Ikenberry(1995), Zhang (2005), Albait ve Sait (2016), Wang vd. (2021), Manconi (2019) gibi araştırmalar, hisse geri alım duyurularının ardından pozitif bir fiyat tepkisi olduğunu gösterirken, Mukherjee ve Chatterjee (2019), Miller ve Prondzinski (2017), Arsoy (2017), Yağcılar ve Arslan (2018) gibi çalışmalar ise hisse geri alımlarının, fiyatlar üzerinde her zaman olumlu bir etki yaratmadığını göstermektedir. Hisse geri alım duyurularının hisse getirileri üzerindeki etkilerine ilişkin ulusal ve uluslararası önceki çalışmaların detayları literatür taraması bölümünde detaylı incelenmiştir.

Çalışma yukarıdaki araştırmalara kıyasla kapsam, yöntem ve bulgular açısından önemli katkılar ve yenilikler sunmaktadır. Çalışma, Borsa İstanbul'da 95 şirketi kapsayan daha geniş ve güncel bir veri seti kullanmıştır. Böylece yalnızca önceki araştırmaların odaklandığı dönemleri değil, bu dönemlerin ötesine geçen daha uzun bir zaman aralığını analiz ederek piyasa koşullarındaki değişimleri yakalamıştır. Farklı sektör ve büyüklükteki şirketleri içeren bu geniş örneklem, geri alım duyurularının etkisini daha genel bir perspektifle değerlendirmeye olanak tanımaktadır. Türkiye özelindeki geri alım uygulamalarına dair bu kapsamlı yaklaşım, literatürdeki boşluğu doldurarak önceki çalışmaların sınırlı dönem ve örneklem yapısını genişletmiştir.

Araştırma, olay analizi yöntemini farklı kısa vadeli zaman pencereleri ve karşılaştırmalı testlerle zenginleştirmiştir. Özellikle, hisse geri alım duyurularının etkisi duyuru öncesi ve sonrası 5, 10 ve 21 günlük pencerelerde ayrı ayrı incelenmiş, böylece piyasa tepkisinin zamanlaması ve sürekliliği detaylı bir biçimde ele alınmıştır. Literatürde genellikle göz ardı edilen duyuru öncesi

ve sonrası getiri dinamiklerini birlikte değerlendiren bu iki yönlü yaklaşım, geri alım kararlarının piyasa üzerindeki etkisini daha derinlemesine analiz etmektedir.

Çalışmada, her bir şirketin duyuru dönemi getirileri BIST-100 endeksinin aynı dönemdeki getirileriyle karşılaştırılmış ve tek örneklem t-testi uygulanmıştır. Yöntem, geri alım duyurusunun getiri etkisinin genel piyasa trendinden istatistiksel olarak ayrışıp ayrışmadığını ortaya koyarak, klasik anormal getiri hesaplamalarına kıyasla farklı bir bakış sunmaktadır. Söz konusu metodolojik yaklaşım ile hisse geri alım duyurularının etkisi konusunda daha güvenilir ve kapsamlı bulgular elde edilmiştir.

Önceki çalışmaların aksine, araştırma bulguları hisse geri alım duyurularının hisse değerleri üzerinde istatistiksel olarak anlamlı ve pozitif bir etki yaratabildiğini göstermektedir. Özellikle 10 günlük ve 21 günlük pencerelerde, geri alım açıklaması yapan şirketlerin hisselerinde anlamlı getiriler gözlemlenmiştir.

Ulaşılan bulgular hisse geri alım duyurularının piyasa tarafından olumlu algılandığı ve etkisinin kısa vadede sürdürülebildiği şeklinde yorumlanabilir. Önceki araştırmalarda anlamlı bulunmayan piyasa tepkilerinin, daha geniş bir veri seti ve farklı yöntemle incelendiğinde belirginleşmesi, Borsa İstanbul'da piyasa etkinliğine dair tartışmalara yeni bir boyut kazandırmaktadır. Sonuçlar, şirketlerin geri alım kararlarının yatırımcı güvenini artırarak hisse performansını destekleyebileceğini ortaya koymakta ve bu etkinin sadece anlık değil, birkaç hafta boyunca sürebileceğine işaret etmektedir. Bu bulgular ışığında, geri alımların uygun koşullarda hissedar değerini artırma potansiyeline sahip olduğu literatüre kazandırılmıştır.

Gelişmekte olan bir piyasa olarak Borsa İstanbul'dan elde edilen sonuçlar, Buyback literatüründe gelişmiş piyasalar dışında elde edilmiş bulgulara eklenerek akademik tartışmaları zenginleştirmektedir. Özellikle ülkemizde yarı güçlü piyasa etkinliği bağlamındaki bulgulara yeni bir perspektif getirerek, piyasanın bilgiye tepkisi konusunda politika yapıcılara ve yatırımcılara ışık tutmaktadır. Araştırma elde edilen sonuçlara dayanarak politika yapıcılar ve yatırımcılar için hisse geri alım stratejilerinin optimize edilmesine, hissedar refahının artırılmasına ve daha şeffaf ve verimli sermaye piyasalarının desteklenmesine yönelik yaklaşımlar sunmaktadır.

2. Literatür Taraması

Hisse geri alım programlarının hisse senedi fiyatları üzerindeki etkisi, finans literatüründe geniş bir şekilde incelenmiştir. Birçok çalışma, geri alımların hisse fiyatlarını olumlu etkilediğini ve hissedar değerini artırdığını gösterirken, bazıları ise bu etkinin her zaman geçerli olmadığını veya piyasa koşullarına bağlı olarak değişebileceğini öne sürmektedir.

Hisse geri alım duyurularının piyasa tepkisi ve finansal etkilerini inceleyen çalışmaların büyük bir kısmı, olay çalışması yöntemi kullanarak kısa vadeli fiyat hareketlerini değerlendirmiştir. Ikenberry vd. (1995), açık piyasa hisse geri alım duyurularının uzun vadeli performansını inceledikleri çalışmalarında, bu tür geri alımların zamanla hissedar değeri oluşturduğunu ve geri alım yapan şirketlerin, yapmayanlara kıyasla dört yıllık ortalama %12,1'lik bir getiri fazlası sağladığını tespit etmişlerdir. Benzer şekilde, Zhang (2005), Hong Kong'daki gerçek hisse geri alımlarını incelediği çalışmasında, şirketlerin genellikle hisse fiyatlarındaki düşüşlerin ardından geri alım yaptıklarını ve küçük, değeri düşük şirketlerin uzun vadeli performanslarının istatistiksel olarak anlamlı olduğunu belirtmiştir.

Hisse geri alım duyurularının kısa ve uzun vadeli etkileri inceleyen Albaity ve Said (2016) Malezya'da 2009-2010 yılları arasında gerçekleştirilen açık piyasa hisse geri alımlarının uzun vadeli hisse getirileri üzerindeki etkisini incelemiş ve geri alım yapan şirketlerin beş yıl içinde yapmayanlara göre %13,2 daha yüksek getiri sağladığını bulmuşlardır. Diğer bir çalışmada Wang vd. (2021), Vietnam'da 2008-2016 yılları arasında hisse geri alımlarının fiyat istikrarı ve likidite üzerindeki etkisini incelemişler ve geri alımların fiyatları istikrara kavuşturma ve likiditeyi artırmada etkili olduğunu bulmuşlardır. Benzer şekilde, Manconi vd. (2019), 31 ülkede 1998-2010 yılları arasında gerçekleştirilen hisse geri alımlarının uzun vadeli hissedar değeri üzerindeki etkisini incelemişler ve piyasa etkinliği ve likiditesinin anormal getirileri artırdığını, dolayısıyla hisse geri alımlarının daha etkin piyasalarda daha etkili olduğunu öne sürmüşlerdir.

Bununla birlikte, bazı çalışmalar hisse geri alımlarının, fiyatlar üzerindeki etkisinin piyasa koşullarına bağlı olduğunu ve geri alımların hisse fiyatları üzerinde her zaman olumlu bir etki yaratmadığını göstermektedir. Örneğin, Mukherjee ve Chatterjee (2019), Hindistan'da açık piyasa hisse geri alım duyurularının hisse fiyatları üzerindeki etkisini araştırmışlar ve genel olarak geri alım sonrasında hisse fiyatlarında bir artış olmadığını bulmuşlardır. Benzer şekilde, Miller ve Prondzinski (2017), 2004-2014 yılları arasında S&P 500 şirketlerinin hisse geri alımlarının hissedar değeri üzerindeki etkisini incelemişler ve geri alımların şirket performansı üzerinde doğrudan bir etkisi olmadığını, etkinin finansal performans, hisse fiyatları ve piyasa koşullarına bağlı olduğunu belirtmişlerdir.

Hisse geri alımlarının finansal stratejiler üzerindeki etkileri de çeşitli açılardan incelenmiştir. Hisse geri alım programları, şirketlerin finansal stratejilerinde önemli bir yer tutmakta ve farklı piyasalarda çeşitli etkiler yaratmaktadır. Örneğin, Stephens ve Weisbach (1998), 1981-1990 yılları arasında 450 açık piyasa geri alım programını analiz ederek, şirketlerin duyurdukları geri alım hedeflerinin %74 ila %82'sini üç yıl içinde gerçekleştirdiklerini bulmuş ve bu durumun şirketlerin esnek bir şekilde geri alım programlarını uyguladıklarını ortaya koymuştur. Farklı bir araştırmada Chen vd. (2018), ekonomik şokların hisse geri alım kararları üzerindeki etkisini inceledikleri çalışmalarında, aşırı değerlenmiş ve düşük kaldıraçlı şirketlerin geri alım programı duyurma olasılıklarının daha yüksek olduğunu ve duyuru sonrasında daha fazla hisse geri aldıklarını bulmuşlardır.

Hisse geri alımlarının stratejik ve finansal boyutlarını araştıran diğer çalışmalarda Wang vd. (2020) ise Vietnam'da 2008-2016 yılları arasında hisse geri alımlarının işletme performansı ve uzun vadeli hisse getirileri üzerindeki etkisini araştırmışlar ve duyuru yılındaki hisse performansının iyileştiğini, ancak sonraki yıllarda kontrol grubuna göre anlamlı bir fark olmadığını bulmuşlardır. Baker ve Wurgler (2004), yöneticilerin temettü ödeme kararlarını yatırımcı taleplerine göre şekillendirdiğini ortaya koydukları "Catering Theory of Dividends" ile yatırımcı beklentilerinin geri alım stratejilerine olan etkisini açıklamıştır. (Autore vd., 2019), aktivist yatırımcıların hisse geri alım kararları üzerindeki etkisini değerlendirerek, bu yatırımcıların geri alım stratejilerini şekillendirmede belirleyici olabileceğini göstermiştir.

Liu ve Swanson (2016), 2003-2014 yılları arasında hisse geri alımlarının hisse fiyatlarını destekleyip desteklemediğini araştırmış ve faiz oranlarındaki artış dönemlerinde şirketlerin hisse geri alımlarını artırarak fiyatları desteklediğini bulmuştur. Drousia vd. (2019), Yunanistan'daki hisse geri alımlarının duyuru günündeki etkisini analiz etmiş ve küçük şirketlerin geri alımlarının düşük değerleme hipoteziyle, büyük şirketlerin geri alımlarının ise fiyat destekleme hipoteziyle uyumlu olduğunu belirlemiştir.

Alquhaif vd. (2020), Malezya'daki hisse geri alım uygulamalarını inceleyerek, 2010-2015 yılları arasında geri alımların arttığını ve bunun sermaye piyasalarının olgunlaşması ve hissedar değerini artırma çabalarıyla ilişkili olduğunu göstermiştir. Kim ve Park (2021), Kore'de hisse geri alımlarının uzun vadeli performansını inceleyerek, kazanç duyurularını geciktirme geçmişi olan firmaların geri alımlar sonrası olumsuz sonuçlar yaşadığını ortaya koymuştur. Chee vd. (2022), ABD ve Malezya'daki hisse geri alımlarının fiyatlandırma üzerindeki etkilerini karşılaştırmış ve ABD'de fiyatları belirleyici bir faktörken, Malezya'da fiyatları bozabilecek nitelikte etkiler yarattığını bulmuştur. Arora (2019), Hintli şirketlerin hisse geri alımlarını neden gerçekleştirdiklerini analiz etmiştir. Çalışma, genel olarak Hintli firmaların, piyasa tarafından hisselerinin düşük değerlendiğine inandıklarında hisse geri alımı yaptıklarını ve bu stratejinin, hisselerin piyasa değerini gerçek değerine yaklaştırmayı ve potansiyel yatırımcılar için daha çekici hale getirmeyi amaçladığını göstermektedir.

Borsa İstanbul üzerine yapılan çalışmalarda ise Türkiye'de hisse geri alımlarının genel olarak hisse fiyatları üzerindeki etkisini değerlendirmiştir. Arsoy (2017), Borsa İstanbul'da 2010-2015 yılları arasında hisse geri alım duyurularının piyasa etkisini incelemiş ve kümülatif anormal getirilerin istatistiksel olarak anlamlı olmadığını bulmuştur. Yağcılar ve Arslan (2018) 2016-2018 yılları arasındaki hisse geri alım duyurularının fiyat hareketleri üzerindeki etkisini incelemiş ve piyasa üzerinde anlamlı bir değişiklik yaratmadığını tespit etmiştir.

Genel olarak, literatürde hisse geri alımlarının hisse fiyatları, piyasa likiditesi ve yatırımcı güveni üzerindeki etkileri farklı piyasalarda farklı sonuçlar vermektedir. Türkiye özelinde yapılan çalışmalar, hisse geri alım duyurularının piyasa fiyatlaması üzerindeki etkisinin genellikle sınırlı olduğunu göstermektedir. Ancak, piyasa yapısı, şirket büyüklüğü ve likidite gibi faktörler, geri alımların etkisini değiştirebilmektedir. Gelecek çalışmaların, bu faktörleri daha kapsamlı ele alarak geri alımların finansal performans üzerindeki uzun vadeli etkilerini değerlendirmesi faydalı olacaktır. İlaveten hisse geri alımlarının yatırımcı güveni, temettü politikaları ve şirketlerin uzun vadeli büyüme stratejileriyle nasıl ilişkilendiğini inceleyen araştırmaların, konuya daha geniş bir perspektif kazandıracağı düşünülmektedir. Bu doğrultuda yapılacak çalışmalar, politika yapıcılar ve şirket yöneticileri için önemli bulgular sağlayarak daha bilinçli kararlar almalarına yardımcı olacaktır.

3 Araştırma Yöntemi ve Veri Seti

Borsa İstanbul'da işlem gören 95 firmanın hisse geri alım kararlarının hisse fiyatları üzerindeki etkisini değerlendirmek üzere yapılan araştırmada SPSS programı kullanılmış ve veriler çeşitli kaynaklardan elde edilmiştir. İncelenen firmaların hisse geri alım duyuruları, 2023 yılı başından araştırmanın yapıldığı tarihe kadar Kamuyu Aydınlatma Platformu'nda (KAP) yönetim kurulları tarafından yapılan açıklamalardan derlenmiştir. Ayrıca, bu şirketlerin hisse senetlerinin kapanış fiyatları ve BIST-100 endeksinin kapanış değerleri de Borsa İstanbul'dan temin edilmiştir. Analiz edilen firmalar, farklı sektörlerde faaliyet göstermekte olup, büyüklükleri de çeşitlilik arz etmektedir.

Söz konusu çalışmada, hisse geri alım duyurularının hisse senedi fiyatları üzerindeki etkisini belirlemek için çeşitli istatistiksel analiz yöntemleri uygulanmıştır. Verilerin normal dağılıp dağılmadığını belirlemek için ilk olarak Kolmogorov-Smirnov testi kullanılmıştır. Normallik varsayımı sağlandığında bağımlı örneklem t-testi, normallik varsayımı

sağlanmadığında ise Wilcoxon işaretli sıra testi kullanılmıştır. Bu yaklaşım, hisse geri alım duyurularının kısa ve orta vadeli piyasa tepkisinin daha güvenilir bir şekilde tahmin edilmesini sağlamıştır. Araştırmada kullanılan verilerin normal dağılım göstermediği tespit edilmiştir ve bu durum, Kolmogorov-Smirnov normallik testi sonuçlarıyla desteklenmiştir. Özellikle, Wilcoxon İşaretli Sıra Testi gibi nonparametrik testler, verilerin normal dağılmadığı durumlarda daha güvenilir sonuçlar sağladığı için çalışmada ön planda tutulmuştur. Bu test, hisse geri alım kararlarının öncesi ve sonrasındaki getiri farklarını değerlendirmek için kullanılmış ve sonuçlar istatistiksel olarak anlamlı bulunmuştur. Ayrıca, Spearman Korelasyon Testi gibi nonparametrik yöntemler de hisse geri alım kararları ile BIST-100 endeksi getirileri arasındaki ilişkiyi analiz etmek için kullanılmıştır. Parametrik testler (bağımlı örneklem t-testi) ise destekleyici bir rol oynamıştır. Bu testler, özellikle büyük örneklem büyüklüklerinde ($n > 30$) Merkezi Limit Teoremi 'ne dayanarak normallik varsayımından bağımsız olarak güvenilir sonuçlar vermektedir.

Çalışma kapsıma dahil olan 95 firmanın günlük kapanış hisse değerleri ve hisse geri alım duyuru tarihleri, sırasıyla Borsa İstanbul ve Merkezi Kayıt Kuruluşu'ndan (MKK) 2023 yılı verileri kullanılarak elde edilmiştir. Çalışmada, iş günleri bazında bir hafta, iki hafta ve bir aya karşılık gelen 5, 10 ve 21 günlük dönemler seçilmiştir. Her bir firma için duyuru tarihinden önceki ve sonraki dönemlerdeki günlük getiri oranlarının kümülatif toplamları hesaplanmıştır. Ardından, hisse geri alım kararlarından önceki ve sonraki 5, 10 ve 21 günlük hisse kapanış fiyatlarının kümülatif getiri toplamları arasındaki farkın istatistiksel olarak anlamlı olup olmadığını belirlemek için eşleştirilmiş örneklem t-testi uygulanmıştır. Kümülatif anormal getiri farkları, benzer dönemlerde BIST-100 endeksinin duyuru tarihleri öncesi ve sonrası kümülatif getiri farklarıyla karşılaştırılmıştır. İki ortalama arasındaki ilişkinin gücünü değerlendirmek amacıyla tek örneklem t-testleri kullanılmıştır. Bu analiz, şirketlerin geri alım uygulamalarının piyasa davranışıyla ilişkili olup olmadığını belirlemek için yapılmıştır.

Araştırma, hisse geri alım kararları ile şirketlerin hisse değerleri arasındaki ilişkiyi ve aynı dönemde BIST-100 endeksinin getiri oranlarını ortaya koymayı amaçlamaktadır. Bu yaklaşım, hisse geri alım kararlarının piyasa endeksi üzerindeki etkisini anlamaya yöneliktir. Spearman sıra korelasyon testleri kullanılarak, hisse geri alım kararları ile şirketlerin hisse değerleri ve BIST-100 endeksinin getiri oranları arasındaki olası korelasyon ilişkileri incelenmiştir. Testler, hisse geri alım kararları ile hisse değerleri ve BIST-100 endeksi getiri oranları arasındaki ilişkiyi analiz etmek için 5, 10 ve 21 günlük dönemlerde gerçekleştirilmiştir.

4. Araştırma Hipotezi ve Getiri Ölçümü

Araştırmanın hipotezleri şöyledir;

Hisse geri alım kararlarının hisse değerleri üzerindeki etkisi için geliştirilen hipotezler:

H_0: Hisse geri alım duyuruları, duyuru öncesi ve sonrası 5, 10 ve 21 günlük dönemlerde hisse getirilerinde istatistiksel olarak anlamlı bir değişikliğe neden olmamaktadır.

H_1: Hisse geri alım duyuruları, duyuru öncesi ve sonrası 5, 10 ve 21 günlük dönemlerde hisse getirilerinde istatistiksel olarak anlamlı bir değişikliğe neden olmaktadır.

Hisse geri alım kararlarının piyasa endeksi (BIST-100) ile ilişkisi için geliştirilen hipotezler:

H_0: Hisse geri alım kararları ile BIST-100 endeksi getirileri arasında istatistiksek olarak anlamlı bir ilişki yoktur.

H_1: Hisse geri alım kararları ile BIST-100 endeksi getirileri arasında istatistiksek olarak anlamlı bir ilişki vardır.

Çalışma, ifade edilen hipotezleri test etmek için çeşitli istatistiksel yöntemler (örneğin, bağımlı örneklem t-testi, Wilcoxon işaretli sıra testi, Spearman korelasyon testi) kullanmış ve sonuçlarını bu hipotezler doğrultusunda değerlendirmiştir.

İlk olarak, her bir şirket için hisse geri alım duyuru tarihinden önce ve sonra sırasıyla 5, 10 ve 21 günlük dönemler için günlük getiri oranlarındaki farklar hesaplanmıştır. Bu farklar, hisse fiyatlarının geri alım kararının öncesi ve sonrasındaki değişimini göstermektedir.

Günlük getiri, bir hissenin bir önceki kapanış fiyatına göre bugünkü kapanış fiyatındaki değişimi gösterir ve aşağıdaki denkle ile hesaplanır. Denklemde yer alan P_{it} güncel hisse fiyatını, P_{it-1} bir önceki günün hisse fiyatını, RR_{it} "i" numaralı hissenin gerçek getiri oranını ifade etmektedir.

$$RR_{it} = \left(\frac{P_{it} - P_{it-1}}{P_{it-1}}\right) * 100 \quad (1)$$

Denklem 2'de gösterilen hisse senedi getirilerinin kümülatif toplamı, belirli bir zaman dilimindeki toplam getiriyi yansıtarak, dönemin sonuna kadar olan performansı göstermektedir.

$$CRR_t = \sum_{\text{İ}=1}^{N} RR_{it} \quad (2)$$

CRR_t= "i"nci hisse senedinin kümülatif getiri oranıdır. Hisse senedi getirilerinin kümülatif toplamı, yatırımcıların farklı zaman dilimlerinde getirileri takip etmelerine ve değerlendirmelerine olanak tanımaktadır; bu, farklı yatırım stratejilerine ve risk iştahlarına uygun olarak değişiklik göstermektedir. Örneğin, kısa vadeli yatırımcılar 5 günlük kümülatif toplamı kullanarak hızlı fiyat dalgalanmalarını inceleyebilirken, orta ve uzun vadeli yatırımcılar 10 günlük ve 21 günlük kümülatif toplamları kullanarak daha istikrarlı bir getiri eğilimini gözlemleyebilirler.

5. Analitik Bulgular

Hisse geri alım kararlarının hisse senedi değerleri üzerindeki etkisi, aşağıda belirtilen istatistiksel yöntemler kullanılarak değerlendirilmiştir. Formül 1 ve Formül 2 kullanılarak yapılan hesaplamalardan elde edilen tanımlayıcı istatistiksel veriler, referans olarak Tablo 1'de sunulmuştur.

Tablo 1. Toplam Getiri Oranlarına İlişkin Tanımlayıcı İstatistiksel Veriler

Kümülatif Getiri (Zaman Periyodu)	Geri Alım	N	Ort.	S.D
5-Gün	Before	95	2.41	43.09
	After	95	2.62	9.30
10-Gün	Before	95	-5.15	43.43
	After	95	6.89	11.22
21- Gün	Before	95	-4.69	44.90
	After	95	8.38	15.42

5 günlük kümülatif toplamda, hisse geri alım kararlarının ardından ortalama hisse getirilerinde belirgin bir artış gözlemlenmektedir. Önceki ortalama getiri yüzde 2,41 iken, karar sonrasında %2,62'ye yükselmiştir. Ayrıca, standart sapmadaki azalma, getirilerde daha yüksek bir istikrarı işaret etmektedir. Özellikle, 10 günlük ve 21 günlük kümülatif toplamlar, hisse geri alım kararlarının ardından hisse getirilerinde önemli artışlar göstermektedir. Özellikle 21 günlük dönemde, ortalama getiri %8,38'e yükselmiştir.

Söz konusu bulgular, hisse geri alım kararlarının ardından hisse getirilerinde belirgin bir artışı işaret etmektedir. 10 günlük ve 21 günlük dönemlerde standart sapmanın önceki döneme kıyasla azalması, bu kararların ardından hisse değerlerindeki artışın istikrarını vurgulamaktadır.

Kolmogorov-Smirnov normallik testi, belirli zaman dilimlerinde (5 gün, 10 gün ve 21 gün) kümülatif getiri oranlarındaki farkın (Sonra-Önce) normal bir dağılıma uyup uymadığını değerlendirmek için kullanılmıştır. Söz konusu testten elde edilen sonuçlar Tablo 2'de yer almaktadır. Tüm zaman dilimleri için p-değeri (Sig.) 0,000 olarak rapor edilmiştir ve bu, istatistiksel olarak anlamlı bir sonuca işaret etmektedir (0,000 <0.01). Başka bir deyişle, veriler normal bir dağılım göstermemektedir. Bununla birlikte, literatürde, örneklem büyüklüğünün 30'u aşması durumunda (95 > 30), veriler normal dağılıma uymasa bile analizlerin sağlamlığının korunduğu belirtilmektedir (Hogg vd., 2013; Gibbons ve Chakraborti, 2014).

Tablo 2. Toplam Getiri Oranı Farkı İçin Kolmogorov-Smirnov Normallik Testinin Sonuçları

Kümülatif Getiri Oranı Farkı (Sonra-Önce)	Kolmogorov-Smirnov		
	İstatistik	df	Sig.
5-Gün	0.33	95	0.000**
10-Gün	0.24	95	0.000**
21- Gün	0.22	95	0.000**

Not: ** ve * t-istatistiklerine göre %1 ve %5 anlamlılık düzeyinde anlamlılığı ifade eder.

Merkezi Limit Teoremi, örneklem büyüklüğü arttıkça, örneklem ortalamasının dağılımının, popülasyon dağılımına yaklaşma eğiliminde olduğunu, popülasyon dağılımının normal olup olmamasına bakılmaksızın ifade etmektedir (Hogg vd., 2013). Bu durum, özellikle büyük örneklemlerle çalışırken geçerlidir ve normal dağılım varsayımı gerektirmeyen parametrik olmayan yöntemlerin kullanılmasına olanak tanır (Gibbons ve Chakraborti, 2014).

Wilcoxon İşaretli Sıralar Testi, ilişkili örnekler arasındaki farkları test etmek için önemli bir yöntemdir. Bu test, eşleştirilmiş t-testi ile aynı hipotezleri değerlendirir ancak t-testinin aksine, verilerin normal dağıldığı varsayımına dayanmaz. Sıralama verileri, normal olmayan dağılımlarda veya merkezi dağılım varsayımlarının karşılanmadığı durumlarda özellikle kullanışlıdır. Ayrıca, bağımlı örneklem verileriyle çalışmak için uygundur (Keller ve Warwick, 1997).

Wilcoxon İşaretli Sıralar Testi, verilerin sıralanmasını ve veri noktaları arasındaki farkların analizini içerir. Bu sıralama süreci, parametrik testlerin gerektirdiği normallik varsayımını ortadan kaldırır. Sonuç olarak, Wilcoxon İşaretli Sıralar Testi, oran, oran benzeri veya sıralama verileri için oldukça uygundur. Bu çalışma kapsamında, hisse geri alım kararları için hesaplanan önce ve sonra hisse getirileri gibi eşleştirilmiş verilerin analizinde özellikle uygulanabilmektedir. Toplam getiri oranlarındaki fark için Wilcoxon işaretli sıralar testi sonuçları Tablo 3'te sunulmuştur.

Tablo 3. Toplam Getiri Oranlarındaki Fark İçin Wilcoxon İşaretli Sıralar Testi Sonuçları

Kümülatif Getiri	Sonra - Önce	Ort. Sırası	Sıralamaların Toplamı	Z	Asymp. Sig. (2-kuyruk)
5-Gün	Negatif Sıra	41.92	1048	-4.573	0.000**
	Pozitif Sıra	50.17	3512		
10-Gün	Negatif Sıra	47.1	706.5	-5.841	0.000**
	Pozitif Sıra	48.17	3853.5		
21- Gün	Negatif Sıra	47.06	800	-5.494	0.000**
	Pozitif Sıra	48.21	3760		

Not: ** ve * t-istatistiklerine göre %1 ve %5 anlamlılık düzeyinde anlamlılığı ifade eder.

Sonuç olarak, hisse geri alım kararından önce ve sonra 5 günlük kümülatif getiri oranları arasında istatistiksel olarak anlamlı bir fark olduğu sonucuna varılmıştır. "Negatif Sıralar" grubunun toplam sıralamaları, "Pozitif Sıralar" grubunun toplam sıralamalarından daha düşüktür. Z-skoru -4,573 ve p-değeri 0,000 olarak rapor edilmiştir; bu da istatistiksel anlamlılığa işaret etmektedir.

Benzer şekilde, hisse geri alım kararından önce ve sonra 10 günlük kümülatif getiri oranları arasında da istatistiksel olarak anlamlı bir fark bulunmaktadır. Negatif sıralamaların toplamı, pozitif sıralamaların toplamından daha düşüktür. Z-skoru -5,841 ve p-değeri 0,000 olduğu için bu sonuç istatistiksel olarak anlamlıdır.

Son olarak, hisse geri alım kararından önce ve sonra 21 günlük kümülatif getiri oranları da istatistiksel olarak anlamlı bir fark göstermektedir. Negatif sıralar grubunun toplam sıralamaları, pozitif sıralar grubunun toplam sıralamalarından daha düşüktür. Z-skoru -5,494 ve p-değeri 0,000 olarak rapor edilmiştir; bu da bu sonucun istatistiksel anlamlılığını doğrulamaktadır.

Tablo 4, Borsa İstanbul'da işlem gören 95 halka açık şirketin hisse değerleri üzerindeki hisse geri alım kararlarının etkisini araştırmak için kullanılan bağımlı örneklemler t-testinin sonuçlarını göstermektedir.

Tablo 4. Bağımlı Örneklemler (Eşleştirilmiş) t-Testi Sonuçları

Kümülatif Getiri (Sonra-Önce)	Ort.	S.D	t	df	Sig. (2-kuyruk)
5-Gün	0.22	44.00	-0.048	94	0.962
10-Gün	12.05	45.26	-2.595	94	0.011*
21- Gün	13.07	47.46	-2.683	94	0.009**

Not: ** ve * t-istatistiklerine göre %1 ve %5 anlamlılık düzeyinde anlamlılığı ifade eder.

Test sonuçlarına göre, 5 günlük dönemde duyuru tarihleri öncesi ve sonrası elde edilen getiri oranları arasındaki fark %0,22 olarak hesaplanmıştır. Ancak bu fark t-testi sonuçlarına göre istatistiksel olarak anlamlı bulunmamıştır (p-değeri; 0,962 > 0,05). Bu sonuç, şirketlerin hisse geri alım kararlarının 5 günlük bir dönemde hisse değerleri üzerinde anlamlı bir etkisinin olmadığını göstermektedir.

10 günlük dönemde, duyuru tarihleri öncesi ve sonrası elde edilen getiri oranları arasındaki fark %12,05 olarak hesaplanmıştır. T-testine göre, bu fark istatistiksel olarak anlamlıdır (p-değeri; 0,011 < 0,05). Bu sonuç, şirketlerin hisse geri alım kararlarının 10 günlük bir dönemde hisse değerleri üzerinde olumlu bir etkisi olduğunu ifade etmektedir.

Son olarak, 21 günlük dönemde duyuru tarihleri öncesi ve sonrası elde edilen getiri oranları arasındaki fark %13,07 olarak hesaplanmıştır. Bu fark da t-testi sonuçlarına göre istatistiksel olarak anlamlı bulunmuştur (p-değeri; 0,009 < 0,05). Bu bulgu, şirketlerin hisse geri alım kararlarının 21 günlük bir dönemde hisse değerleri üzerinde olumlu bir etkisi olduğunu göstermektedir.

Tablo 4'teki sonuçlar, şirketlerin hisse geri alım kararlarının hisse değerleri üzerinde potansiyel olarak olumlu bir etki yarattığını göstermektedir. Bu etkinin 5 günlük bir dönemde istatistiksel olarak anlamlı olmamasına rağmen, 10 ve 21 günlük dönemlerde istatistiksel olarak anlamlı olduğu görülmektedir. Bu durum, hisse geri alım kararlarının piyasa tarafından olumlu bir sinyal olarak algılanmasına bağlanabilir; yatırımcılar bu kararları şirketlerin güçlü finansal performansının bir göstergesi olarak görülmektedir.

Tablo 5, BIST-100 endeksinin 5, 10 ve 21 günlük kümülatif getiri oranlarının, BIST-100 endeksinin ortalama getirilerinden farklılık gösterip göstermediğini belirlemek için kullanılan tek örneklem t-testinin sonuçlarını göstermektedir.

Tablo 5. Tek Örneklem t-Testi sonuçları

Kümülatif Getiri	Sonra-Önce Ort.	BIST-100 Ort.	Ort. Farkı	t	df	Sig. (2-kuyruk)
5-Gün	0.22	2.20	-1.98	-0.440	94	0.661
10-Gün	12.05	5.45	6.597	1.421	94	0.159
21- Gün	13.07	4.90	8.166	1.677	94	0.097

Not: ** ve * t-istatistiklerine göre %1 ve %5 anlamlılık düzeyinde anlamlılığı ifade eder.

Tek örneklem t-testinin sonuçlarına göre, hisse geri alım kararları öncesi ve sonrası 5 günlük dönemdeki ortalama kümülatif getiri oranı -1,98 olarak hesaplanmıştır. Bu durum, hisse geri alım kararlarının ortalama olarak olumsuz bir etkiye sahip olduğunu düşündürmektedir. Ancak, t-değeri -0,440 ve p-değeri (Sig.) 0,661 > 0,05 olduğundan, bu farkın istatistiksel olarak anlamlı olmadığı dolayısıyla, hisse geri alım kararlarının bu dönemde BIST-100 endeksi üzerinde istatistiksel olarak anlamlı bir etkisinin olmadığı anlaşılmaktadır.

Takip eden 10 günlük dönemde, hisse geri alım kararları öncesi ve sonrası kümülatif getiri oranları arasındaki ortalama fark 6,597 olarak hesaplanmıştır. Bu durum, hisse geri alım kararlarının ortalama olarak olumlu bir etkiye sahip olduğunu göstermektedir. Ancak, t-değeri 1,421 ve p-değeri (Sig.) 0,159 > 0,05 olduğundan, bu farkın istatistiksel olarak anlamlı olmadığı görülmektedir. Bu nedenle, hisse geri alım kararlarının bu dönemde BIST-100 endeksi üzerinde anlamlı bir ortalama etkiye sahip olmadığı sonucuna varılabilir.

Son olarak, 21 günlük dönemde hisse geri alım kararları öncesi ve sonrası kümülatif getiri oranları arasındaki ortalama fark 8,166 olarak hesaplanmıştır. Bu durum, hisse geri alım kararlarının ortalama olarak olumlu bir etkiye sahip olduğunu ifade etmektedir. Ancak, t-değeri 1,677 ve p-değeri (Sig.) 0,097 > 0,05 olduğundan, bu farkın istatistiksel olarak anlamlı olmadığı görülmektedir. Bu nedenle, hisse geri alım kararlarının 21 günlük dönemde BIST-100 endeksi üzerinde istatistiksel olarak anlamlı bir etkisi olduğu söylenemez.

Tek örneklem t-testine dayanarak, hisse geri alım kararlarının BIST-100 endeksi üzerinde anlamlı bir ortalama etkisinin olmadığı açıktır. 5, 10 ve 21 günlük dönemlerde kümülatif getiri oranları ortalama olarak pozitif eğilim göstermiş olsa da bu farklılıklar istatistiksel olarak anlamlı

bir seviyeye ulaşmamıştır. Bu nedenle, hisse geri alım kararlarının BIST-100 endeksi üzerinde belirgin bir ortalama etkisinin (pozitif ya da negatif) olup olmadığına dair kesin bir sonuca varılamamaktadır.

Spearman korelasyon testi sonuçları (Tablo 6), hisse geri alım kararları ile BIST-100 endeksinin getiri oranları arasında pozitif bir korelasyon olduğunu göstermektedir. Bu durum, hisse geri alım kararlarının hisse değerlerini olumlu etkileyebileceğini, yani hisse fiyatlarını artırabileceğini işaret etmektedir.

Tablo 6. Spearman Korelasyon Testi Sonuçları

Spearman Korelasyonu	Kümülatif Getiri Oran Farkı	Kümülatif BIST-100 Getiri Oranı	N	Sig. (2-kuyruk)
5-Day	1.000	0.181	95	0.080
10-Day	1.000	0.253	95	0.013*
21- Day	1.000	0.268	95	0.009**

Not: ** ve * t-istatistiklerine göre %1 ve %5 anlamlılık düzeyinde anlamlılığı ifade eder.

Spearman testi sonuçlarına göre, 5 günlük dönemde hisse geri alım kararlarının hisse değerleri üzerindeki etkisi ile BIST-100 endeksinin getiri oranları arasında pozitif bir ilişki bulunmuştur. Ancak, bu ilişki istatistiksel olarak anlamlı değildir (p-değeri 0,080 > 0,05). Bu nedenle, hisse geri alım kararları, hisse değerleri ve BIST-100 endeksi arasında bu dönemde anlamlı bir ilişki olduğunu söylemek için yeterli kanıt bulunmamaktadır.

Takip eden 10 günlük geri alım döneminde, kümülatif getiri oranları ile BIST-100 endeksinin getiri oranları arasında güçlü bir pozitif korelasyon gözlemlenmiştir (rho = 0,253, p-değeri = 0,013). Bu durum, hisse geri alım kararlarının 10 günlük bir dönemde hisse değerlerini daha anlamlı bir şekilde artırma potansiyeline sahip olduğunu göstermektedir.

Son olarak, 21 günlük geri alım döneminde, kümülatif getiri oranları ile BIST-100 endeksinin kümülatif getiri oranları arasında çok güçlü bir pozitif korelasyon gözlemlenmiştir (rho = 0,268, p-değeri = 0,009). Bu bulgu, hisse geri alım kararlarının hisse değerlerini artırma potansiyelinin 21 günlük dönemde en yüksek seviyeye ulaştığını ve bu ilişkinin BIST-100 endeksi ile daha güçlü olduğunu göstermektedir.

Bu analizler, hisse geri alım kararlarının şirketlerin hisse değerleri üzerinde olumlu bir etkisi olduğunu ve bu etkinin zamanla arttığını göstermektedir. Özellikle, bu etkinin en belirgin olduğu dönem 21 günlük dönemdir ve BIST-100 endeksi ile yakın bir ilişki içerisindedir.

6. Sonuç ve Değerlendirme

Bu araştırma, Borsa İstanbul'da işlem gören 95 firmanın hisse geri alım duyurularına ilişkin derinlemesine bir inceleme gerçekleştirmiştir. Çalışmanın sonuçları, hisse geri alım duyurularının hisse senetleri üzerinde standart ve pozitif yönlü bir etkiye sahip olduğunu ve bu etkinin belirli dönemlerde istatistiksel olarak anlamlı olduğunu ortaya koymaktadır. 5 günlük zaman diliminde hisse senedi oynaklığında önemli bir farklılık gözlemlenmemekle birlikte, 10 günlük ve 21 günlük zaman dilimlerinde hisse senedi fiyatlarında önemli bir artış yaşanmaktadır. Bulgulara dayanarak, hisse geri alım duyurularının zaman içinde hissedarlar tarafından daha olumlu karşılandığı anlaşılmaktadır. İlk zaman diliminde belirgin bir etki gözlemlenmemekle birlikte, 5 günlük zaman

diliminde hisse senedi ortalamalarında bir artış eğilimi görülmektedir, ancak bu artış istatistiksel anlamlılığa ulaşamamaktadır. Bununla birlikte, standart sapmadaki azalma, piyasanın daha istikrarlı hale geldiğini göstermektedir. Benzer bir eğilimle, 10 günlük ve 21 günlük zaman dilimlerinde hisse senetlerinde önemli bir artış gözlenmektedir. 21 günlük zaman diliminde ise hisse getirilerinde artışın yanı sıra standart hatanın minimal olması, hisse geri alım duyurularının kalıcı bir etki yarattığını göstermektedir.

Çalışma özellikle 10 günlük ve 21 günlük dönemlerde fiyatlarda belirgin bir artış olduğunu ortaya koymaktadır. Söz konusu bulgular, piyasaların zaman içinde hisse geri alım işlemlerine verdiği tepkinin değiştiğini ve yatırımcıların, şirketlerin duyuru sonrası dönemlerde sağlıklı bir performans göstermesi halinde geri alımlara daha olumlu yaklaştığını göstermektedir. Hisse geri alımlarının şirket değerlemesi üzerindeki etkisi, sektör ve şirket büyüklüğü gibi çeşitli faktörlere bağlı olarak değişebilmektedir.

Hisse geri alım kararlarının BIST-100 endeksi ile ilişkilendirilmesine yönelik analizler ise, genel piyasa koşullarının hisse geri alımlarının etkisini belirlemede önemli bir rol oynadığını göstermektedir. Tek örneklem t-testlerinin sonuçlarına göre, hisse geri alım kararlarının BIST-100 endeksi üzerinde ortalama düzeyde anlamlı bir etkisi bulunmamaktadır. Bununla birlikte, bu kararların hisse değerleri üzerindeki olumlu etkileri, piyasa tarafından olumlu karşılanmakta ve yatırımcılar tarafından şirketin finansal sağlamlığının göstergesi olarak değerlendirilmektedir.

Çalışmadan elde edilen sonuçlara göre şirketlerin hisse geri alım kararlarını stratejik bir araç olarak nasıl kullanabileceğine dair önemli çıkarımlar ortaya konulmuştur. Hisse geri alımları, yatırımcı güvenini artırma, hisse fiyatlarını destekleme ve uzun vadeli hissedar değerini koruma gibi amaçlarla değerlendirilebilir. Ancak, geri alım duyurularının zamanlaması, şirketin genel finansal durumu ve piyasa koşulları gibi faktörler, bu kararların etkinliğini doğrudan etkilemektedir. Test sonuçları, hisse geri alım kararlarının hisse değerleri ile BIST-100 endeksinin getiri oranları arasında pozitif bir ilişki olduğunu göstermekle birlikte söz konusu ilişki, 10 ve 21 günlük dönemlerde istatistiksel olarak anlamlı bulunmuştur. Dolayısıyla, hisse geri alım kararlarının hisse değerlerini artırma ve hisse fiyatlarını yükseltme potansiyeline sahip olduğu sonucuna varılabilir. Araştırmanın bulguları, hisse geri alım kararlarının şirketlerin hisse değerlerini artırmada etkili bir yol olabileceğini göstermektedir. Özellikle, 21 günlük geri alım döneminde hisse değerleri üzerindeki etkiler en belirgin düzeye ulaşmıştır. Bu doğrultuda, firmaların hisse geri alım duyurularını uzun vadeli ve firma özelinde bir stratejinin parçası haline getirmesi, hisse değerlerini artırma açısından etkili bir karar olacaktır.

Örneğin, Borsa İstanbul'da hisse geri alımlarının şirket hisse fiyatları üzerindeki etkisi incelendiğinde, geri alım duyurularını takiben şirket hisse fiyatlarında hafif bir artış olduğu gözlemlenmektedir. Detaylı olarak incelendiğinde, şirket hisse fiyatları 5 günlük zaman diliminde artış göstermektedir, ancak bu artış istatistiksel olarak anlamlı değildir. Bununla birlikte, 10 günlük ve 21 günlük periyotlarda şirket hisse fiyatlarında istatistiksel olarak anlamlı bir artış gözlemlenmektedir. Özellikle 21 günlük periyotta, ortalama getirilerde belirgin bir artış görülmekte olup, bu durum hisse geri alımlarının kalıcı ve olumlu bir etkiye sahip olduğunu ortaya koymaktadır.

Davranışsal finans perspektifinden bakıldığında, yatırımcılar duyuru sonrası ilk birkaç gün içinde geri alım kararlarına temkinli yaklaşabilir ve fiyat tepkisi anında ortaya çıkmayabilir. Ancak, daha uzun vadede, yatırımcılar şirketin finansal stratejisine olan güveni artırarak hisse fiyatlarını yukarı çekebilmektedirler. Hisse geri alım duyurularına piyasanın verdiği tepkinin

anında değil, gecikmeli olabileceği düşünülmelidir. Hisse geri alımlarının etkileri, sadece şirket bazlı faktörlere değil, aynı zamanda piyasanın genel durumu ve makroekonomik gelişmelere de bağlı olacaktır. Örneğin, duyuru tarihleri sırasında piyasalarda mevcut olan belirsizlikler, küresel ekonomik gelişmeler veya sektörel haberler, hisse geri alım kararlarının etkisini kısa vadede gölgeleyecektir. Çalışmada 10 ve 21 günlük dönemlerde anlamlı fiyat değişimleri gözlemlenmiş olması, bu görüşü desteklemektedir. Araştırmada 5 günlük dönem içinde gözlemlenen fiyat artışı istatistiksel olarak anlamlı olmasa da daha uzun vadeli analizlerde anlamlı artışların görülmesi, piyasa katılımcılarının hisse geri alımlarına verdiği tepkinin kademeli olabileceğini göstermektedir. Bu nedenle, hisse geri alımlarının piyasa üzerindeki etkisini tam olarak değerlendirebilmek için yalnızca kısa vadeli sonuçlara odaklanmak yerine, orta ve uzun vadeli trendleri de dikkate almak gerekmektedir.

Netice itibarıyla, söz konusu çalışma, Borsa İstanbul'da hisse geri alımlarının fiyatlandırma mekanizmalarındaki rolüne dair bütüncül bir bakış açısı sunmaktadır. Hisse geri alım işlemlerini piyasa mekanizmaları ile ilişkilendirerek analiz etmektedir. Gelecekteki çalışmalar, hisse geri alımlarının farklı piyasa koşullarında uzun vadeli etkilerini test edebilir ve yatırımcı tepkileri, likidite seviyeleri ve makroekonomik faktörler gibi değişkenleri kontrol altına alarak analiz yapabilir. Bu tür çalışmalar, hisse geri alımlarının kısa vadeli piyasa tepkileri üzerinde anlamlı bir etkiye sahip olup olmadığını ve bu stratejilerin firmaların uzun vadeli finansal sağlığı, sermaye maliyeti ve piyasa katılımcılarının beklentileri açısından ne tür bir rol oynadığını aydınlatabilir. Özellikle gelişmekte olan piyasalar bağlamında, hisse geri alımlarının piyasa etkinliği üzerindeki etkileri daha ayrıntılı bir şekilde incelenmelidir. Hisse geri alım duyurularının kamuoyuna açıklanmasının mı yoksa uzun vadeli olarak yürütülmesinin mi daha fazla değer yarattığını belirlemek için daha fazla kanıta ihtiyaç vardır. Ayrıca, davranışsal finans perspektifinden bakıldığında, bu tür finansal eylemler ve piyasa katılımcılarının bu eylemleri nasıl yorumladığına dair analizler, geri alım duyurularının piyasa tepkileri üzerindeki etkisini daha iyi anlamaya yardımcı olacaktır. Bu açıdan çalışma, ortaya koyduğu yaklaşım ile kurumsal yöneticilere, politika yapıcılara ve piyasa katılımcılarına bilinçli kararlar almalarına katkı sağlamaktadır.

Araştırma ve Yayın Etiği Beyanı
Etik kurul izni ve/veya yasal/özel izin alınmasına gerek olmayan bu çalışmada araştırma ve yayın etiğine uyulmuştur.

Araştırmacıların Katkı Oranı Beyanı
Yazarlar makaleye eşit oranda katkı sağlamış olduklarını beyan eder.

Araştırmacıların Çıkar Çatışması Beyanı
Bu çalışmada herhangi bir potansiyel çıkar çatışması bulunmamaktadır.

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AN EMPIRICAL ANALYSIS OF SHARE BUYBACK DECISIONS IN BORSA ISTANBUL

EXTENDED SUMMARY

Aim of the Study

The aim of this study is to examine the short and medium-term effects of share buyback announcements on the share prices of 95 firms traded on Borsa Istanbul (BIST) in 2022-2023. Share buybacks are one of the most important financial instruments used by firms to reorganize their capital structure and maximize shareholder value. This study aims to provide meaningful implications for both academic studies and financial applications by analyzing the effects of share buyback announcements on share prices and market performance.

Scope of the Study and Literature Review

The impact of share buybacks on share prices has been discussed in the finance literature for decades. While early studies such as Ikenberry et al. (1995) and Zhang (2005) show that there is a positive price reaction following share buyback announcements, studies on a Turkish sample such as Arsoy (2017) and Yağcılar and Arslan (2018) find no statistically significant effect. This suggests that the market reaction to buybacks may differ across countries and even within the same market over time. This study examines how investors perceive buybacks and compares the literature findings with a larger dataset by focusing on a larger sample and a more recent time period in Borsa Istanbul.

Methodology

The study is based on the share buyback announcements of 95 firms disclosed on the Public Disclosure Platform (KAP) in the period 2022-2023. Pre-announcement and post-announcement 5, 10, and 21-day stock returns are analyzed. Since the data are not normally distributed, nonparametric tests such as the Wilcoxon Signed Rank Test and Spearman Correlation Test are primarily used, and due to the large sample size (n=95), the dependent sample t-test is used as a complementary test. Single sample t-tests were also conducted for comparison with BIST-100 index returns. These methods aim to explore the interaction of share repurchases with market indicators (BIST-100) in multiple ways.

Contribution to the Literature

The findings reflect that in the case of Borsa Istanbul, the share buyback announcement makes little positive contribution in the short term, but has a significant positive effect in the medium term (10 and 21 days). This result provides new evidence for the belief that buybacks will be perceived in a certain way by a wider range of investors. Behaviorally, it has been argued that investors view a buyback announcement as a positive signal, and the price effect is supported after a few weeks.

This study makes an original contribution to the existing literature on buybacks in Turkey by including recent as well as historical data. The data reveal that buybacks do not have statistically significant short-horizon returns, but instead have 10–21-day horizon returns.

Policy Recommendations

Disclosure efficiency in the market can be improved by making it easier for firms to disclose buybacks more openly, and for policymakers and regulators to provide investors with easy access to these disclosures. Management can work to protect and enhance shareholder value by aligning buyback strategies with long-term growth strategies. Furthermore, as an investment tool for shareholders, share buybacks can serve not only as a means to achieve a rapid price movement in the short term but also as a strategy that can contribute to shareholder returns in the medium term. Therefore, monitoring share buyback announcements and determining the overall financial health of the company become key financial metrics to be considered in investment decisions.

Finally, this research contributes significantly to academic studies and financial practices through a careful examination of the impact of share buybacks in Borsa Istanbul. The results indicate that share buybacks should be considered a strategic tool for companies and investors and a starting point for further research in this context.

Ekonomi, Politika & Finans Araştırmaları Dergisi, 2025, 10(1): 429-443
Journal of Research in Economics, Politics & Finance, 2025, 10(1): 429-443
Araştırma Makalesi / Research Article, https://doi.org/10.30784/epfad.1622810

TÜRKİYE'DE ELEKTRİK TÜKETİMİ VE EKONOMİK BÜYÜME ARASINDAKİ İLİŞKİNİN BÖLGESEL ANALİZİ

Regional Analysis of the Relationship between Electricity Consumption and Economic Growth in Türkiye

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Anahtar Kelimeler:
Elektrik Tüketimi, Ekonomik Büyüme, Nüfus Yoğunluğu, Beşerî Sermaye, Nedensellik Analizi

JEL Kodları:
C23. O11, Q43

Öz

Elektrik tüketimi ülkelerin gelişmişlik düzeyini ölçmede önemli bir gösterge olarak kabul edilmektedir. Ekonomik büyüme, kentleşme, beşerî sermaye gibi pek çok unsur elektrik tüketimi ile ilişkilidir. Literatürde elektrik tüketimi ve ekonomik büyüme arasındaki ilişki saklama hipotezi, enerji odaklı büyüme hipotezi, geri bildirim hipotezi, tarafsızlık hipotezi ve koruma hipotezi olmak üzere beş farklı hipotez ile açıklanmaktadır. Bu çalışma Türkiye'de bölgesel bazda elektrik tüketimi ve ekonomik büyüme arasındaki nedensellik ilişkisini test etmektedir. Bu amaçla, 81 il için 2008-2021 dönemini kapsayan yıllık veriler kullanılarak Juodis, Karavias ve Sarafidis'in (2021) tarafından geliştirilen Granger nedensellik analizi uygulanmaktadır. Bu yöntem hem tek değişkenli hem de çok değişkenli nedensellik analizlerine olanak tanımaktadır. Elde edilen bulgulara göre Türkiye'deki iller için elektrik tüketiminden ekonomik büyümeye doğru tek yönlü bir nedensellik ilişkisi gözlenmektedir. Bu sonuç Türkiye'de enerji odaklı büyüme hipotezinin geçerli olduğunu göstermektedir. Çalışmanın diğer bulgularına göre nüfus yoğunluğu ile ekonomik büyüme arasında tek yönlü, beşerî sermaye ile ekonomik büyüme arasında çift yönlü bir nedensellik ilişkisi olduğu gözlenmektedir.

Keywords:
Electricity Consumption, Economic Growth, Population Density, Human Capital, Causality Analysis

JEL Codes:
C23. O11, Q43

Abstract

Electricity consumption is considered an important indicator for measuring the development level of countries. Various factors, such as economic growth, urbanization, and human capital, are associated with electricity consumption. In the literature, the relationship between electricity consumption and economic growth is explained through five different hypotheses: the conservation hypothesis, the energy-focused growth hypothesis, the feedback hypothesis, the neutrality hypothesis, and the preservation hypothesis. This study examines the causal relationship between electricity consumption and economic growth on a regional level in Türkiye. To do so, we apply the Granger causality analysis developed by Juodis, Karavias, and Sarafidis (2021) for 81 provinces over the 2008–2021 period. This method allows for both univariate and multivariate causality analyses. The findings indicate a unidirectional causality relationship from electricity consumption to economic growth for provinces in Türkiye. This result suggests that the energy-focused growth hypothesis is valid for Türkiye. Furthermore, the study reveals a unidirectional causality from population density to economic growth and a bidirectional causality between human capital and economic growth.

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Makale Geliş Tarihi (Received Date): 18.01.2024 *Makale Kabul Tarihi (Accepted Date): 27.03.2025*

1. Giriş

Sanayi devrimi ile birlikte üretimdeki kitlesel artış insanlar için enerjinin önemini artırmıştır. Zamanla enerjinin yoğun olarak kullanıldığı endüstriyel ve tarımsal üretimdeki artış, artan nüfusun hayatta kalması ve günlük işlerin sürdürülebilirliğinde enerjiye olan gereksinim enerjiyi insanoğlu için zorunlu bir mal haline getirmiştir. Diğer taraftan enerjiye olan talebin giderek artmasının bir sonucu olarak enerjiye bağımlılık artarken; aynı zamanda özellikle birincil enerji kaynaklarının sınırlı olması ve dengesiz dağılımı ülkeleri enerji sorunu ile karşı karşıya getirmektedir. 1973-1974 ve 1977-1978 yıllarında yaşanan enerji krizleriyle birlikte ülkeler açısından enerji artık ucuz ve kolay erişilebilen bir mal olma özelliğini kaybetmiştir. Bir taraftan enerji kaynaklarının dünya coğrafyası üzerindeki eşitsiz dağılımı ve ülkeler arasındaki anlaşmazlıklar, diğer taraftan ülkelerin nüfuslarının artması, kentleşmenin hızlanması, kişi başı gelir seviyesi artışının enerji talebi üzerinde yarattığı baskıyla enerjinin önemi daha da fazla artmaktadır. Böylece ülkelerin enerjinin sürdürülebilirliğini sağlamaya yönelik politikaları, ülkelerin istikrarlı ekonomik performans sergilemelerini kolaylaştırabilecek stratejik bir alan haline gelmektedir (Altıntaş ve Koçbulut, 2014: 38; Ursavaş ve Yıldırım, 2017: 56; Recepoğlu vd., 2020: 70). Enerjinin ekonomik faaliyetlerdeki rolünün önemi ampirik ve teorik çalışmaların da önemli bir araştırma konusu olmasına yol açmaktadır. Özellikle 1970'lerde yaşanan enerji krizleri enerji tüketimi ile ekonomik büyüme arasındaki ilişkiyi araştıran ampirik ve teorik çalışmaların artmasına neden olmaktadır (Kraft ve Kraft, 1978; Samouilidis ve Mitropoulos, 1984; Yu ve Choi, 1985; Burney, 1995; Stern, 2000; Yang, 2000; Fatai vd., 2004; Chen vd., 2007; Borozan, 2013; Aslan vd., 2014).

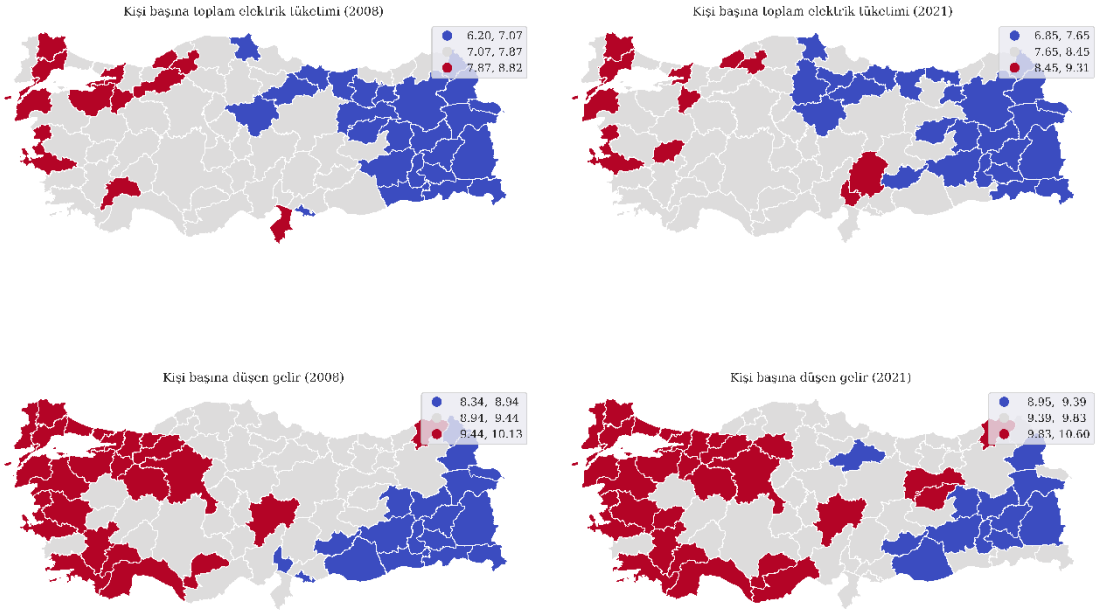
Enerji tüketimi ve ekonomik büyüme arasındaki ilişki oldukça karmaşıktır. Bir yandan enerji endüstrilere güç vererek, ulaşımı kolaylaştırarak ve teknolojik gelişmeleri destekleyerek ekonomik faaliyetlerin önemli bir itici gücü olarak hizmet etmektedir. Enerjinin temel bir girdi olarak bu rolü, daha yüksek enerji tüketiminin ekonomik büyümeyi teşvik edebileceğini göstermektedir. Öte yandan ekonomik büyüme, daha yüksek üretim seviyeleri, daha fazla tüketici zenginliği ve genişleyen altyapı ihtiyaçları nedeniyle enerji talebinin artmasına neden olmaktadır. Literatürde enerji tüketimi ve ekonomik büyüme arasındaki nedensel ilişki beş farklı hipotez ile açıklanmaktadır. Bunlardan birincisi, Saklama Hipotezi'dir (Büyümeye Bağlı Enerji Tüketimi Hipotezi). Buna göre, ekonomik büyümenin enerji tüketimini yönlendirdiği öne sürülmektedir. Ekonomiler genişledikçe, daha yüksek üretim düzeylerini, sanayileşmeyi ve iyileşen yaşam standartlarını desteklemek için enerji talebi artmaktadır (Altınay ve Karagöl, 2005).

İkinci yaklaşım Enerji Odaklı Büyüme Hipotezi'dir. Bu hipoteze göre enerji tüketiminin ekonomik büyümeyi yönlendirmede kritik bir faktör olduğu savunulmaktadır. Yeterli ve güvenilir enerji kaynakları üretkenliği artırabilir, sanayileşmeyi kolaylaştırabilir ve teknolojik yeniliği destekleyerek ekonomik kalkınmayı teşvik edebilir. Üçüncü yaklaşım olan Geri bildirim Hipotezi'ne göre enerji tüketimi ile ekonomik büyümenin karşılıklı olarak birbirini güçlendirdiği çift yönlü bir nedensellik ilişkisi olduğu öne sürülmektedir. Ekonomik büyüme enerji talebini artırırken, enerji altyapısı ve kullanılabilirliğindeki iyileşmeler ekonomik faaliyetleri artırmaktadır. Enerji ile ekonomik büyüme arasındaki ilişkiyi açıklayan dördüncü hipotez olan Tarafsızlık Hipotezi'ne göre, enerji tüketimi ile ekonomik büyüme arasında anlamlı bir ilişkinin olmadığı ileri sürülmektedir. Enerji kullanımındaki değişiklikler ekonomik büyümeyi doğrudan etkilememekte bu da teknolojik gelişmeler ve beşerî sermaye gibi diğer faktörlerin daha önemli rol oynayabileceğini göstermektedir (Chen vd., 2007). Son olarak

Koruma Hipotezi, enerji tüketiminin azaltılmasının ekonomik büyümeyi mutlaka engellemediğini öne sürmektedir. Enerji verimliliği iyileştirmeleri ve sürdürülebilir uygulamalar, enerji kullanımını ekonomik büyümeden ayırabilir, enerji kaynaklarını korurken büyümeyi teşvik edebilir (Ağır ve Kar, 2010: 152; Aslan vd., 2014: 2).

Enerji kaynakları içerisinde elektrik enerjisinin pek çok açıdan farklı bir önemi bulunmaktadır. Birincisi, elektrik enerjisi doğada hazır olarak bulunmamakta, yani üretilen bir enerji biçimidir. İkincisi, elektrik enerjisi diğer enerji kaynaklarının kullanılmasını veya dönüştürülmesini sağlayan bir enerji kaynağıdır. Üçüncüsü, kullanımı kolaylığının olması ve çevreyi kirletmeyen bir enerji olmasıdır. Son olarak elektrik enerjisi kullanımı modern ekonomilerin dinamiklerini anlamak için önemli bir gösterge olarak kabul edilmektedir. Ekonomik büyüme, sanayileşme, kentleşme ve yaşam standartlarındaki iyileşmeler gibi birçok yapısal değişim, elektrik tüketimi ile yakından ilişkilidir. Türkiye gibi gelişmekte olan ülkelerde, bu ilişkinin dinamiklerini incelemek hem bölgesel kalkınma politikalarının oluşturulmasında hem de sürdürülebilir büyüme stratejilerinin belirlenmesinde kritik bir rol oynamaktadır (Öncel vd., 2017).

Şekil 1'de ekonomik büyüme ve kişi başına toplam elektrik tüketiminin 2008 ve 2021 yılındaki mekânsal dağılımı gösterilmektedir. Buna göre ülkenin batısında kalan illerde kişi başına toplam elektrik tüketimi daha yüksek iken; doğu bölgelerde daha düşüktür. Benzer biçimde ekonomik büyüme düzeyi batıdaki illerde daha yüksek iken, doğuda daha düşüktür. Buna göre Türkiye'de elektrik tüketimi ile ekonomik büyüme arasında nedensel bir ilişkinin olduğunu söylemek mümkündür.



Şekil 1. İllere göre Kişi Başına Elektrik Tüketimi ve Ekonomik Büyüme Dağılımı
Not: Haritalarda bölgeler, Fisher-Jenks optimizasyon algoritmasına göre üç kategoriye ayrılmıştır. Kırmızı renkteki iller en yüksek, gri renkteki iller orta düzey, mavi renkteki iller ise en düşük düzeyde kişi başı elektrik tüketimi ve ekonomik büyüme değerlerini göstermektedir.

Bu çalışmanın amacı Türkiye'nin iller arasında elektrik tüketimi ve ekonomik büyüme arasındaki nedensel ilişkiyi test etmektir. Bu bağlamda çalışma hem metodolojik açıdan hem de bölgesel düzeyde sağladığı bulgularla literatüre önemli bir katkı sunmaktadır. Bu çalışma i) Türkiye'de elektrik tüketimi ve ekonomik büyüme arasındaki nedensellik ilişkisini bölgesel düzeyde ele alarak, farklı iller arasındaki dinamikleri ortaya koymaktadır. Mevcut literatür genellikle ulusal düzeyde analizlere odaklanırken, bu çalışma iller bazında detaylı bir değerlendirme sunarak bölgesel heterojenliği vurgulamaktadır. ii) 2008-2021 dönemini kapsayan geniş bir zaman aralığını ele alarak, uzun vadeli eğilimleri ve yapısal değişiklikleri göz önünde bulundurmakta, böylece daha sağlam sonuçlara ulaşmaktadır. iii) Juodis vd. (2021) tarafından geliştirilen Granger nedensellik analizinin kullanımı hem tek değişkenli hem de çok değişkenli analizlere olanak tanıyarak daha kapsamlı ve güvenilir sonuçlar sunmaktadır. Bu yöntem, literatürde sık kullanılan geleneksel nedensellik testlerine kıyasla daha güçlü tahminler sağlayabilir. iv) Bu çalışma, Türkiye bağlamında enerji odaklı büyüme hipotezinin geçerli olduğunu göstermekte ve böylece enerji politikalarının ekonomik büyüme üzerindeki etkisini vurgulamaktadır. Bu, enerji ve ekonomik büyüme literatürüne ülke özelinde yeni bir perspektif sunmaktadır. v) Çalışmada elektrik tüketimi yanında beşerî sermaye ve nüfus yoğunluğu gibi faktörlerin ekonomik büyüme ile olan ilişkisi nedensellik ilişkisi bakımından incelenerek mevcut literatüre ek bir boyut kazandırılmaktadır. Çalışmanın ikinci bölümünde konuyla ilgili literatür incelemesi yer almaktadır. Üçüncü bölümde ekonometrik yöntem ve son olarak sonuç ve politika önerilerine yer verilmektedir.

2. Literatür İncelemesi

Literatürde elektrik tüketimi ve ekonomik büyüme ilişkisini inceleyen pek çok çalışma bulunmaktadır. Bu çalışmaların önemli bir çoğunluğu nedensellik analizi kullanmakta ve değişkenler arasındaki nedensellik ve eş bütünleşme ilişkisini test etmektedir. Bu çalışmada literatür incelemesi çalışılan ülke ve ülke gruplarına göre sınıflandırılmaktadır. Örneğin, Böhm (2008) 15 AB ülkesinde 1978-2005 dönemine ait verileri kullanarak elektrik tüketimi ve ekonomik büyüme arasındaki ilişkiyi nedensellik analizi ile test etmektedir. Elde edilen bulgulara göre nedensellik sonuçları ülkeden ülkeye değişirken; uzun dönemde değişkenler arasında eş bütünleşme ilişkisine rastlanmamaktadır. Sinha (2009), 1980-2004 yılları arasında 88 ülkede elektrik tüketimi ve gelir arasındaki ilişkiyi test etmektedir. Nedensellik testi sonuçlarına göre değişkenler arasında çift yönlü nedensel bir ilişki olduğu görülmektedir. Benzer biçimde Acaravcı ve Öztürk (2010) çalışmasında 1990-2006 dönemi için 15 geçiş ekonomisinde elektrik tüketimi ve ekonomik büyüme ilişkisini test etmektedir. Pedroni eş bütünleşme testinin sonuçlarına göre elektrik tüketimi ile ekonomik büyüme arasında uzun vadede bir denge ilişkisinin olmadığını göstermektedir.

Öztürk ve Acaravcı (2010) çalışmasında Arnavutluk, Bulgaristan, Macaristan ve Romanya'da enerji tüketimi ile GSYİH arasındaki nedensel ilişkiyi test etmektedir. 1980-2006 dönemini kapsayan çalışmada elde edilen bulgulara göre Macaristan'da değişkenler arasında çift yönlü nedensellik ilişkisi görülürken; diğer ülkelerde değişkenler arasında herhangi bir nedensellik ilişkisi gözlenmemektedir. Lawal vd. (2020), çalışmasında 1971-2017 döneminde Sahra altı Afrika ülkelerinde elektrik tüketimi ile ekonomik büyüme ilişkisini test etmektedir. GMM metodunun kullanıldığı çalışmanın bulgularına göre ekonomik büyüme ile elektrik tüketimi arasında pozitif ilişki olduğu gözlenmektedir. Azam vd. (2021) çalışmasında 10

gelişmekte olan ülkede enerji tüketimi ile ekonomik büyüme arasındaki ilişkiyi test etmektedir. FMOLS sonuçlarına göre yenilenebilir enerji ve elektrik tüketimi ekonomik büyümeyi pozitif anlamda etkilemektedir. Espoir vd. (2023) çalışmasında 1980-2018 döneminde 51 Afrika ülkesinde yenilenebilir elektrik tüketimi, yenilenemez elektrik tüketimi ve ekonomik büyüme arasındaki ilişkiyi PMG yöntemi kullanarak test etmektedir. Çalışmanın bulguları hem yenilenemeyen hem de yenilenebilir elektrik tüketiminin ekonomik büyüme üzerinde pozitif etkisi olduğunu göstermektedir. Literatürde tek ülkeli analiz yapan çalışmalardan Soytas vd. (2001) çalışmasında 1960-1995 dönemine ait veriler kullanarak Johansen-Juselius eş bütünleşme ve vektör hata düzeltme modelini kullanmaktadır. Elde edilen bulgulara göre Türkiye'de enerji tüketiminden GSYİH'ye doğru tek yönlü bir nedensellik olduğu görülmektedir. Altınay ve Karagöl (2005) çalışmasında 1950-2000 yılları arasında elektrik tüketimi ve GSYİH arasındaki ilişkiyi Dolado–Lütkepohl ve standart Granger nedensellik testleri ile araştırmaktadır. Elde edilen bulgular elektrik tüketiminden gelire doğru tek yönlü bir nedensellik olduğuna dair güçlü kanıtlar ortaya koymaktadır. Aydın (2010) çalışmasında 1965-2017 dönemine ait veriler kullanarak elektrik tüketimi ve ekonomik büyüme arasındaki ilişkiyi zaman ve frekans boyutunda test etmektedir. Çalışmanın sonucunda elde edilen bulgular, zaman boyutunda herhangi bir nedensellik ilişkisinin olmadığını gösterirken, frekans boyutunda Türkiye için uzun vadede ilişkinin yönünün enerji tüketiminden ekonomik büyümeye doğru olduğunu göstermektedir. Kapusuzoğlu ve Karan (2010), 1975-2006 dönemini kapsayan çalışmada nedensellik ilişkisini test etmektedir. Elde edilen bulgular ekonomik büyümeden elektrik tüketimine doğru tek yönlü nedensellik olduğunu göstermektedir.

Shuyun ve Donghu (2011) çalışmasında Çin'de 1980-2007 dönemine ait veriler ile elektrik tüketimi ve reel GSYİH arasındaki ilişkiyi test etmektedir. VECM yönteminin kullanıldığı çalışmanın sonuçları değişkenler arasında çift yönlü nedensellik olduğunu göstermektedir. Tang vd. (2013) çalışmasında 1974-2009 döneminde Portekiz'de elektrik tüketimi ile ekonomik büyüme arasındaki ilişkiyi çok değişkenli bir model kullanarak araştırmaktadır. Elde edilen bulgulara göre kısa ve uzun vadede elektrik tüketimi ile ekonomik büyüme arasında çift yönlü bir nedensellik olduğuna dair kanıtlar bulunmaktadır. Altıntaş ve Koçbulut (2014) çalışmasında 1960-2011 dönemine ait verileri ile ARDL yöntemini kullanmaktadır. Elde edilen bulgulara göre elektrik tüketiminden ekonomik büyümeye doğru tek yönlü nedensellik ilişkisi olduğu gözlenmektedir. Ayrıca uzun dönemde ekonomik büyüme elektrik tüketimini pozitif yönde etkilemektedir. Savaş ve Durğun (2016) çalışmasında 1980-2010 dönemi için yaptığı çalışmada ekonomik büyümeden elektrik tüketimine doğru tek yönlü nedensellik ilişkisi olduğunu gözlemlemektedir

Literatürde bazı çalışmalar elektrik tüketimi ve ekonomik büyüme ilişkisini bölgesel ve sektörel olarak ele almaktadır. Örneğin; Ağır ve Kar (2010) 2000 yılı için Türkiye'nin 81 ilinde elektrik tüketimi ile ekonomik büyüme arasındaki ilişkiyi test etmektedir. Yatay kesit regresyon analizi sonuçlarına göre elektrik tüketimi ekonomik büyümeyi pozitif olarak etkilemektedir. Li vd. (2011) çalışmasında Çin'in 30 ilinde elektrik tüketimi ve ekonomik büyüme arasındaki ilişkiyi test etmektedir. 1980-2007 dönemini kapsayan çalışmada panel eş bütünleşme analizi uygulanmaktadır. Elde edilen bulgular değişkenler arasında eş bütünleşme ilişkisi olduğunu doğrulamaktadır. Abbasi vd. (2020) çalışmasında 1970-2018 döneminde Pakistan'da sanayi sektöründe elektrik tüketimi, fiyatlar ve ekonomik büyüme arasındaki ilişkiyi incelemektedir. VECM modelinin kullanıldığı çalışmaların bulgularına göre değişkenler arasında uzun dönemli anlamlı bir ilişki olduğu gözlenmektedir. Benzer biçimde Abbasi vd. (2021) çalışmasında

Pakistan'da sektörel bazda elektrik tüketiminin gelir üzerindeki etkisini test etmektedir. VECM modelinin kullanıldığı çalışma sektörel bazda elektrik tüketiminin uzun dönemde ekonomik büyümeyi etkilediğini göstermektedir. Rahman vd. (2020) çalışmasında Çin'de 1981-2016 yıllarında enerji üretimi, enerji tüketimi ve ekonomik büyüme arasındaki ilişkiyi araştırmaktadır. FMOLS yöntemi sonuçları, kömür, petrol ve doğal gaz tüketimi ve üretiminin GSYİH büyümesi üzerinde uzun vadeli pozitif etkisinin varlığını doğrulamaktadır.

Literatürde Türkiye için sektörel ve bölgesel olarak yapılan çalışmalar da bulunmaktadır. Örneğin, Usta (2016) Türkiye'de 26 bölgede (Düzey 2) elektrik tüketimi ve bölgesel gayri safi katma değer arasındaki ilişkisi test etmektedir. 2004-2011 dönemini ele alan çalışmada panel regresyon yöntemi uygulanmaktadır. Elde edilen bulgular bölgesel elektrik tüketimindeki artışın bölgesel ekonomik büyümeyi artırdığını göstermektedir. Usta ve Berber (2017) çalışmasında 1970-2012 dönemine ait verileri kullanarak sektörel bazda elektrik tüketimi ile ekonomik büyüme arasındaki ilişkiyi test etmektedir. Toda-Yamamato nedensellik analizinin kullanıldığı çalışmada ulaştırma ve sanayi sektörlerinde elektrik tüketimi ve ekonomik büyüme arasında çift yönlü nedensellik ilişkisi tespit edilirken tarım ve konut sektörlerinde herhangi bir nedensel ilişki gözlemlenmemektedir. Çadırcı ve Güner (2020) çalışmasında Türkiye'nin 81 ilinde sektörel elektrik tüketim ile ekonomik büyüme arasındaki ilişkiyi test etmektedir. 2004-2016 dönemi için yapılan çalışmada panel ARDL yöntemi kullanılmaktadır. Elde edilen bulgulara göre uzun dönemde ticarethane ve meskenlerdeki elektrik tüketimi ile o illin reel GSYH'si arasında anlamlı ve pozitif bir ilişki bulunmaktadır.

3. Veri Seti ve Ekonometrik Yöntem

3.1. Veri Seti

Bu çalışma 2008-2021 dönemine ait yıllık veriler kullanılarak Türkiye'de 81 ilde kullanılan elektrik tüketimi, nüfus yoğunluğu, beşerî sermaye ve ekonomik büyüme arasındaki nedensellik ilişkisini test etmektedir. Çalışmada elektrik tüketimi (lnec) değişkeni olarak kişi başına toplam elektrik tüketimi (kilowatt cinsinden), nüfus yoğunluğu (lnpop) değişkeni olarak kilometrekareye düşen kişi sayısı, beşerî sermaye (lnhc) değişkeni olarak yüksekokul veya fakülte mezunu oranı, ekonomik büyüme (lngdppc) değişkeni olarak kişi başı reel GSYİH kullanılmaktadır. Çalışmada kullanılan tüm veriler TÜİK veri tabanından elde edilmektedir. Tablo 1 verilere ait tanımlayıcı istatistikleri göstermektedir.

Tablo 1. Tanımlayıcı İstatistikler

	Gözlem sayısı	Ortalama Değer	Standart Sapma	Minimum Değer	Maksimum Değer
lngdppc	1,134	9.482581	0.3794613	8.335277	10.59504
lnec	1,134	7.656293	0.6064832	6.154858	9.306014
lnpop	1,134	4.262053	0.8446598	2.302585	8.022569
lnhc	1,134	2.344347	0.4025413	0.7747272	3.243373

3.2. Ekonometrik Yöntem

Çalışmada elektrik tüketimi ve ekonomik büyüme arasındaki nedensel ilişkileri test etmek için Juodis ve diğerleri (2021) tarafından geliştirilen Granger nedensellik analizi

kullanılmaktadır. Bu yöntem Granger nedenselliğinin yokluğunu doğrulamakta ve hem homojen hem de heterojen katsayı panel veri modellerine uygulanmaktadır. Yöntemin temel yeniliği sıfır ve homojen Granger nedensellik parametreleri varsayımıdır. Bu özellik, belirli parametreler üzerinde birleştirilmiş sabit etki tahmincisi kullanarak √NT yakınsama oranına ulaşmaktadır. Ayrıca, "Nickell önyargısını" azaltmak için yöntem, Split Panel Jackknife yöntemini kullanmakta ve daha sonra önyargı düzeltilmiş tahminciye dayalı bir Wald testi gerçekleştirmektedir (Juodis vd., 2021; Xiao vd., 2023; Apaydın, 2024). Ek olarak, yöntem hem tek değişkenli hem de çok değişkenli nedensellik analizlerine olanak tanımaktadır. Bu testi gerçekleştirmeden önce ilk olarak Breusch-Pagan (1980) (Lagrange Multiplier-LM) ve Pesaran (2004) (Cross-section Dependence-CD) ile Pesaran vd. (2008) (Bias-Adjusted Cross Sectionally Dependence Lagrange Multiplier- CDLM) testleri ile yatay kesit bağımlılığı test edilmektedir. Yatay kesit bağımlılık testlerinin sonuçlarına dayanarak, elektrik tüketimi ve gelir arasındaki uzun dönemli ilişkiyi test edebilmek için CIPS ikinci nesil birim kök testi uygulanmaktadır. Nedensellik testini uygulamadan önce uzun dönemde değişkenler arasında eş bütünleşik ilişki olup olmadığı test edilmektedir. Son olarak panel nedensellik testi uygulanmaktadır.

Modelde tüm değişkenler logaritmik formda kullanılmaktadır. Analizde kullanılan model aşağıdaki gibidir:

$$lngdppc_{i,t} = \alpha_0 + \alpha_1 lnec_{i,t} + \alpha_2 lnpop_{i,t} + \alpha_3 lnhc_{i,t} + u_{i,t} \quad (1)$$

Yukarıdaki modelde $lngdppc$, $lnec$, $lnpop$, $lnhc$ sırasıyla ekonomik büyüme, kişi başı elektrik tüketimi, nüfus yoğunluğu ve beşerî sermayeyi temsil etmektedir. u ise hata terimini ifade etmektedir.

Elektrik tüketimi, ekonomik büyüme, nüfus yoğunluğu ve beşerî sermaye arasındaki nedensellik ilişkisini test etmek için ilk olarak seriler arasında yatay kesit bağımlılığı test edilmektedir. Bu amaçla Breusch-Pagan (1980) LM testi, Pesaran (2004) CD testi ve Pesaran vd. (2008) LM_{adj} ve CDLM testleri uygulanmaktadır. Elde edilen sonuçlar Tablo 2'de gösterilmektedir. Buna göre seriler arasında yatay kesit bağımlılığı olduğu görülmektedir.

Tablo 2. Yatay Kesit Bağımlılığı Testi

	lngdppc	**lnec**	**lnpop**	**lnhc**
t-istatistik ve olasılık değerleri				
LM_{BP}	39830.33 0.0000	33026.55 0.0000	29389.10 0.0000	44994.73 (0.0000)
CD_{LM}	454.5471 0.0000	370.0264 0.0000	324.8398 0.0000	518.7023 0.0000
LM_{adj}	451.4317 0.0000	366.9110 0.0000	321.7245 0.0000	515.5870 0.0000
CD	199.0259 0.0000	178.4923 0.0000	112.8484 0.0000	212.1186 0.0000

Yatay kesit bağımlılığını gözlenmesi nedeniyle serilere ikinci nesil birim kök testi uygulanmaktadır. Bu nedenle Pesaran vd. (2013) tarafından geliştirilen CIPS testi (yatay kesit artırılmış panel birim kök testi) uygulanmaktadır. CIPS testi sonuçları Tablo 3'te gösterilmektedir. Buna göre tüm değişkenler birinci farkında durağan hale gelmektedir. Diğer bir ifade ile değişkenlerin entegrasyon derecesi 1'dir.

Tablo 3. Birim Kök Testi Sonuçları

Değişkenler	Sabitli		Sabitli-Trendli	
	t-istatistiği	Olasılık Değeri	t-istatistiği	Olasılık Değeri
lngdppc	-1.855	0.117	-2.339	0.265
Δlngdppc	-2.570	0.000*	-3.532	0.000*
lnec	-1.748	0.379	-1.762	1.000
Δlnec	-2.270	0.000*	-4.262	0.000*
lnpop	-1.771	0.310	-2.102	0.895
Δlnpop	-2.772	0.000*	-3.309	0.000*
lnhc	-1.717	0.476	1.700	1.000
Δlnhc	-2.690	0.000*	-2.991	0.000*

Not: * serinin %1 anlamlılık düzeyinde durağan olduğunu göstermektedir

Panel veri analizi uygulanan çalışmalarda serilerin homojen olup olmadığı yapılan testlerin geçerliliği açısından önemli olmaktadır. Bu çalışmada serilerin homojenlik varsayımı Pesaran ve Yamagata'nın (2008) önerdiği delta testi kullanılarak test edilmektedir. Delta testine ait boş ve alternatif hipotezler aşağıdaki gibidir:

H_0: Eğim katsayıları homojendir.

H_1: Eğim katsayıları heterojendir.

Delta testi sonuçlarına göre Tablo 4'te t-istatistiğinin olasılık değerleri 0.05 değerinden küçüktür. Dolayısıyla boş hipotez reddedilmektedir. Başka bir ifadeyle eğim katsayıları heterojendir.

Tablo 4. Eğim Heterojenliği Testi

	Delta	Olasılık Değeri
Δ	12.586	0.000
Δ_{adj}	15.698	0.000

Değişkenler arasında hem yatay kesit bağımlılığı hem de heterojenlik olduğundan seriler arasında uzun dönemli eş bütünleşme ilişkisi Westerlund (2007) eş bütünleşme testi ile test edilmektedir. Tablo 5'te gösterilen eş bütünleşme testi sonuçlarına göre uzun dönemde değişkenler arasında eş bütünleşme ilişkisi olduğu görülmektedir.

Tablo 5. Westerlund (2007) Eş Bütünleşme Testi

İstatistik	Değer	Z Değeri	Olasılık	Robust Değeri
Gt	-2.331	-5.460	0.000*	0.017
Ga	-5.349	3.547	1.000	0.003
Pt	-14.515	-2.032	0.021**	0.055
Pa	-3.958	0.445	0.672	0.035

Not: * %1, ** %5 anlamlılık düzeyini göstermektedir.

Tablo 6'da nedensellik sonuçları gösterilmektedir. Panel A'da çok değişkenli nedensellik sonucuna göre elektrik tüketimi, nüfus yoğunluğu ve beşerî sermaye değişkeninden ekonomik büyümeye doğru tutarlı bir nedensel ilişki olduğu görülmektedir. Panel B'de ise tek değişkenli nedensellik analizinin sonuçları gösterilmektedir. Buna göre ekonomik büyüme ile elektrik

tüketimi ve nüfus yoğunluğu arasında tek yönlü, ekonomik büyüme ile beşerî sermaye arasında ise çift yönlü nedensellik ilişkisi gözlenmektedir.

Tablo 6. Nedensellik Testi

Panel A: Çok Değişkenli Nedensellik		
H_0:Seçili yardımcı değişkenler lngdppc'nin Granger nedeni değildir.	**Gecikme Uzunluğu (lag)**	**HPJ Wald Test İstatistiği**
lnec, lnpop, lnhc ⇒ lngdppc	1	13.1508 (0.0043)
Panel B: Tek Değişkenli Nedensellik		
H_0: x y'nin Granger nedeni değildir.	**Gecikme Uzunluğu (lag)**	**HPJ Wald Test İstatistiği**
lngdppc ⇒ lnec	1	0.1157 (0.7338)
lnec ⇒ lngdppc	1	3.2830 (0.0700)***
lngdppc ⇒lnpop	1	25.0428 (0.0000)*
lnpop ⇒ lngdppc	1	0.1107 (0.7393)
lngdppc ⇒lnhc	1	221.9355 (0.0000)*
lnhc ⇒lngdppc	1	7.8965 (0.0050)*

Not: *, ** ve ***, nedensellik olmadığı yönündeki sıfır hipotezinin sırasıyla %1, %5 ve %10 anlamlılık düzeylerinde reddedildiğini gösterir. Ayrıca, yarım panel Jackknife test istatistikleri, kesitsel heteroskedastisiteye dayanıklı varyansın tahmin sonuçlarını gösterir. Optimum gecikme uzunluğu, Bayes bilgi kriterlerine göre otomatik olarak belirlenir.

4.Sonuç ve Tartışma

Bu çalışma Türkiye'de kişi başına elektrik tüketimi, kişi başına gelir, beşerî sermaye ve nüfus yoğunluğu arasındaki nedensel ilişkileri araştırmaktadır. Çalışmada elde edilen sonuçlara göre Türkiye'de 81 ilde kişi başı elektrik tüketiminden ekonomik büyümeye doğru tek yönlü bir nedensellik ilişkisi olduğu gözlenmektedir. Çalışmanın bu sonucu literatürde Soytas vd. (2001) Altınay ve Karagöl (2005), Aydın (2010) gibi çalışmaların bulguları ile benzerdir. Bu çalışmalar zaman serisi yöntemlerini kullanarak Türkiye'de elektrik tüketimi ile ekonomik büyüme arasındaki nedensel ilişkileri test etmekte ve elektrik tüketiminden ekonomik büyümeye doğru tek yönlü bir nedensel ilişkinin olduğunu göstermektedir. Bu sonuç Türkiye'de Enerji Odaklı Büyüme Hipotezi'nin geçerli olduğunu göstermektedir. Buna göre elektrik tüketimi ekonomik büyümeyi yönlendirmede önemli bir unsurdur. Diğer bir ifadeyle elektrik tüketimi ekonomik faaliyetleri desteklemekte ve ekonomik büyümenin önemli bir belirleyicisidir. Elektrik tüketimi, üretim kapasitelerinin artırılması, endüstriyel faaliyetlerin sürdürülmesi ve hizmet sektörünün büyümesi için temel bir unsurdur. Daha fazla elektrik tüketimi, genellikle daha yüksek yaşam standartları, sanayileşme, kentleşme ve altyapı gelişimiyle ilişkilendirilir. Türkiye özelinde, bu durum özellikle sanayileşmiş bölgelerde ekonomik büyümeyi hızlandırabilir.

Çalışmanın bir diğer bulgusuna göre ekonomik büyümeden nüfus yoğunluğuna doğru tek yönlü bir nedensellik ilişkisi olduğu görülmektedir. Buna göre yüksek ekonomik büyüme, bireylerin refah seviyelerini artırmakta ve bu da yoğun nüfuslu şehirlere doğru göçü teşvik etmektedir. Bireyler daha yüksek gelir elde edebilecekleri ve iş olanakları, eğitim imkanları ve yaşam standartlarının daha iyi olduğu bölgelere göç etme eğilimindedirler. Bu da nüfus yoğunluğunu artırmaktadır. Diğer yandan nüfus yoğunluğu ile birlikte yerleşim birimleri, iş yerleri ve sanayi daha yakın mesafelerde yoğunlaşır. Bu durum, bir bölgede elektrik talebinin daha yoğun olmasına ve kişi başına düşen elektrik tüketiminin de bu talepten dolayı artmasına neden olmaktadır (Njoh, 2003; Turok ve Mcgranahan, 2013: 468).

Çalışmanın bir diğer bulgusu ise beşerî sermaye ve ekonomik büyüme arasındaki ilişki ile ilgilidir. Buna göre beşerî sermaye ile ekonomik büyüme arasında çift yönlü nedensellik ilişkisi görülmektedir. Buna göre daha eğitimli bir iş gücü, daha yüksek üretkenliğe, teknoloji kullanımına ve inovasyona yol açarak ekonomik büyümeyi artırmaktadır. Diğer yandan ekonomik büyüme arttıkça eğitim ve sağlık alanında daha fazla yatırım yapılmakta ve bu beşerî sermayenin daha da artmasını sağlamaktadır (Lucas, 1988; Barro: 1991; Tsamadias ve Prontzas, 2012).

5. Politika Önerileri

Bu çalışmada Türkiye'de iller arasında kişi başına elektrik tüketimi, kişi başına gelir, beşerî sermaye ve nüfus yoğunluğu arasındaki ilişki test edilmektedir. Buna göre Türkiye'de kişi başı elektrik tüketiminden ekonomik büyümeye doğru tek yönlü bir nedensellik ilişkisi olduğu gözlenmektedir. Türkiye'de bölgesel olarak elektrik tüketimi ve ekonomik büyüme arasındaki nedensel ilişki göz önünde bulundurulduğunda Türkiye'nin enerji politikalarının ekonomik büyüme stratejileriyle uyumlu bir şekilde geliştirilmesi gerekmektedir. Bu çerçevede, enerji arz güvenliği, yenilenebilir enerji kaynaklarının kullanımı ve bölgesel kalkınmayı hedefleyen politikalar önceliklendirilmelidir. Örneğin; elektrik üretim ve dağıtım altyapısının güçlendirilmesi, ekonomik büyümeyi destekleyebilir. Özellikle kırsal ve az gelişmiş bölgelerde enerjiye erişimin artırılması, bu bölgelerin ekonomik potansiyelini ortaya çıkarabilir. Bunun yanı sıra Türkiye'nin enerji üretiminde yenilenebilir kaynaklara yönelmesi hem enerji güvenliğini artırabilir hem de sürdürülebilir bir büyüme sağlayabilir. Güneş ve rüzgâr enerjisi gibi yenilenebilir kaynaklara yapılan yatırımlar ekonomik büyümeyi destekleyebilir. Enerji talebi yüksek olan bölgelere yönelik altyapı yatırımları yapılabilir. Böylece bölgesel kalkınma farklılıkları azaltılabilir. Enerji tüketiminin ekonomik büyümeye katkısını artırmak için enerji yoğun sektörlerde teknolojik gelişmeler teşvik edilebilir.

Türkiye'de iller arasında nüfus yoğunluğu ve beşerî sermayenin ekonomik büyümeye katkısını artırmak için nüfusun yoğun olduğu bölgelerde ekonomik faaliyetleri destekleyecek altyapı ve ulaşım yatırımları artırılmalıdır. Nüfus yoğunluğunu dengelemek için az yoğun bölgelerde ekonomik fırsatlar yaratacak teşvikler (örneğin, vergi indirimleri, yatırım teşvikleri) uygulanabilir. Aşırı nüfus yoğunluğu, gelir artışını olumsuz etkileyebilir. Bu nedenle, şehirleşme süreçleri iyi yönetilmeli ve plansız kentleşme önlenmelidir. Türkiye'de ekonomik büyüme için önemli olan daha fazla yetenekli iş gücü üretmek için beceri temelli eğitim sağlanmalıdır. Özellikle, bölgesel ihtiyaçlara uygun mesleki eğitim programları oluşturulmalıdır. Yükseköğretim ve AR-GE yatırımları hem beşerî sermayeyi artırır hem de kişi başına geliri desteklediğinden, üniversite-sanayi iş birlikleri teşvik edilmelidir.

Araştırma ve Yayın Etiği Beyanı (Declaration of Research and Publication Ethics)
Etik kurul izni ve/veya yasal/özel izin alınmasına gerek olmayan bu çalışmada araştırma ve yayın etiğine uyulmuştur.

Araştırmacıların Katkı Oranı Beyanı
Yazarlar makaleye aşağıdaki gibi katkı sunduklarını beyan eder.
1. Yazar Giriş (%75), Literatür İncelemesi (%100), Ekonometrik Yöntem (%75), Sonuç (%75)
2. Yazar Giriş (%25), Ekonometrik Yöntem (%25), Sonuç (%25)

Araştırmacıların Çıkar Çatışması Beyanı
Bu çalışmada herhangi bir potansiyel çıkar çatışması bulunmamaktadır.

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REGIONAL ANALYSIS OF THE RELATIONSHIP BETWEEN ELECTRICITY CONSUMPTION AND ECONOMIC GROWTH IN TURKIYE

EXTENDED SUMMARY

Aim of the Study

The purpose of this study is to test the causal relationship between electricity consumption and economic growth in 81 provinces of Turkey. This study differs from the studies in the literature in two aspects. First, this study applies panel causality analysis by including 81 provinces of Turkey. Second, in this study, in addition to electricity consumption, population density and human capital variables of 81 provinces are used.

The Literature

There are many studies in the literature testing the relationship between electricity consumption and economic growth. While some studies such as Azam et al. (2021), Böhm (2008), focus on the relationship between electricity and economic growth in different country groups, Sinha (2009), Acaravcı and Ozturk (2010), Lawal et al. (2020); other studies follow time series methods. (Tang et al. 2013, Abbasi et al. 2020, Rahman et al. 2020, Abbasi et al. 2021). Lastly, some studies focus on the relationship between electricity consumption and economic growth on a sectoral, regional, or provincial basis in Turkey in the literature. (Soytas et al., 2001; Altınay ve Karagöl, 2005; Aydın, 2010; Kapusuzoğlu ve Karan, 2010; Altıntaş ve Koçbulut, 2014; Usta, 2016; Savaş ve Durğun, 2016; Çadırcı ve Güner, 2020).

The contribution of this study to the literature can be explained from a methodological perspective. Unlike other studies, this study applies the Granger causality analysis developed by Juodis, Karavias ve Sarafidis'in (2021). This method enables both univariate and multivariate causality analyses.

Methodology

We follow Juodis, Karavias ve Sarafidis'in (2021) method to test the causality between electricity consumption and economic growth, population density, and human capital in 81 provinces of Turkey. This method verifies the absence of Granger causality and applies to both homogeneous and heterogeneous coefficient panel data models. The method's main innovation is its assumption of zero and homogeneous Granger causality parameters. This feature employs a pooled fixed effects estimator on specific parameters, achieving an $\sqrt{NT}$ convergence rate. Furthermore, to mitigate the "Nickell bias", the method utilizes the Split Panel Jackknife method and subsequently conducts a Wald test based on the bias-corrected estimator (Juodis et al., 2021; Xiao et al., 2023). In addition, the method enables both univariate and multivariate causality analyses.

Results

The findings of the study reveal that there is a multivariate causal linkage from electricity consumption, population density, and human capital to GDP per capita. Also, the results show that there is a unidirectional causality between GDP per capita, electricity consumption, and population density while there is a bidirectional causal linkage between human capital and GDP per capita. This result shows that the Energy-Focused Growth Hypothesis is valid in Turkey. Accordingly, electricity consumption is an important factor in directing economic growth.

Conclusion and Policy Implications

Considering this result, it shows that Turkey's energy policies should be developed in line with economic growth strategies. In this context, policies targeting energy supply security, the use of renewable energy resources, and regional development should be prioritized. For instance, i) strengthening electricity production and distribution infrastructure can support economic growth. Increasing energy access, particularly in rural and underdeveloped regions, can help unlock the economic potential of these areas. ii) Transitioning to renewable resources in Turkey’s energy production can enhance energy security and ensure sustainable growth. Investments in renewable resources such as solar and wind energy can further contribute to economic growth. iii) Infrastructure investments in regions with high energy demand can help reduce regional development disparities. iv) To increase the contribution of energy consumption to economic growth, technological advancements in energy-intensive sectors should be encouraged.