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ARTIFICIAL INTELLIGENCE-ASSISTED MACHINE LEARNING METHODS FOR FORECASTING GREEN BOND INDEX: A COMPARATIVE ANALYSIS

Yeşil Tahvil Endeksinin Tahmini için Yapay Zeka Destekli Makine Öğrenme Yöntemleri: Karşılaştırmalı Bir Analiz

Yunus Emre Gür[*], Ahmed İhsan ŞİMŞEK[**] & Emre BULUT[***]

Abstract

The main objective of this study is to contribute to the literature by forecasting green bond index with different machine learning models supported by artificial intelligence. The data from 1 June 2021 to 29 April 2024, collected from many sources, was separated into training and test sets, and standard preparation was conducted for each. The model's dependent variable is the Global S&P Green Bond Index, which monitors the performance of green bonds in global financial markets and serves as a comprehensive benchmark for the study. To evaluate and compare the performance of the trained machine learning models (Random Forest, Linear Regression, Rational Quadratic Gaussian Process Regression (GPR), XGBoost, MLP, and Linear SVM), RMSE, MSE, MAE, MAPE, and R^2 were used as evaluation metrics and the best performing model was Rational Quadratic GPR. The concluding segment of the SHAP analysis reveals the primary factors influencing the model's forecasts. It is evident that the model assigns considerable importance to macroeconomic indicators, including the DXY (US Dollar Index), XAU (Gold Spot Price), and MSCI (Morgan Stanley Capital International). This work is expected to enhance the literature, as studies directly comparable to this research are limited in this field.

Keywords:
Green Bonds, Machine Learning, Rational Quadratic Gaussian Process Regression, SHAP Analysis, Nonlinear Relationships.

JEL Codes:
C45, C53, G12, Q56.

Öz

Bu çalışmanın temel amacı, yeşil tahvil endeks değerlerini yapay zeka destekli farklı makine öğrenmesi modelleri ile tahmin ederek literatüre katkıda bulunmaktır. Çeşitli kaynaklardan bir araya getirilen, 1 Haziran 2021 ile 29 Nisan 2024 tarihlerini kapsayan veriler, eğitim ve test kümelerine ayrılmış ve her biri için standart ön işlemler gerçekleştirilmiştir. Modelin bağımlı değişkeni, küresel finans piyasalarındaki yeşil tahvillerin performansını izleyen ve çalışma için kapsamlı bir ölçüt görevi gören Küresel S&P Yeşil Tahvil Endeksi'dir. Eğitilen makine öğrenmesi modellerinin (Random Forest, Doğrusal Regresyon, Rasyonel Kuadratik Gauss Süreci Regresyonu (GPR), XGBoost, MLP ve Doğrusal DVM) performansını değerlendirmek ve karşılaştırmak için değerlendirme ölçütleri olarak RMSE, MSE, MAE, MAPE ve R^2 kullanılmış ve en iyi performans gösteren model Rasyonel Kuadratik GPR modeli olmuştur. SHAP analizinin son bölümü modelin tahminlerini etkileyen başlıca faktörleri ortaya koymaktadır. Modelin DXY (ABD Doları Endeksi), XAU (Spot Altın Fiyatı) ve MSCI (Morgan Stanley Capital International) gibi makroekonomik göstergelere büyük önem verdiği görülmektedir. Bu çalışmanın, literatürde doğrudan karşılaştırılabilir benzer çalışmaların sınırlı olması nedeniyle alana önemli bir katkı sağlayacağı düşünülmektedir.

Anahtar Kelimeler:
Yeşil Tahviller, Makine Öğrenmesi, Rasyonel Kuadratik Gauss Süreci Regresyonu, SHAP Analizi, Doğrusal Olmayan İlişkiler.

JEL Kodları:
C45, C53, G12, Q56.

[*] Assist. Prof. Dr., Fırat University, Faculty of Economics and Administrative Sciences, Türkiye, yegur@firat.edu.tr
[**] Assist. Prof. Dr., Fırat University, Faculty of Economics and Administrative Sciences, Türkiye, aisimsek@firat.edu.tr
[***] Res. Assist. Dr., Fırat University, Faculty of Economics and Administrative Sciences,, Türkiye, ebulut@firat.edu.tr

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1. Introduction

Green projects are often funded via green crowdfunding which are connected to sustainable agriculture, forestry, waste management, renewable energy, and water conservation among others. Green initiatives have three core objectives - to minimize ecological footprint, protect natural assets, and stop causing environmental harm. This aligns with the triple bottom line of sustainability—the process by which companies manage their financial, social, and environmental risks, obligations, and opportunities, while also increasing long-term shareholder value; all three must be met, as well as maintained and improved upon, in order for corporations to ensure that they meet their needs for future generations to come. Climate initiatives often need additional upfront capital seem riskier and have slower returns than conventional choices, which makes green projects less attractive to private-sector investors, causing very limited investments. To this end, it is absolutely essential that private sector investments in green schemes are promoted and encouraged. Investors may lend money to green projects via financial products like interest-free green bonds and green sukuk (green bonds).

Introduced in 2007, green bonds began attracting financial market interest as environmental and sustainable investing gained prominence. The issuance of green bonds has expanded dramatically in recent years as seen in Figure 1.

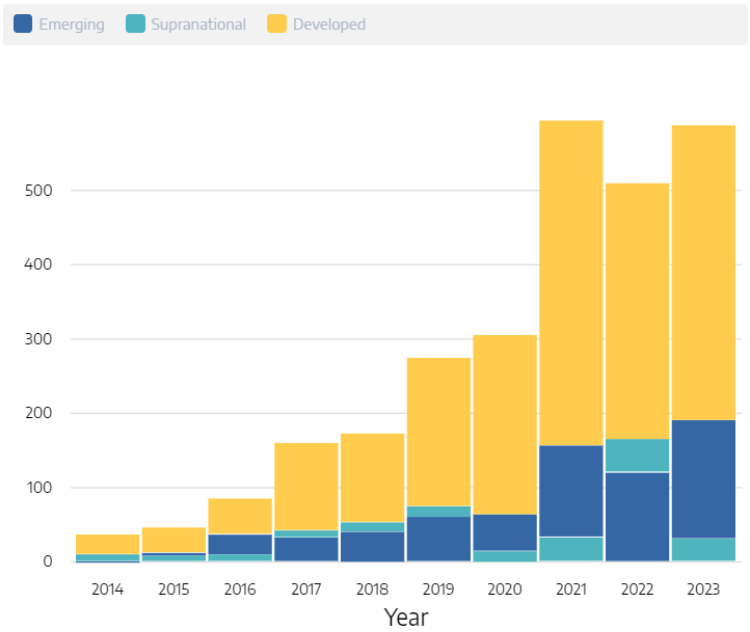

Figure 1. Amount of Issued Green Bonds
Source: www.climatebonds.net

The issue of green bonds entails soliciting funds from bond investors to finance initiatives like energy efficiency and renewable energy. Accurately estimating and projecting the market dynamics of green bonds is crucial for investors and regulators, as their popularity grows. The variables that impact the price of green bonds have been the subject of several studies that have highlighted the importance of these aspects (Tu et al., 2020; Dorfleitner et al., 2022; Verma and Bansal, 2023; Marín-Rodríguez et al., 2022; Çetin, 2022; Wei et al., 2024).

In this context, predicting the price of green bonds will continually relate to broader economic dimensions (both micro and macro), as well as commodity and financial markets and alternative investment prices. This paper's major goal is to answer the research question, which is to estimate the value of green bonds using both conventional (Linear models) and artificial intelligence-based forecasting techniques (Non-linear models), both of which have the ability to affect the green bond index. To represent stock markets across various regions, the Morgan Stanley Capital International Index (MSCI) is utilized, while the Global S&P Green Bond Index (HGGB) is employed to capture the performance of green bonds in the global financial market. Furthermore, our analysis includes a composite of traditionally perceived low-risk assets, such as gold (XAU), the US Dollar Index (DXY), and West Texas Intermediate (WTI). In addition to these, Bitcoin (BTC) is examined, the leading cryptocurrency by market capitalization, which presents a notably distinct risk profile compared to the other assets. Within the scope of the research, random forest, rational quadratic Gaussian Process Regression (GPR), XGBoost, MLP (non-linear), linear SVM, and linear regression (linear) methods were used. The data analyzed covers from June 1, 2021 until April 29, 2024.

The Global S&P Green Bond Index was chosen as the dependent variable in this study because of its extensive representation of green bonds in the global financial markets. This index provides a benchmark for the performance of bonds issued to finance ecologically sustainable projects, reflecting the fast growth of the relatively new green bond category. The index is well-regarded and encompasses bonds from many industries and geographical regions, rendering it an appropriate selection for reflecting global trends and dynamics in sustainable financing. Moreover, its broad scope enables the evaluation of the general trends and predictability of green bonds in relation to macroeconomic issues, which corresponds with the study's aim of comprehending how various variables affect the pricing of green bonds. This index facilitates an evaluation of global green bond market dynamics, enhancing the study's results' robustness and usefulness.

Despite being managed by a Canadian company, the Global S&P Green Bond Index tracks green bonds issued in various regions, including the USA, Germany, China, and others, which have the highest climate bond values. This index represents the global green bond market holistically by including bonds from many issuers from many industries and locations. This index was chosen over country-specific indexes because it provides a holistic perspective of the global green bond market, which is important for studying worldwide green bond patterns and macroeconomic issues. The Global S&P Green Bond Index was chosen for this research because it represents a wide range of countries rather than just one.

With the use of artificial intelligence-supported approaches, which are presently in short supply, this study seeks to add to the body of literature by shedding light on future research on the prediction of the green bond index. In addition to reducing investors' risk perception of green bonds, a relatively new financial instrument, and increasing their profitability, increasing the demand for green bonds and reducing the cost of financing green projects can be achieved by accurately estimating the green bond index.

There are five parts to the research. The introduction is covered in the first portion, and the second part is a review of the literature on green bonds and the variables influencing them. This is fully detailed in the third part of the study on the methods. The fourth part is the conclusion of the study. Lastly, Part 5 concludes and suggests recommendations.

2. Literature Review

Green bonds can also help bridge the financing gap of climate and ecologically favorable investments for those who will not invest directly in climate solutions. The World Bank issued the world's first green bonds (labeled climate bonds) in 2007 with the aim of providing investment instruments that incorporate environmental, social, and governance criteria, more specifically criteria designed using these markers as the lifespan of underlying investments. As far back as 2007, The European Investment Bank launched the first green bond for energy efficiency and renewable energy projects in the amount of 600 million EUR (Ehlers and Packer, 2017). The issuance of green bonds, an innovative financial instrument, was a major breakthrough in the fight against climate change and the promotion of sustainable development goals.

The price anticipation of green bonds based on commodity is a complicated and intricate one and how these factors play around each other are very different. Indeed, research has shown it to be possible to forecast the prices of various asset classes, including the green bonds, using the commodity prices, for example (Chen et al., 2010). Commodity prices and bond prices contain information about the relationship between investment opportunities in the emergence of market volatility hedges (Hong and Yogo 2012). Moreover, some researchers also investigate on the price prediction of corporate green bonds using AI models like artificial neural networks. And this is represented by the interest in new prediction methods (Çetin, 2022). Green bonds and the support from the house bond research have been demonstrated in a variety of studies, which highlight the diversification benefits of green bonds for investors as a portfolio investment alternative, and associations between green bonds and conventional asset classes (Abakah et al., 2022). Research on the Predictability of Commodity-Prices by Different Branches of the US Government Bond Yield Curve: There is also evidence that there may be a connection between bond yields and commodity price movements (Idilbi-Bayaa and Qadan, 2021). In fact, advanced models like copulas and transfer entropy have been used to study the dynamic link between green bonds with conventional asset classes, especially commodities indexes (Hung, 2021). Research suggests the importance of including commodity prices in forecasting models (Black et al., 2014). In a separate study, Broadstock and Cheng (2019) investigated how the co-movement between black and green bond prices changes over time by allowing for time-varying volatility in the financial market, unpredictability in the financial market, the business cycle, the crude oil price, and the news associated with the green bond. In their study, it is found that macro-economic variables and micro variables are equally influential on the green bond price. When market conditions are unfavorable, this means that the market is interconnected and defines a feedback link between oil prices and green bond prices (Marín-Rodríguez et al., 2022).

Like commodity prices, exchange rates have a profound effect on financial markets. In other words, it is important to analyze and understand the impact of foreign exchange rates on the prices of green bonds to manage investment strategies. The relationship between exchange rates and bond yields is analyzed by Tsui and Zhang (2021). One of the methods for predicting green bond prices is presented by Jia (2021) who used deep learning algorithms to forecast exchange rates and financial indices such as the CSI 300 Index. It has also been documented that commodity prices do exert an impact on exchange rates, implying the changes in commodity prices are widespread and have profound implications on financial markets (Zou et al., 2017, Ghoshray and Pundit, 2020). Wei et al. (2024) and Tu et al. (2020) examine the effect of exchange rates, commodity price levels, market volatility, and global economic indicators on the functionality of

the green bond market by examining Commodities prices, currency rates, and especially the price of WTI crude oil are the three key foundation stones for green bond market trends.

In literature, a large number of studies have examined the correlation of green bonds with other financial markets and have demonstrated the forecast performance of models based on these correlations. More recently, there has also research on price spillovers and co-movement effects between the green bond market and other financial markets (e.g., Reboredo, 2018 and Dutta et al., 2021 showing that price shocks in green bonds are affected by foreign exchange markets). Furthermore, in their analyses of green bonds and financial markets, Reboredo and Ugolini (2020) and Naeem et al. (2021) highlight the robust relationship between green bonds and the USD index and bond index.

It was also mentioned in the literature how gold price affects green bond price forecasting. Gao and Zhang (2023) also show that the gold price is significantly associated with green bonds, highlighting an important role played by gold in the volatility of the green bond price. In addition, it is controlled for cointegration between gold prices and other asset classes and therefore argued that bond risk premiums can be estimated from commodity prices, especially gold prices (Bouri et al., 2021a; Bouri et al., 2021b).

The price of green bonds is now being discussed in line with the cryptosystem markets of that era. Huynh et al. (2020) found that green bonds are necessary for climate hedging. Yadav et al. (2022) conducted research on cross-market linkages for green bonds with crypto and other markets. In their study, it is found that the green bond market provides protection against risk. Since the analysis of green bond price prediction is a very complex task, information on stock exchanges, stocks, and indices is very important. Different studies have tried to clarify the relationship between these factors. Accordingly, Xi and Jing (2021) investigate the extent to which returns of listed firms change after green bond issuance and find that investor demand for green bonds has an undeniable impact on security value. Consistently, Zhou and Cui (2019) find that green bond issuance has a positive impact on the stock price of firms with better profitability and operational performance. According to Lebelle et al. (2020), for firms in 28 countries between 2007 and 2017, stock prices increased following green bond issuance announcements. Moreover, Chai et al. (2022) reported that green bonds have a positive correlation with stock returns.

Green bond price forecasting using Artificial Intelligence (AI) has attracted much attention. Cetin (2022) used Artificial Neural Network models to build a framework and identify predictors based on green bonds to forecast corporate green bond prices. This resulted in better forecasting accuracy facilitated by the application of artificial intelligence in modeling green bond price dynamics. Wang et al. (2022a) developed a CEEMDAN-LSTM-based model for forecasting the green bond index. Furthermore, Artificial Neural Networks with time series algorithms and Machine Learning techniques have been applied to forecast asset prices in non-stationary financial time series (Dutta et al., 2020). More specifically to financial assets, tree-based ensemble machine learning models such as Random Forest and XGBoost have been applied to green bond forecasting where their models have achieved better results than tree-based ensemble machine learning models (Ampomah et al., 2020). These models demonstrate how artificial intelligence can predict the prices and values of financial assets. Models such as backpropagation neural networks and extreme learning machine neural networks have obtained success in predicting bond dynamics with stock prices (Maneejuk, 2023). AI has also been used to predict the prices of green securities and machine learning methods as well, such as Random Forests are among the forecast

methods used in different financial applications (Sadorsky, 2021). Dorfleitner et al. (2022) stressed the pricing of green bonds is mostly dependent on the influence of extrinsic variables, and the extent of on environmentally friendly efforts in accordance with which models can be constructed using AI-assisted methods to predict green bond prices. Together, these papers have underscored the importance of AI-supported approaches in the prediction of green bond prices.

This study improves the literature by offering a novel perspective through the integration of AI-assisted methodologies into current green bond pricing forecasting models. This study aims to determine the most effective model by comparing several machine learning models, in contrast to prior research that primarily examined the link between commodity prices, currency rates, macroeconomic indicators, and the green bond index. This study further identifies the macroeconomic elements to which the model assigns more significance using SHAP analysis, a topic rarely addressed in the literature, and emphasizes the importance of variables such as DXY, gold prices, and MSCI. In these aspects, our work diverges from the extant literature both methodologically and practically.

3. Methodology

This study uses machine learning and the fundamentals of artificial intelligence in predicting the daily green bond index. This paper contains a Section with respect to Dataset, its preprocessing steps, hardware and software features of the computer for the analysis, machine learning models for the prediction process, performance evaluation metrics, and the proposed approach.

3.1. Dataset and Preprocessing

This tool-based analysis forecasts the daily green bond index based on data from 1 June 2021 to 29 April 2024. The analysis begins on 1 June 2021, which corresponds to the inception date of the index used in this study. In a highly volatile market, determining a precise starting point can be challenging. To address this, June was chosen as it represents a midpoint in the year, offering a balanced reference for analysis. Moreover, as shown in Graphic 1, 2021 witnessed a significant rise in green bond transactions, marking a pivotal period for sustainable finance. The dataset consists of 710 daily observations of the MSCI, Gold Spot Price, WTI, US Dollar Index (DXY), Global X S&P Green Bond Index ETF, and Bitcoin Spot Price (BTC/USD). In Table 1, the sources of the variables that make up the data collection are shown.

Table 1. Sources of the Variables

Variables	Curency	Type	Source
MSCI	USD	Input	investing.com
Gold Spot Price	USD	Input	investing.com
WTI	USD	Input	investing.com
Dollar Index (DXY)	USD	Input	investing.com
Bitcoin Spot Price	USD	Input	investing.com
Global X S&P Green Bond Index ETF	CAD	Output	finance.yahoo.com

Devereux (2009) argues that although there is volatility in the CAD/USD parity, these fluctuations do not affect the stability of the CAD/USD parity in the medium and long run and

therefore the relative impact of the parity can be neglected. For this reason, the Global X S&P Green Bond Index ETF variable is denominated in CAD while the other variables are denominated in USD.

The data set obtained above was then imported from an Excel file using Python's Pandas package. Also the dropna() function from Python's Pandas package was used to remove any NaN (missing) values from the dataset during data preprocessing. Next, the data frame was divided into the independent variable (X) and dependent variable (Y). The data were standardized using min-max scaling as part of a preprocessing stage. This improves the performance of the models by converting each feature to a value between 0 and 1. In Equation 1, this scaling is shown.

$$x_{scaled} = \frac{x - x_{min}}{x_{max} - x_{min}} \quad (1)$$

Following the data normalization procedure, the training and test sets of the data set were separated for the regression process. Using the "train test split" command, the data was divided such that the training set included 80% of the data and the test set comprised 20% (568 training data and 142 test data sets were obtained). In order to ensure consistency in this process and to allow comparison of model performances by splitting the data sets in the same way each time, the 'random_state' parameter was also used during data partitioning. Random_state acts as a random number seed, ensuring that the same data partitioning is repeated in each run and the results are comparable. This ensures consistency between different trials (Bisht and Bisht, 2022).

3.2. Software and Hardware

Sign with green papers shall be predicted in this study. The data for the prediction is obtained from published daily through the report database. Eight models are employed using the scikit-learn library, a popular Python library for the implementation of various machine-learning models. The scikit library is preferred in the sub-section because, in comparison with the other libraries, using the scikit library is the easiest way to implement random forest, linear regression, rational quadratic GPR, XGBoost, MLP, and linear SVM models (Hao and Ho, 2019). For the rational quadratic GPR model, the authors used the GaussianProcessRegressor class from the scikit library. The scikit library is also used for the implementation of random forest and linear regression. Based on the explanations given for each model. The library recommended for the XGBoost model is the xgboost library, while the SVM module of the sci-kit-learn library was used for the linear SVM model. For multilayer perceptron models, the tensorflow or Keras libraries were used. These libraries are powerful and are widely used in making models for data analysis and machine learning (Gevorkyan et al., 2019). The pandas and numpy libraries were also used for making models for data manipulation and computation as well as for other general mathematical calculations. Moreover, the matplotlib and Seaborn libraries were used for data visualization during data processing and model evaluation. Using these libraries together, various machine-learning projects can be completed from start to finish.

The computer hardware utilized for all regression procedures is characterized by the following specifications. The processor is represented by a high-performance 8-core Intel Core i7-10700K. In comparison to lower generations of Intel processors, it facilitates higher performance when dealing with larger datasets and conducting more complex mathematical operations. The amount of RAM stands at 32 GB is DDR4, which appears to be sufficient to avoid

capacity shortages during datawork and model training. The graphics card enacting NVIDIA GeForce RTX 3080 type also belongs to the category of powerful GPUs. It is primarily tasked with enhancing computational power, a feature that is valuable when dealing with machine learning models. The amount of storage is equal to 1TB which is provided by means of an NVMe SSD.

3.3. Machine Learning Models

3.3.1. Random Forest Model

Random Forest was introduced as a machine-learning technique by Breiman in 2017 (Chen et al., 2020). This is known as Bagging, a random forest model method that randomly selects more features through a forest (or collection) of decision trees to improve node partitioning and then improves model performance without overfitting (Ren et al., 2020). This algorithm has been applied in a wide variety of fields as it is very cost-effective in tasks related to prior pattern recognition. The random forest has also been used in medical prognosis to predict response to treatment, survival rates, and clinical behavior in complex diseases such as mid-to-late stage cervical cancer (Liu et al., 2021) and anti-LGI1 encephalitis (Li et al., 2022). Furthermore, the random forest model has been used in environmental research on soil moisture and hydrology (Wang et al., 2022b) and in taste and odor prediction in drinking water reservoirs (Kehoe et al., 2015). In addition to these, random forest models have been implemented in green bond market studies in order to forecast price movements, performance scores, and volatilities (Xia et al., 2022; D'Amato et al., 2022; Soltani et al., 2024).

Random forest methods are known for their application to complex data features and their strong predictive performance. This is because it is very simple, versatile, and can easily work with high-dimensional data (Muñoz et al., 2018). The random forest model has undergone other modifications and extensions. For example, Shahhosseini (2021) considered weighted random forest models for classification tasks. Also, for forecasting tasks, Sun et al. (2020) propose randomized Shapley forests. Random forest is a very flexible and easy-to-use algorithm that can be used in most of the highly competitive solutions. Batch learning combined with decision trees is a very powerful support for various prediction problems.

3.3.2. Linear Regression Model

Usually, the Linear Regression Model is used for linear regression. A statistical technique, multivariate analysis aims to understand and predict the relationship between a dependent variable (Y) and multiple independent variables (x1, x2,..., xk). The goal of linear regression is to estimate the value of each regression coefficient, considering the sign, size, and statistical inference of each predictor variable. The forecast target of linear regression estimates how well the explanatory variables can predict the explicative variable (Harrell, 2015). Linear Regression Prediction Models formula is give in Equation 2 (Pentoś et al., 2022):

$$Y_t = X_t\beta + \varepsilon_t \quad (2)$$

This is given by the equation Y_t, the expected value at time t. The vector β = (β0, β1, ..., βk) relates the independent and dependent variables. The vector X_t= (1, x1t, x2t,..., xjt) is a j-dimensional vector containing the j-dependent variables at time t. The stochastic error term at

time t is denoted by ε_t, where t=1, ..., N and the error terms are chosen from a Gaussian distribution.

3.3.3. Rational Quatratic GPR Model

The GPR approach was first suggested by Rasmussen (2003). GPR has the advantage over other techniques that allow easy combinations of multiple ML tasks such as parameter estimation. Thus the regression simplified and its control on the output diminished, which shall make the whole process of regression explicable. The flexible kernel function of GPR is able to provide a confidence interval for prediction whereas GPR works very well even with a small training data set. A limitation of the prediction method is that its cost of computing grows cubically with |x|, which is impractical for all but small data sets (Su et al., 2019). Recent advances from the machine learning community have focused on the development of non-parametric methods to handle very nonlinear problems; one of the most well-known is the Gaussian process (GP). The system includes some stochastic variables, and it is considered that the distribution of all the input and output data is Gaussian. The GP assumes probability distributions for any feasible function that are consistent with the training dataset. Because of this, a GP's variable count is infinite and increases with the size of the training dataset. GPR is a mathematical model made up of a kernel function t(x, x') and a mean function n(x). (Zazoum, 2022).

$$F(x) = GPR(n(x), t(x, x') \tag{3}$$

The measure of central tendency for the variable F is represented by the sign n (x). The values of the test input "x" and test output "Y" are linked in the following way.

$$Y = F(x) + \varepsilon \tag{4}$$

The independent noise term is represented by the symbol ε. It is covered by a distribution with zero mean and σ_m variance. It has the following definition:

$$\varepsilon = D(0, \sigma_m^2) \tag{5}$$

The sample from the dataset follows a marginal probability, which is defined as:

$$H(y|f) = D(y|f, \sigma_m^2 J) \tag{6}$$

$$Y = [Y_1, Y_2, Y_3, \dots\dots\dots, Y_n]^T \tag{7}$$

$$f = [f(x_1), f(x_2), f(x_3), \dots\dots\dots, f(x_m)]^T \tag{8}$$

The forecast dataset conforms to a specific distribution, which is defined by:

$$H(Y_s|x, x', Y) = D(\mu_s, \sigma_s^2) \tag{9}$$

$$\mu_s = k_{sM}(k_m + \sigma_m^2 J)^{-1} Y \tag{10}$$

$$\sigma_s^2 = k_{ss} - k_{sM}(k_m + \sigma_m^2 J)^{-1} k_{Ms} \tag{11}$$

μ_s and σ_s^2 are the posterior mean and posterior variance respectively (in the case of GP). For the Input Layer, x and J are square matrices of size (M x M) and k_{sM} is the covariance matrix between training and test data, respectively.

3.3.4. SVM Model

Cortes and Vapnik introduced the support vector machine (SVM) in 1995 as supervised learning. SVM has a number of advantages, such as the ability to handle small sample sizes, the generalization of dimensional spaces well and flexibility etc. It also can recover from the shortcomings of local optimal solutions. The kernel of statistical learning theory, central of learning theory SVM, The SVM considers three main tasks: density-probability estimation, regression prediction and pattern recognition. The fundamental principle of SVM is to establish a continuous functional linkage between input and output views, relying on a few training data points. The objective is to make sure that the regression function can be as smooth as possible while minimising the error between the predicted regression value and the actual output value (Liu et al., 2020). Successive states of the SVM approach are defined in Equation 12-18.

$$f\ (x) = \ \omega^T\ (x) + b \tag{12}$$

$$L(f\ (x), y, \varepsilon) = f(x) = \begin{cases} 0 & |y - \ f\ (x)| \le \varepsilon \\ |\ y - f\ (x)| - \varepsilon & |y - \ f\ (x)| > \varepsilon \end{cases} \tag{13}$$

$$\begin{cases} Min. \frac{1}{2}\|\omega\|^2 + C\sum_{i=1}^{n} \xi_i \\ sub.t. \begin{cases} y_i - \omega\Phi(x_i) - b \le \varepsilon + \xi_i \\ -y_i + \omega\Phi(x_i) + b \le \varepsilon + \xi_i^* \\ \xi_i, \xi_i^* \ge 0 \end{cases} \end{cases} \tag{14}$$

$$\omega^* = \sum_{i=1}^{l} (\alpha_i - \alpha_i^*)\, \Phi(x_i) \tag{15}$$

$$b^* = \frac{1}{N_{nsv}} \left\{ \sum_{0<\alpha_i<C} \left[y_i - \sum_{x_i \in SV} (\alpha_i - \alpha_i^*) K(x_i, x_j) - \varepsilon \right] + \sum_{0<\alpha_i<C} \left[y_i - \sum_{x_j \in SV} (\alpha_j - \alpha_j^*) K(x_i, x_j) + \varepsilon \right] \right\} \tag{16}$$

$$K(x_i, x_j) = \exp\left(-\frac{\|x - x_i\|^2}{2\sigma^2}\right) \tag{17}$$

$$f(x) = \ \sum_{i=1}^{l} (\alpha_i - \alpha_i^*) K(x_i, x) + b^* \tag{18}$$

The SVM calculates a linear regression function denoted as f(x) in a high dimension space. That is the sample vector with x being any real number. Mapping of that function is done in non-linear fashion. This is of great benefit for the optimization problem, as it is used the linear insensitivity loss function L(f (x), y, ε). The loss function is represented by Equation 14. Equation 14 represents the input vector as $\boldsymbol{x_i}$ and the output value as $\boldsymbol{y_i}$. The variables in question are associated with a certain serial number, denoted by the symbol i. The set of real numbers, represented by the letters R, includes the variables $\boldsymbol{x_i}$ and $\boldsymbol{y_i}$. The dimension of the input vector is d. In this case, the cardinality of the items in an input vector is indicated by the variable d. The number of training samples is indicated by n. The degree of accuracy in regression analysis is indicated by the symbol ε. The variable C represents a penalty factor that quantifies the severity of the penalty imposed on a data sample when its mistake surpasses the threshold value ε. The slack variables $\boldsymbol{\xi_i}$ and $\boldsymbol{\xi_i^*}$ are used to apply penalties on the complexity of the fitting parameters. In order to ascertain the estimation of variables a and b, it is imperative to address the optimization problem as delineated in Equations 15 and 16. The variable $\boldsymbol{N_{nsv}}$ represents the number of support vectors that have been explicitly identified. The Lagrange multipliers, represented by $\boldsymbol{\alpha_i}$ and $\boldsymbol{\alpha_i^*}$, must satisfy the condition of being greater than or equal to zero. Equation 17 in this particular case employs the kernel function, represented as $\boldsymbol{K(x_i, x_j)}$. The Gaussian kernel function, known

for its exceptional capacity to generalize, is selected. Equation 18 denotes the ultimate regression function. The SVM model employed a kernel function.

3.3.5. XGBoost Model

The machine learning technique XGBoost is helpful in predicting prices. This technique has been used in a wide range of fields, such as stock price prediction (Zheng et al., 2017; Yue et al., 2021), home price prediction (Zaki et al., 2022; Sharma et al., 2024), power price prediction (Wu et al., 2022), gold price prediction (Jabeur et al., 2024), and stock market collapse forecasting (Zhu et al., 2022). Additionally, according to Simsek (2024), XGBoost has also been used in the process of enhancing the performance of models that anticipate stock prices. Traditional Boosting Tree approaches only rely on first derivatives. The distributed training of the n^{th} tree becomes more difficult when the residual from the preceding n-1 trees is included. Through the use of second-order Taylor expansion of the loss function, CPU multithreaded processing is optimized in XGBoost. XGBoost uses a variety of methods to reduce overfitting (Li et al., 2019).

The method outlined in Equations 19-26 is used to solve the XGBoost algorithm. Equation 19 represents the collection of regression trees, denoted as F. The variable f_k reflects the number of learners who are weak, whereas K represents the total number of learners who are weak. Equation 20 provides the goal function. The parameter $l\left(y_i, \hat{y}_i{}^{(t)}\right)$ in Equation 20 includes a range of loss functions that are used to address specific problems. Equation 20 is often used to measure the discrepancy between the actual value (y_i) and the predicted value ($\hat{y}_i{}^{(t)}$), as well as the overall intricacy of the model, denoted by $\sum_{k=1}^{t}\Omega(f_k)$. To evaluate the major component, substitute the expected value ($\hat{y}_i{}^{(t)}$) for the sample i^{th} in the repeated cycle t^{th}. The calculation is performed by using the subsequent approximation of the Taylor series at the expected value of y from the previous iterations, referred to as ($\hat{y}_i{}^{(t-1)}$), as seen in Equation 19. In Equation 22, the variables g_i and h_i represent the first and subsequent derivatives of the loss function $l\left(y_i, \hat{y}_i{}^{(t)}\right)$. Based on the information provided above, now it can be calculated the derivative by substituting the corresponding formulas from Equations 22, 23, and 24 into Equation 20. Equations 25 and 26 may be used to formulate solutions for a problem. The numerical representation of the outcomes of the loss function is denoted by the variable obj*. A lower score indicates that the assessed tree structure is more idealistic. The variable w_j^* offers the optimal answer for the weighting variables in the specific case under evaluation.

$$\hat{y}_i = \emptyset(x_i) = \sum_{k=1}^{K} f_k(x_i), f_k \in \mathcal{F} \tag{19}$$

$$\min L^{(t)}(y_i, \hat{y}_i{}^{(t)}) = \min\left(\sum_{i=1}^{n} \iota\left(y_i, \hat{y}_i{}^{(t)}\right) + \sum_{k=1}^{t}\Omega(f_k)\right) \tag{20}$$

$$\Omega(f) = \gamma T + \frac{1}{2}\lambda w^2 \tag{21}$$

$$\min L^{(t)} = min\left(\sum_{i=1}^{n}\left[g_i f_t(x_i) + \frac{1}{2}h_i f_t^2(x_i)\right] + \Omega(f_t)\right) \tag{22}$$

$$g_i = \partial_{\hat{y}_i{}^{(t-1)}} l\left(y_i, y_i^{t-1}\right) \tag{23}$$

$$h_i = \partial^2_{y_i^{t-1}} l(y_i, y_i^{t-1}) \tag{24}$$

$$fw_j^* = -\frac{\sum g_i}{\sum h_i + \lambda} \tag{25}$$

$$obj^* = -\frac{1}{2}\sum_{j=1}^{T}\frac{(\sum g_i)^2}{\sum h_i + \lambda} + \gamma . T \tag{26}$$

The usefulness and superiority of XGBoost in comparison to other machine learning algorithms has been shown by the fact that it has been demonstrated to be a flexible and strong tool for price prediction across a variety of distinct areas.

3.3.6. Multilayer Perception (MLP) Model

MLP is a simple type of artificial neural network with only one or many continuous layers. At a minimum, a multilayer perceptron should contain an input layer, a hidden layer and an output layer. MLP architecture usually has several hidden layers, which can be used to solve difficult problems (such as approximation) because they provide approximate solutions. By its nature, the Association Representation is a directed graph that maps a set of input vectors to a set of output vectors and reflects the MLP concept. It is a layer of node models that are connected in some way to the members of the next layer. Synaptic connections are also known as synapses or links (Pinkus, 1999; Gao et al., 2020). MLP models are used to model complex situations and predict test scores in multidimensional data (Wilamowski, 2009).

After calculating the weighted sum of inputs with the bias unit, on each unit, or neuron, an activation function is applied in an MLP. The outcome is then produced. The mathematical representation of the result produced by the neuron, is given by Equation 27.

$$a_j = f(\sum_{i=1}^{n} w_{ij}x_i + b_j) \tag{27}$$

Here, a_j is the activation or output of the neuron j, "f" is the activation function which can be sigmoid, tanh, ReLU etc where w_{ij} is the weight between the input i and the neuron j. Additionally, b_j is the input value "i" and x_i is the bias value of neuron j. In MLP, each layer receives signals from all neurons in the previous layer and multiplies these signals by weights. The output of a neuron can also be given as input to the next layer. This process continues until the output layer is reached. For the final activation function in the output layer, it may depend on whether the problem is a regression or classification problem. This allows the network to calculate the errors in the outputs that the network penalizes and then adjust the weights of the network to minimize the errors (Boughrara et al., 2016). This is a mathematical update of the weights as in Equation 28:

$$w_{ij}^{new} = w_{ij}^{old} - n\frac{aE}{aw_{ij}} \tag{28}$$

where 'w_{ij}^{new}' is the new weight value, 'w_{ij}^{old}' is the existing weight value, 'n' is the learning rate, 'E' is the error function and '$\frac{aE}{aw_{ij}}$' is the partial derivative of the error function for the weight. As mentioned above, the hyperparameter configurations for all the methods analyzed in this study were made with the Random Search algorithm and are shown in Table 2.

Table 2: Determined Hyperparameters of the Models as a Result of Optimization with Random Search Algorithm

Random Forest	**Linear Regression**	**Rational Quadratic GPR**
n_estimators: 100	Preset: Linear	Basis Function: Constant
max depth: 40	Terms: Linear	Kernel Function: Rational Quadratic
min samples split: 2	Robust option: Off	Use Isotopric Kernel: Yes
min samples leaf: 1	Fit_intercept: True	Kernel Scale: 1.0
max features: log2	Random state: 42	Signal Standard Deviation: 1.0
bootstrap: False		Sigma: 1.0
Random state: 42		Optimize Numeric parameters: Yes
criterion: gini		n_restarts_optimizer: 0
		Alpha: 1e-10
		Random state: 42
Linear SVM	**XGBoost**	**MLP**
Preset: Linear	Subsample: 0.7	Activation: ReLU
Epsilon: 0.1	n_estimators: 300	Alpha: 0.01727
C: 100	max_depth: 7	Hidden layer sizes: (50,50)
PCA: Disabled	learning rate: 0.05	Learning rate: Adaptive
Max_iter: 1000	colsample_bytree: 1.0	Learning_rate_init: 0.00073
Tol: 1e-3	min_child_weight: 1	Max_iter: 1000
Shrinking: True	gamma: 0	Optimizer: Adam
Cache_size: 200	reg_alpha: 0	Loss Function: Mean Squared Error (MSE)
Verbose: False	reg_lambda: 1	Batch_size: 32
Random state: 42	scale_pos_weight: 1	Beta_1: 0.9
	Random state: 42	Beta_2: 0.999
		Epsilon: 1e-8
		Early stopping: False
		Tol: 1e-4 Random state: 42

3.3.7. SHAP (Shapley Additive Explanation) Approach

Machine learning has demonstrated significant potential in predicting time series data, yet the lack of interpretability in its predictions often hinders practical applications. To address this challenge, Lundberg and Lee (2017) introduced the SHAP (SHapley Additive exPlanations) method, which is designed to explain the predictions of complex machine learning models, including LightGBM, NGBoost, CatBoost, XGBoost, and Scikit-learn tree-based algorithms.

SHAP builds on the foundational concepts of game theory proposed by Shapley (1953), offering a systematic approach to assess the contribution of each input feature to a model's prediction. By calculating Shapley values, the method enables users to determine how much each variable influences the outcome for a specific input instance. This level of transparency helps bridge the gap between the black-box nature of machine learning models and the need for explainable, actionable results. The Shapley value is calculated as follows (Jabeur et al., 2024):

$$\hat{\phi}_j = \frac{1}{K} \sum_{k=1}^{K} (\hat{g}\left(x_{+j}^{m}\right) - \hat{g}\left(x_{-j}^{m}\right)) \quad (29)$$

where $\hat{g}\left(x_{+j}^{m}\right)$ represents the forecast for particular input (x), but with a stochastic number of feature values.

Lundberg et al. (2018) developed TreeSHAP, a specialized approach for interpreting gradient boosting models such as XGBoost. TreeSHAP improves upon conventional methods like feature importance metrics and partial dependence plots by offering a more precise and consistent explanation of feature contributions within the model. Jabeur et al., (2024) propose that TreeSHAP interaction values can be determined in the following manner:

$$\emptyset_{i,j} = \sum_{S \subseteq N\{i,j\}} \frac{|S|\,!\,(M - |S| - 2)\,!}{2\,(M-1)\,!}\delta_{ij}(S) \tag{30}$$

While i $\neq j, \delta_{ij}(S) = f_x(S \cup \{i,j\} - f_x(S \cup \{i\}$ - $f_x(S \cup \{j\}$ + $f_x(S)$, M represents the quantity of features, whereas S represents all potential feature subsets. SHAP values enhance our comprehension of tree models by including feature significance, feature dependency visualizations, local explanations, and summary plots.

3.4. Performance Evaluation

Different evaluation measures such as MSE, MAE, MAPE, RMSE, and R^2 were used to observe how well the machine learning models performed the obtained results were used evaluate the prediction accuracy and efficiency of green bond prices models. The mathematical calculations of these metrics are shown in Equation 31-35 respectively.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N}(y_i - \hat{y}_i)^2}{N}} \tag{31}$$

$$MAE = \frac{\sum_{i=1}^{n}|y_i - \hat{y}_i|}{N} = \frac{\sum_{i=1}^{n} e_j}{N} \tag{32}$$

$$MAPE = \frac{\sum_{t=1}^{n}\frac{u_i}{Y_i}}{N} \times 100 \tag{33}$$

$$MSE = \frac{1}{N}\sum_{i=1}^{N}(y_i - \hat{y}_i)^2 \tag{34}$$

$$R^2 = 1 - \frac{\sum_i (y_i - \hat{y}_i)^2}{\sum_i (y_i - \mu)^2} \tag{35}$$

where y_i means the true rating in testing data set at time i; $\hat{y}_i$ means the prediction rating at time i; e refers to the error of the model; u means the difference between the actual value and the predicted value; N is the quantity of rating prediction pairings between the test data and the predicted results.

3.5. Proposed Approach

This research compares the performance of many artificial intelligence and machine learning models to determine which forecasting model is the most successful in predicting green bond values. This approach is designed to enhance forecasting accuracy and optimize financial analysis processes. The steps of data collection, preprocessing, and model training were meticulously planned and executed. Furthermore, a variety of indicators are used to evaluate the models' performance. An explanation of the general organization and functioning of the suggested method is given in this context via a diagram, upon which a thorough analysis will be based. Figure 2 depicts the suggested approach's visualization.

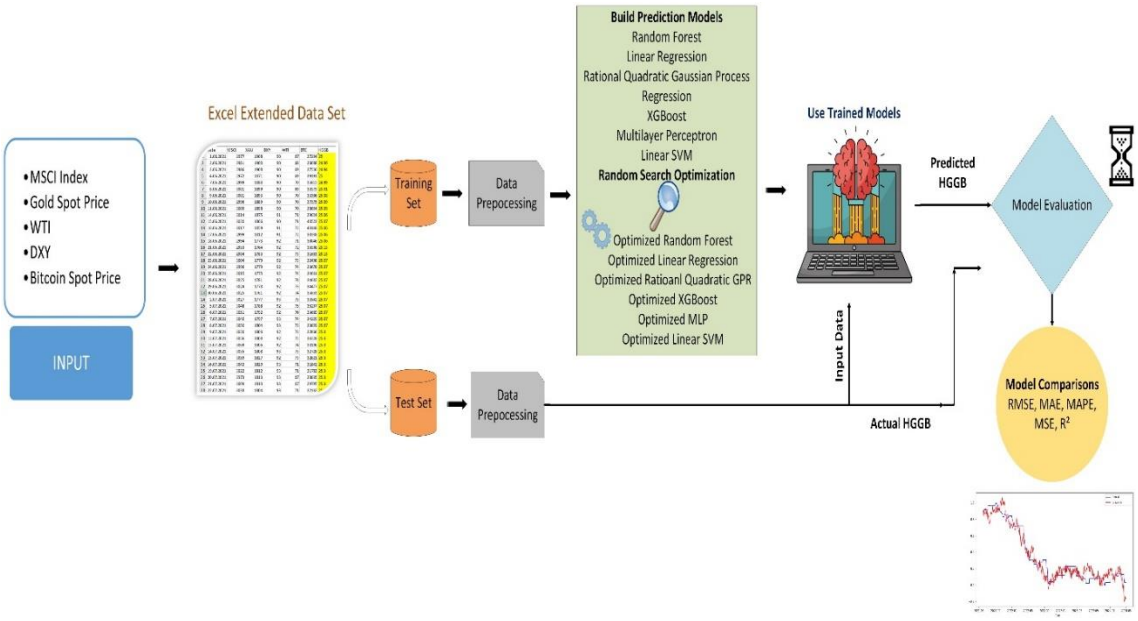

Figure 2. Proposed Approach

The approach outlined in Figure 2 follows a multi-stage and systematic process for forecasting green bond index. Initially, an extensive dataset is constructed using independent variables such as the MSCI, Gold Spot Price, WTI, DXY, and Bitcoin Spot Price. After that, this dataset is split into training and test sets, and each set goes through a series of data pretreatment procedures to be ready for modeling. During the modeling phase, various machine learning and artificial intelligence methods are employed. These models include Random Forest, Linear Regression, Rational Quadratic GPR, XGBoost, MLP, and Linear SVM. In addition, the models apply random search optimization, which helps increase the performance of each model. The training data is used in the training of the models which are then applied to the test one generating predictions. As such, the predictions made are compared to the actual HGGB values. In addition, measured performance against RMSE, MAE, MAPE, MSE, and R2 are as follows: The models will also be compared: the results from the two models will be compared to evaluate how well the models are performing relative to each other and how accurately the models are predicting green bond prices. Lastly, the final end goal of the quantitate analysis is to streamline the process of financial analysis and identify the best model for the future value that can be expected.

4. Findings

In this section, first, it is presented a correlation analysis between the variables used in the study. The results of the correlation analysis are shown in Figure 3. Following the correlation analysis, it is presented a discussion of the results of the AI-based machine learning techniques and their performance in green bond forecasting. Five different evaluation metrics are used to measure the accuracy and efficiency of the models: Random Forest, Linear Regression, Rational Quadratic GPR, XGBoost, MLP, and Linear SVM. In the first step, the models are trained using data from the training set. After comparing the training performances, the results are measured using R^2, MAE, RMSE, MAPE, and MSE for comparison purposes. The prediction plot of the

training results is shown in Figure 3, while Table 3 shows the metric measurements of the training results.

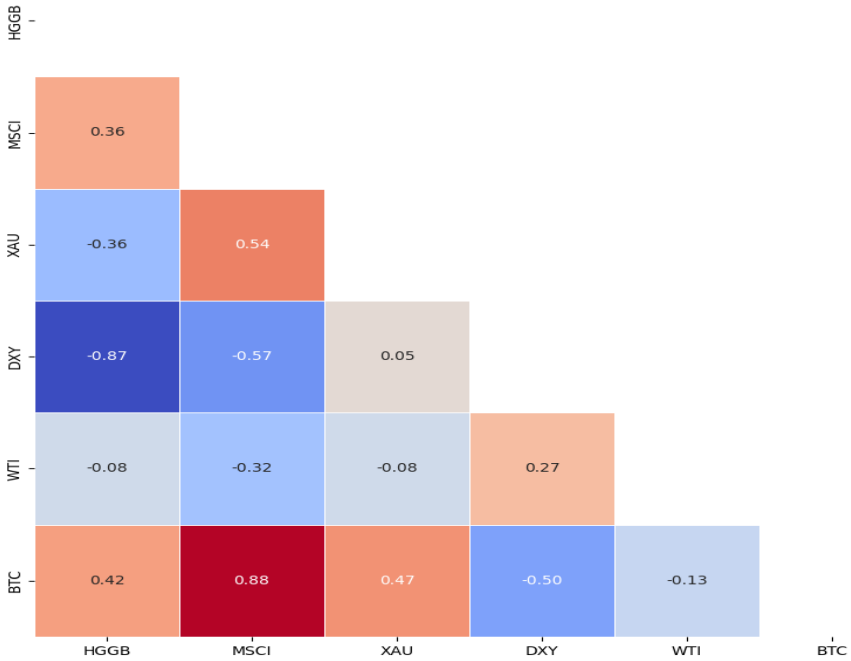

Figure 3. Correlation Matrix (Upper Triangle)

The correlation matrix in Figure 3 shows the relationship between HGGB (the dependent variable) and other independent variables, as well as the relationships between the independent variables themselves. Looking at the correlations of HGGB with other variables, it is seen that the highest positive correlation is with BTC (Bitcoin) at 42%, indicating that HGGB has a moderately positive relationship with Bitcoin prices. A positive correlation of 36% was also observed with the MSCI (international stock index). On the other hand, its correlations with XAU (gold price) and DXY (US dollar index) are negative by 0.36% and 0.87%, respectively. This suggests that the HGGB has a particularly strong negative correlation with the DXY, indicating that as the dollar index increases, the HGGB tends to decrease in a statistically linear relationship. The strong negative correlation between HGGB and DXY (−87%) aligns with the SHAP analysis results, which identify DXY as the most influential variable in predicting HGGB fluctuations. This correlation reinforces DXY's dominant role in the model's predictions. Among the other independent variables, the strong positive correlation between MSCI and BTC (88%) is noteworthy, suggesting that the price movements of the two assets are closely correlated. WTI (crude oil prices), on the other hand, is generally weakly correlated with other variables. In particular, its relationship with HGGB is very weak, with a negative correlation of 8%.

Figure 4 shows the prediction graphs of the training results of the models used in the prediction of the green bond index. In the Random Forest, Rational Quadratic GPR, and XGBoost models, the lines between the actual (blue) and predicted (red) values are closely intertwined, indicating that these models produce highly accurate predictions on the training set. The tight match between the anticipated and real values indicates a high level of model performance.

Conversely, although the Linear Regression, MLP, and Linear SVM models also produced reasonably accurate predictions, there are notable discrepancies between the actual and predicted values in certain periods. This is primarily due to their limited capacity to capture non-linear relationships adequately. The models with the highest overall performance were the Random Forest, Rational Quadratic GPR, and XGBoost models; the models with the worst performance were the Linear Regression, MLP, and Linear SVM models. These findings indicate which models are more effective on the training set.

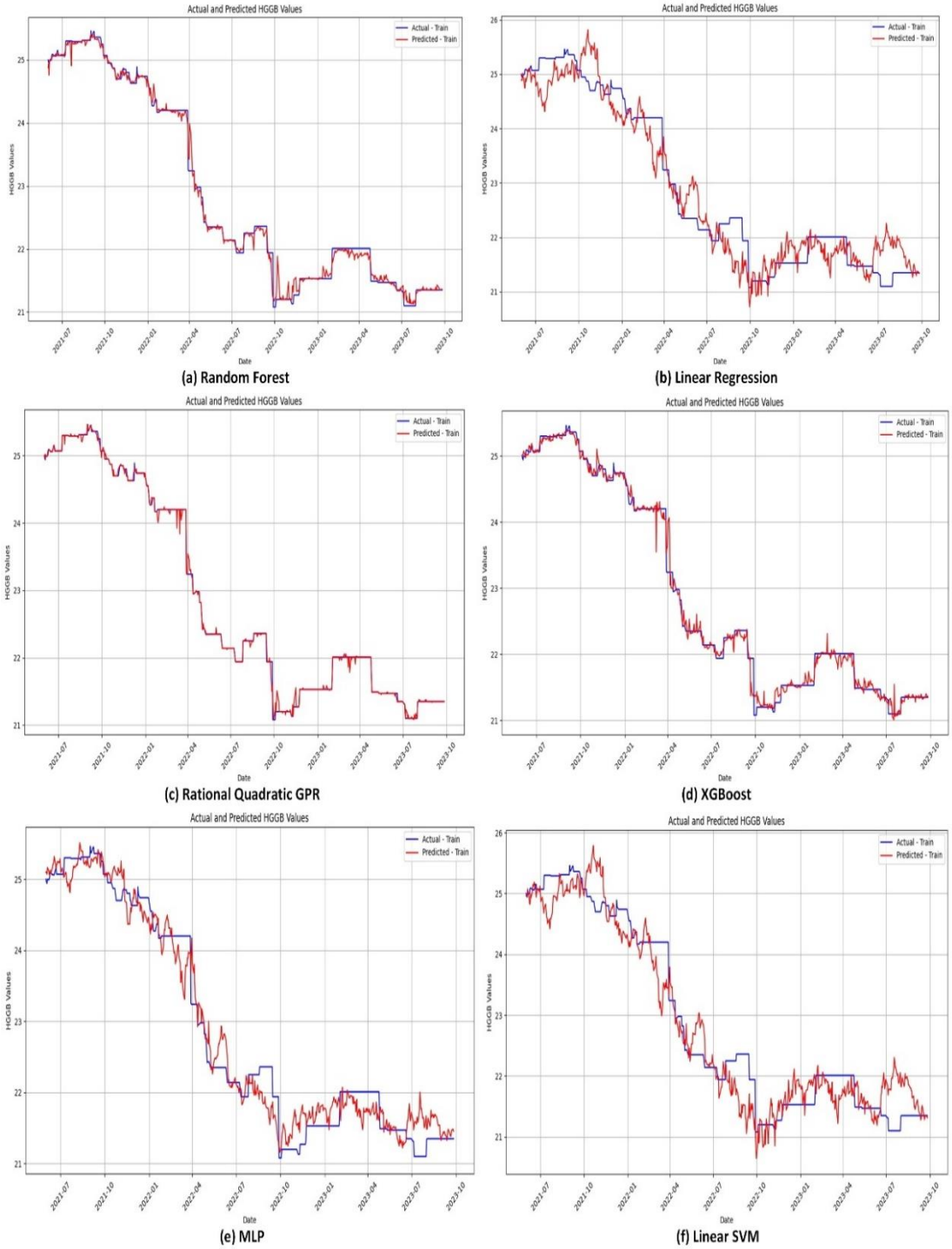

Figure 4. Prediction Graphs of the Training Set of the Models

Table 3. Metric Measurements of Training Results of the Models

	Random Forest	Linear Regression	Rational Quadratic GPR	XGBoost	MLP	Linear SVM
RMSE	0.0125	0.0942	0.0057	0.0076	0.0721	0.0945
MSE	0.0010	0.0088	0.0001	0.0006	0.0052	0.0089
MAE	0.0093	0.0736	0.0021	0.0018	0.0572	0.0749
MAPE	0.0029	0.0145	0.0004	0.0006	0.0113	0.0147
R^2	0.9969	0.9184	0.9999	0.9998	0.9520	0.9175

Additionally, the metric measurements of the training results of the models, as presented in Table 3, provide a detailed view of each model's performance. With an RMSE of 0.0057, MSE of 0.0001, MAE of 0.0021, MAPE of 0.0004, and R^2 of 0.9999, the Rational Quadratic GPR model performs the best, showing that the predicted values almost exactly match the actual values. Similarly, with an RMSE of 0.0076, MSE of 0.0006, MAE of 0.0018, MAPE of 0.0006, and R^2 of 0.9998, the XGBoost model did very well. With an RMSE of 0.0125, MSE of 0.0010, MAE of 0.0093, MAPE of 0.0029, and R^2 of 0.9969, the Random Forest model likewise showed great performance. In contrast, the MLP model demonstrated strong performance with an RMSE of 0.0721, MSE of 0.0052, MAE of 0.0572, MAPE of 0.0113, and R^2 of 0.9520. The Linear Regression model performed quite well, although it struggled to capture non-relativistic correlations with RMSE = 0.0942, MSE = 0.0088, MAE = 0.0736, MAPE = 0.0145, and R^2 = 0.9181. The Linear SVM model showed an average performance with RMSE = 0.0945, MSE = 0.0089, MAE = 0.0749, MAPE = 0.0147 and R^2 = 0.9175. The Rational Quadratic GPR model was the most effective model in predicting the green bond index. In general, the numerical results revealed that the XGBoost and Random Forest models also performed well. Figure 5 below reports the prediction graphs of the models on the test set.

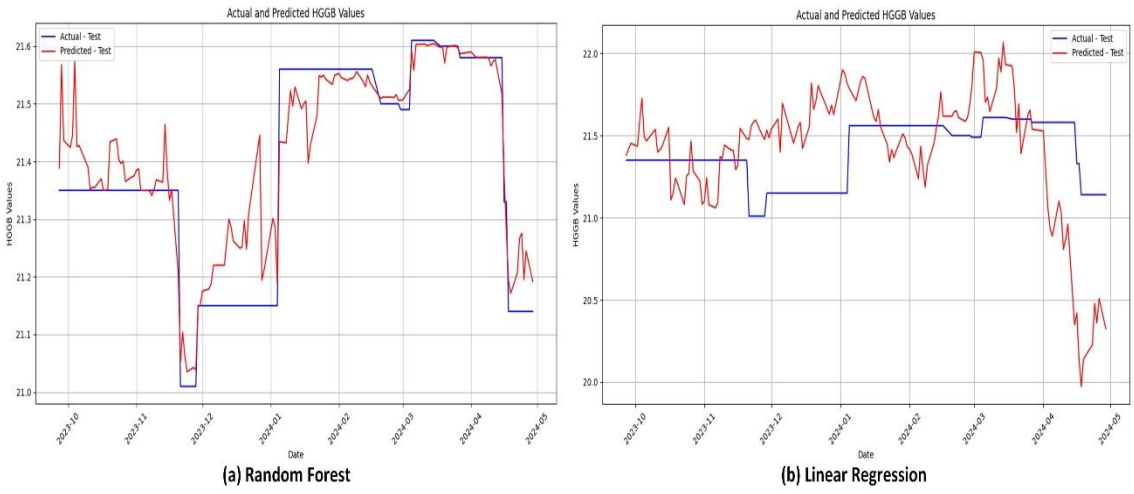

Figure 5. Prediction Graphs of the Test Set of the Models

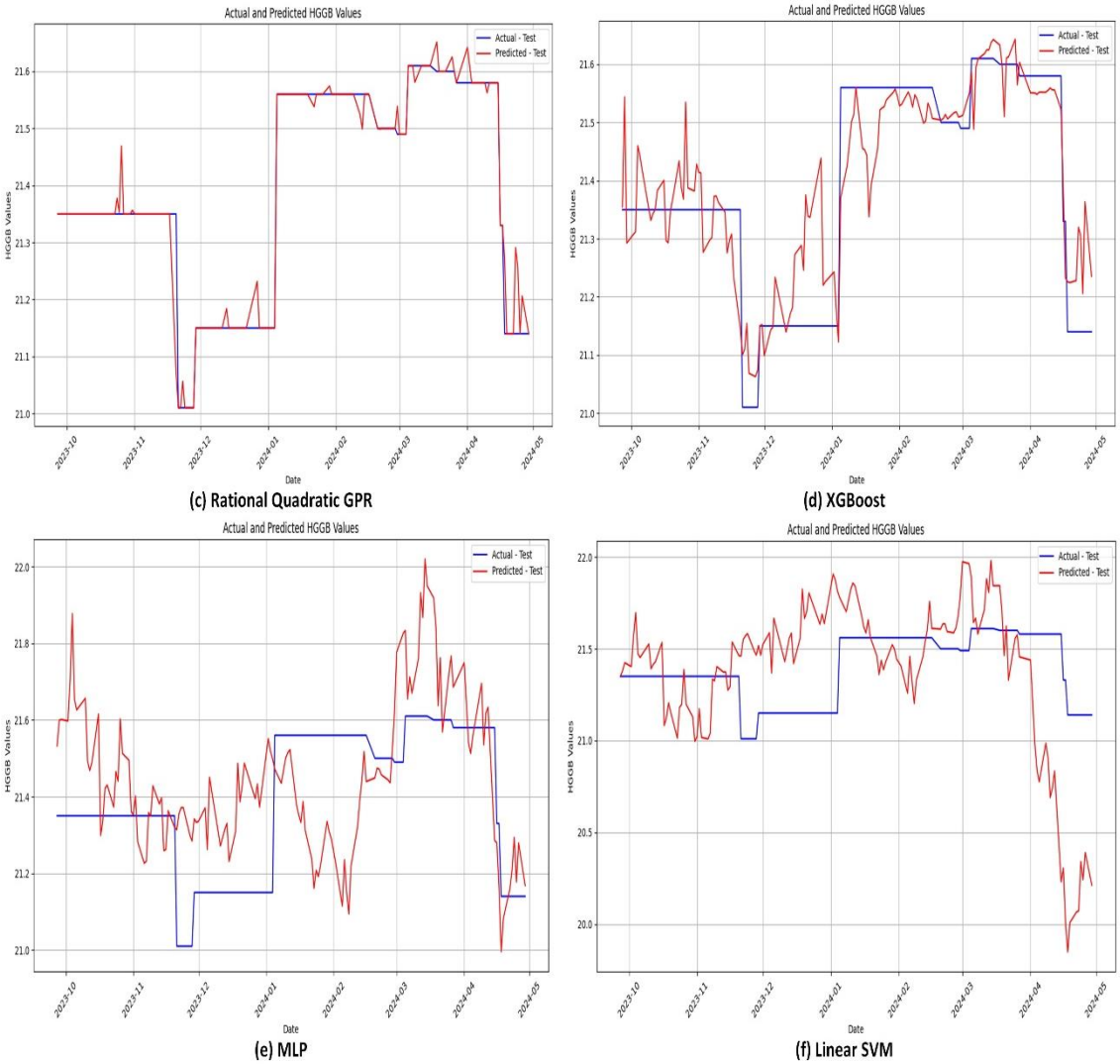

Figure 5. Continued

The graphs presented in Figure 5 illustrate test outcomes for the various models used to predict green bond index. Specifically, these graphs plot the changes in realized and predicted over time. It was determined that the most performing model was the Rational Quadratic GPR model, as the lines connecting realized and anticipated values show a very accurate forecast. In addition, the Random Forest and XGBoost models had very close to reality-predicted values on the test data. The MLP model, which was used to find non-linear relationships in data, presents very accurate forecasts. Finally, the Linear Regression and Linear SVM models showed that the predicted values were significantly different because the models were unable to find non-linear relationships properly. These experiments once again revealed that the most suitable model for forecasting green bond index is Rational Quadratic GPR, followed by other two models from the previous tests, XGBoost and Random Forest. Furthermore, the MLP model is one of the most performing models as well, while the Linear Regression and Linear SVM provide the weakest results. It should be noted that the results offered in Table 4 are used to arrive at these conclusions.

Table 4. Metric Measurements of Test Results of the Models

	Random Forest	Linear Regression	Rational Quadratic GPR	XGBoost	MLP	Linear SVM
RMSE	0.0305	0.1019	0.0260	0.0324	0.0781	0.1026
MSE	0.0010	0.0103	0.0006	0.0011	0.0061	0.0105
MAE	0.0178	0.0818	0.0181	0.0187	0.0645	0.0837
MAPE	0.0035	0.0160	0.0035	0.0037	0.0127	0.0163
R^2	0.9897	0.9181	0.9946	0.9885	0.9510	0.9172

A thorough understanding of each model's performance may be obtained from the metric measures of the test results of the models shown in Table 4. Among the models, the Rational Quadratic GPR model performs the best, with R^2 of 0.9946, RMSE of 0.0260, MSE of 0.0006, MAE of 0.0181, and MAPE of 0.0035. This demonstrates very high prediction accuracy by demonstrating a very little discrepancy between the actual and projected numbers. The XGBoost model also performed extremely well, with an R^2 of 0.9885, RMSE of 0.0324, MSE of 0.0011, MAE of 0.0187 and MAPE of 0.0037. The Random Forest model performed well with an RMSE of 0.0305, MSE of 0.0010, MAE of 0.0178, MAPE of 0.0035, and R^2 of 0.9897. MLP model — RMSE of 0.0781, MSE of 0.0061, MAE of 0.0645, MAPE of 0.0127 and 0.9510 R^2, which is not as good as two other models but still a good result. The average Linear Regression and Linear SVM models (respectively) achieved RMSE values of 0.1019 and 0.1026, MSE values of 0.0103 and 0.0105, MAE values of 0.0818 and 0.0837, MAPE values of 0.0160 and 0.0163, and R^2 values of 0.9181 and 0.9172. These results illustrated that the Rational Quadratic GPR model is the most suitable to establish predictive models for the green bond index, with Random Forest, and XGBoost being the second and third effective models respectively, and the MLP method is effective but slightly worse than the two above models, Lasso regression, linear regression, linear SVM presented mediocre performance.

In this study, time series cross-validation is used to evaluate the model while preserving the temporal structure of the data. n_splits=5 is chosen and the dataset is split into five sequential folds, where each training set progressively contains past observations and the corresponding validation set consists of future data points immediately following the training period. This approach avoids data leakage by maintaining the chronological order of the data and simulating real-world forecasting scenarios where future observations are not available during model training (Montaño et al., 2020). As a result, time series cross-validation provides a reliable assessment of the model's generalization performance over time and its predictive ability in unseen future periods (Blossier et al., 2017). The scores, obtained from time series cross-validation results in Table 5, are shown which again indicates the generalization competencies of our models.

Table 5. Metric Measurements of Time Series Cross-Validation Results of the Models

	Random Forest	Linear Regression	Rational Quadratic GPR	XGBoost	MLP	Linear SVM
RMSE	0.0499	0.0985	0.0442	0.0704	0.0736	0.0985
MSE	0.0026	0.0097	0.0021	0.0051	0.0055	0.0097
MAE	0.0329	0.0750	0.0267	0.0542	0.0580	0.0745
MAPE	0.0065	0.0148	0.0052	0.0107	0.0114	0.0148
R^2	0.9745	0.9072	0.9798	0.9507	0.9475	0.9074

Table 5 presents the results of the time series cross-validation for six models, evaluated using multiple performance metrics: RMSE, MSE, MAE, MAPE, and R^2. The Rational Quadratic GPR achieved the best performance across all metrics, with the lowest RMSE (0.0442), MSE (0.0021), MAE (0.0267), and MAPE (0.0052), along with the highest R^2 (0.9798), indicating its superior generalization capability and accuracy in capturing the patterns within the data. The Random Forest model also demonstrated strong performance, achieving an R^2 of 0.9745 and competitive error values, with an RMSE of 0.0499 and MAPE of 0.0065, positioning it as the second-best performer. In contrast, the Linear Regression and Linear SVM models yielded the highest error values, such as RMSE of 0.0985 and MAPE of 0.0148, with relatively lower R^2 values of 0.9072 and 0.9074, respectively, indicating their limited ability to handle the complexity of the dataset. The XGBoost and MLP models achieved intermediate performance, with R^2 values of 0.9507 and 0.9475, respectively, and moderate error metrics. These results demonstrate that nonlinear and ensemble-based models, such as Rational Quadratic GPR and Random Forest, are better suited for the underlying time series data due to their capacity to capture complex relationships, while linear models show relatively lower performance in comparison.

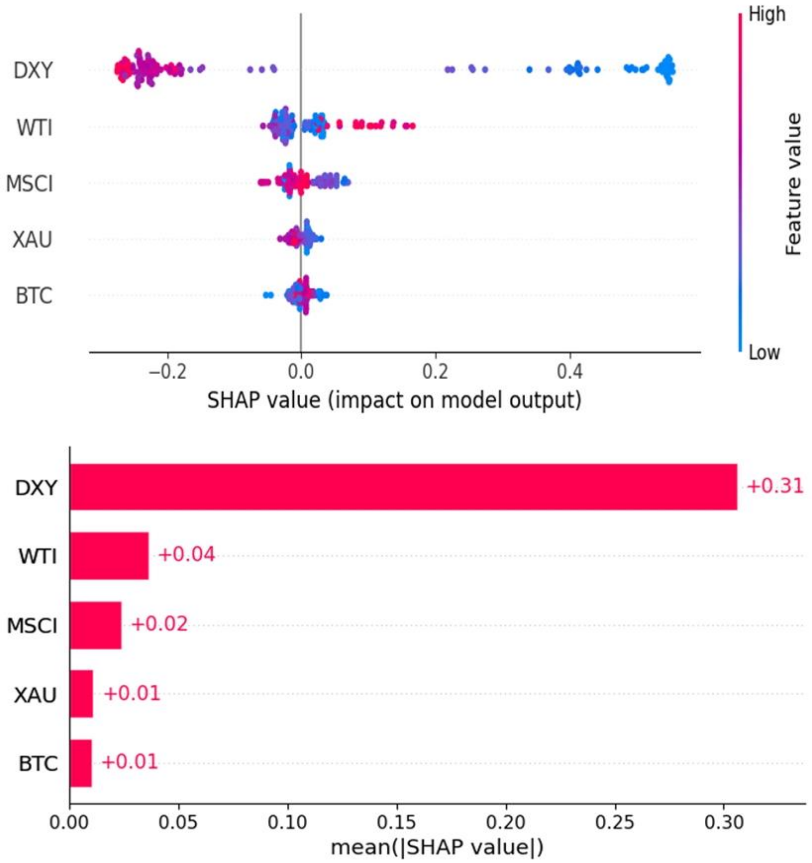

Figure 6. SHAP Analysis Results of Rational Quadratic Gaussian Process Regression Model

Figure 6 presents the results of the SHAP analysis, illustrating the feature importance assigned by the Rational Quadratic GP regression model and the impact of each independent variable on the model's predictions. In the SHAP summary plot (top), the horizontal axis represents the SHAP value, indicating the marginal impact of each feature on the model output,

while the colour indicates the feature value (red for high values and blue for low values). In the SHAP bar chart (below), the features are ranked by their average absolute SHAP value, highlighting their relative importance in the model. The DXY (US Dollar Index) stands out as the most influential determinant in the model, with the largest average absolute SHAP value. The wide dispersion of SHAP values for the DXY indicates its complex and non-linear relationship with the model's predictions. Importantly, high DXY values (red dots) tend to have a negative impact on model performance, while low DXY values (blue dots) generally have a positive impact. WTI (crude oil price) is the second most important variable but with a more limited impact compared to DXY. In contrast to DXY, the SHAP values for WTI are more concentrated around zero. However, high WTI values (red dots) tend to have a positive effect, while low WTI values (blue dots) tend to reduce model performance. The narrower range of SHAP values for WTI suggests a more consistent but weaker impact on predictions. The MSCI index shows a relatively small impact, with SHAP values clustered around zero. Both high and low values of the MSCI (red and blue dots) do not show a consistent direction of influence, indicating its limited contribution to the model. Similarly, the gold price (XAU) and bitcoin price (BTC) are the least influential variables, with SHAP values largely clustered around zero. In summary, a high WTI helps model forecasts, while a low WTI has a negative impact. High DXY values negatively affect model forecasts, while low DXY values have a positive effect. The MSCI index has a minimal and inconsistent influence, while XAU shows a distinct pattern where high values negatively impact performance, and low values positively influence it. BTC remains the least influential variable, with negligible contribution to model predictions.

5. Conclusion, Discussion and Recommendations

This study utilizes various artificial intelligence-supported machine learning methods to forecast the green bond index. Green bonds are crucial in financing sustainable and environmentally friendly projects, making accurate price predictions highly significant for investors and policymakers. By using many machine learning models to better capture the oscillations and nonlinearities in the green bond market, this study advances the discipline.

This is distinctive to the study in that it explains the working mechanism of the Rational Quadratic GPR model because of SHAP analysis and exemplifies higher results compared to the rest of the studies resembling the same kind. In the training and testing stages, the trained Rational Quadratic GPR model was found to be the best model among the models used in this study. Based on the cross-validation results, the Rational Quadratic GPR model has the lowest error rates along with the highest accuracy in RMSE, MSE, MAE, MAPE, and R^2 metrics. This model found success because it able the nonlinear, bond index. Our model accurately captured extreme events in the green bond market, including bursts of energy price shocks and COVID-19-induced economic turbulence over the period of the dataset.

The SHAP analysis shows that economic, macro, and financial characteristics such as DXY (US Dollar Index) and WTI (West Texas Oil) are important in influencing the model forecasts. This analysis has explained the features that have more weight and will affect the forecast results. A high DXY or WTI helps model forecasts, while a low DXY or WTI has a negative impact. Similarly, higher values of the MSCI increase forecasts, while lower values decrease them. BTC (Bitcoin Spot Price) and XAU (Gold Spot Price) affect the forecasts in a more balanced way and with a smaller effect area than the others. These findings are important in explaining how the

model makes predictions and which factors are more important for predicting the value movement of the green bond.

The results of the study are in line with prior findings in the literature. Studies by Wang et al. (2022a) and Çetin (2022) show how good artificial intelligence models predict the values of green bonds. As the predictions from these experiments have demonstrated, the rational quadratic GPR model is better as it can incorporate nonlinear interactions. In addition, the findings are consistent with Reboredo (2018) and Abakah et al. (2022), which delve into relationships between the green bond market and other related financial assets dynamism. However, the research does have some limitations. For one, assessments run over a larger time frame might offer a better evaluation of the models' performance as the data set covers only limited time. Next up, other methods could again improve the hyperparameterization of the models. Wider and diversified datasets need to be used in the future for the evaluation of the models as well as newer optimization techniques. Additionally, a deeper dive into other factors that can drive the value of green bonds could create a model more precise.

In conclusion, this research aims to exhibit the potential of machine learning-based tools with AI support in predicting the value of green bonds, and provides prospective areas of research using this research. Importantly, the Rational Quadratic GPR model was competent at predicting fluctuations and outliers in the green bond market, while identifying nonlinear relationships, one of the study's principal findings. This indicates that this model can be used for a general financial analysis and investment selection initiative.

This study provides a basis for comprehending the dynamics of green bond markets via advanced machine learning approaches; yet, several opportunities for additional investigation remained. Future studies should examine the effects of currency volatility by standardizing all data into a uniform currency, such as USD. Although our research indicates negligible effects of CAD/USD fluctuations over the study period, precise currency adjustments may heighten sensitivity. Furthermore, expanding the dataset to encompass extended timeframes and incorporating a broader array of green bond indexes will enhance the validity of the results, particularly during times of economic instability. Ultimately, investigating supplementary factors like interest rates or ESG measures, together with employing sophisticated machine learning techniques such as ensemble learning, may enhance predictive accuracy and broaden the usefulness of these models in sustainable finance. By focusing on these aspects, subsequent research might enhance the comprehension of green bond dynamics and refine financial forecasting instruments.

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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THE RELATIONSHIP BETWEEN INCOME DISTRIBUTION, INFLATION AND ECONOMIC GROWTH: EXAMINING THE ASYMMETRIC RELATIONSHIP BASED ON THE KUZNETS HYPOTHESIS WITH FOURIER FUNCTIONS

Gelir Dağılımı, Enflasyon ve Ekonomik Büyüme İlişkisi: Kuznets Hipotezine Dayalı Asimetrik İlişkinin Fourier Fonksiyonlar ile İncelenmesi

Serhat ALPAĞUT*

Keywords:
Income Distribution, Inflation, Economic Growth, Asymmetry, Fourier Functions.

JEL Codes:
B22, B23, C20, D63, O11.

Abstract

The relationship between inflation, economic growth, and income distribution in Türkiye is examined in this study. The F-ADL cointegration test was applied as the econometric method. The first result obtained is that economic growth has an increasing effect on income inequality. The second result is that inflation has a reducing effect on income inequality. The third result is that inflation and economic growth have an asymmetric relationship with income distribution. Economic growth initially has a positive effect on income inequality and then a negative effect beyond a certain threshold, indicating a "reverse U" shaped relationship. This result shows that the Kuznets hypothesis is valid in Türkiye. Regarding the relationship between inflation and income inequality, inflation initially has a negative effect, and then, after a certain threshold, the effect becomes positive, indicating a "U" shaped relationship. The findings are consistent with the literature. When relationships are linear, a single policy may be sufficient; however, in cases of asymmetric relationships, varied and multiple policies may be required. Thus, it is advisable to consider the asymmetry in the design of income distribution-regulating and welfare-enhancing economic policies.

Anahtar Kelimeler:
Gelir Dağılımı, Enflasyon, Ekonomik Büyüme, Asimetri, Fourier Fonksiyonlar.

JEL Kodları:
B22, B23, C20, D63, O11.

Öz

Bu çalışmada Türkiye'de enflasyon, ekonomik büyüme ve gelir dağılımı ilişkisi incelenmiştir. Ekonometrik yöntem olarak F-ADL eş bütünleşme testi uygulanmıştır. Elde edilen ilk sonuç ekonomik büyümenin gelir eşitsizliğini artırıcı etkisi olduğudur. İkinci sonuç enflasyonun gelir eşitsizliğini azaltıcı etkisi olduğudur. Üçüncü sonuç ekonomik büyüme ve enflasyonun gelir dağılımı ile ilişkisinde asimetrik ilişkinin var olduğudur. Ekonomik büyüme gelir eşitsizliğini önce pozitif etkilemekte ve bir noktadan sonra negatif etkilemektedir. Bu durum "ters U" şeklinde bir ilişkiyi ifade etmektedir. Bu sonuç Kuznets hipotezinin Türkiye için geçerli olduğunu göstermektedir. Enflasyon ve gelir eşitsizliğini ilişkisinde ise enflasyon önce negatif etkilemekte bir noktadan sonra etki pozitif olarak gerçekleşmektedir. Bu durum enflasyon ve gelir eşitsizliği ilişkisinin "U" şeklinde olduğunu göstermektedir. Elde edilen sonuçlar literatürle uyumludur. İlişkiler doğrusal olduğunda zaman içerisinde tek bir politika yeterli olabilirken asimetrik ilişkilerde değişken ve çoklu politikalara ihtiyaç olabilmektedir. Bu sebeple gelir dağılımını düzenleyici ve refah artırıcı ekonomi politikalarının uygulamasında ilişkilerin asimetrik olabileceği gerçeği dikkate alınarak düzenlemelerin yapılması tavsiye edilir.

* Asst. Prof. Dr., Ağrı İbrahim Çeçen University, Eleşkirt Vocational School, Finance-Banking and Insurance Department, Türkiye, salpagut@agri.edu.tr

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1. Introduction

Inflation and income distribution are among the issues that are emphasized and studied in economic literature. In developing countries like Türkiye, high inflation can have negative effects on income distribution. A fair and balanced income distribution has an effect that increases social welfare. Increasing social welfare affects economic growth through different mechanisms. Some researchers argue that increasing income inequality negatively affects economic growth (Kravis, 1960; Hussain et al., 1994; Barro, 2000). However, some researchers such as Kuznets (1955) states that this negative effect can vary over time (Paukert, 1973; Papanek and Kyn, 1986; Campano and Salvatore, 1988; Ram, 1995; Dawson, 1997; Zang, 1998; Huang and Lin, 2007). The variable situation mentioned is due to asymmetry. Kuznets (1955) states that while income inequality increases in the early stages of economic growth, it decreases in later periods. Of course, this hypothesis has been applied by many researchers on different economies. Some researchers have also stated that this hypothesis may not be valid (Anand and Kanbur, 1993; Ogwang, 1995; Jacobsen and Giles, 1998; Gallup, 2012; Huang et al., 2012). The relationship between income distribution and economic growth, which is on the agenda of many researchers today, continues to be investigated.

An increase in inflation generally refers to an increase in the general price level. Increases in inflation levels change the purchasing power of individuals in different income groups. Inflation mostly negatively affects middle- and lower-income groups (Bach and Stephenson, 1974; Parkin and Laidler, 1975; Blinder and Esaki, 1978; Fischer and Modigliani, 1978; Cardoso et al., 1995; Easterly and Fischer, 2001; Romer and Romer, 1998). However, apart from the general acceptance, there are also studies indicating that inflation may not negatively affect income distribution (Doepke and Schneider, 2006; Adam and Zou, 2016; Herradi et al., 2023). There is no definitive consensus in the literature on the relationship between income distribution and inflation. However, a detailed examination of the relationship between inflation and income distribution can enable more effective formation of economic policies.

There are many studies on income distribution, inflation, and economic growth. Some of these studies focus on economic growth and income inequality, while others focus on inflation and income inequality. A much more limited number of studies have examined the effects of both inflation and economic growth on income inequality. This study aims to contribute to this limited literature.

The research has two contributions to the literature. First, as far as can be reached, the use of Fourier functions is quite new in the literature reviewed. The examination of the subject with the new econometric method will deepen the subject. The contribution of Fourier functions is that structural breaks can be captured softly. Considering the recent period, Türkiye has experienced important structural breaks such as natural disasters, pandemic outbreaks, and military uprisings. The traditional approach suggests adding a dummy variable to represent each structural break. It is quite difficult for the traditional approach to correctly reflect too many breaks to econometric models. Since Fourier functions are structures that can capture breaks without the need for sudden breaks and without knowing the starting date, there is no need for additional structural change studies in the model to be applied. Second, although the asymmetric effect of economic growth on income inequality has been studied in studies conducted on Türkiye, the asymmetric effect of inflation has not been studied. In this respect, the study fills the gap in the literature. Reconsidering

the effect of the high inflation that Türkiye has experienced in recent years on income distribution will contribute to the correct evaluation of the recent period.

In the planning of the study, firstly the theoretical information on the subject will be presented. Then the literature studies will be mentioned. In the following section, the methodology will be presented by introducing the data and hypotheses and the empirical results will be shared. In the conclusion section, there is a general evaluation.

2. Theoretical Backgrounds

2.1. Relationship between Inflation and Income Distribution

Periods of high inflation are processes that negatively affect the healthy functioning of the market, causing a decrease in purchasing power and changes in income distribution. Employers can easily add price changes to the price of their products for sale. Moreover, in addition to actual inflation, which depends on market characteristics, employers can also reflect expected inflation in their prices. In this sense, employers may have incomes equal to or perhaps above inflation (Bach and Stephenson, 1974:1). On the other hand, employee groups do not benefit from the reflection of expected inflation in wages. However, workers also receive income loss caused by inflation with a lag. This situation leads to significant income transfers between employers and employees.

Increases in the money supply are considered to be the direct cause of inflation. This phenomenon has been accepted in economic literature since the quantity theory of classical economics. An increase in the money supply at the rate of EG (Economic Growth) will not change the general equilibrium in the economy and will not lead to inflation. Countries increase their money supply more than necessary in certain periods for certain reasons. Since this situation will accelerate inflation, increases in money supply are considered a cause of INCI (Income Inequality). In addition to this situation, central banks set short-term interest rates to control monetary balances in the market and ensure price stability. Depending on the changes in the general economic situation (for example, the depreciation of the domestic currency due to the increase in the demand for foreign currency), it takes the interest rates out of the required range. This situation represents inflation created by central banks and has disruptive effects on income distribution. Richard Cantillon (1775) evaluated the effect of such increases in the money supply on INCI using a different approach. Once money is created, it is neither equally nor simultaneously distributed among individuals. This phenomenon, called the Cantillon Effect, is a concept that expresses that the new money created by the money supply goes to high-income groups and arrives very late to lower-income groups. This structure of the money supply indicates that the neutrality of money is disturbed. In this phenomenon, the excess money supply is expressed as new money. This new money falls primarily into the hands of one group. The effect channel is that this new money brings wealth to the group that acquires it before it causes inflation. This is the unjust enrichment of one group. On the other hand, the group that receives new money late receives new money after inflation has occurred. The second group will be impoverished as the purchasing power of the new money will decrease (Sieroń, 2017: 640). The Cantillon effect is an approach that expresses the deepening of the phenomenon that the money supply distorts the distribution of income through inflation.

Upon further examination of inflation and income distribution through macroeconomic variables, the phenomenon of unemployment becomes. This phenomenon, particularly emphasized by the Keynesian school, is referred to in the literature as the Phillips curve. As a result of rising inflation, wages increase. These wage increases are also a cost factor for employers (Shao and Silos, 2017: 127). Companies lay off some employees to control rising costs. This macroeconomic phenomenon causes the unemployment rate to increase in countries. This means that a certain group cannot earn an income. It is noteworthy that those who lose their jobs due to this type of unemployment are usually individuals who belong to the low-income group. (Blinder and Esaki, 1978: 604). In summary, inflation appears as a phenomenon that creates INCI by causing poor people to lose their jobs.

The increase in food prices is particularly important for low-income segments. Food makes up a larger share of the consumption basket of the poor. Since the share of food consumption of people in the high-income group is relatively small, it is not of great importance (Walsh and Yu, 2012: 6). With the increase in inflation, the purchasing power of the poor is mostly spent on food, leaving them unable to meet other necessities of life. Thus, inflation makes the poor poorer.

Another channel affecting inflation and INCI occurs in the asset market. Rising inflation due to the Pigou effect causes an increase in the nominal value of existing assets. This situation increases the nominal wealth of asset owners. However, there are different income groups in a country. Since lower-income groups that do not acquire assets do not have such assets, an increase in wealth cannot be expected (Muhibbullah and Das, 2019: 142). In addition, since lower income groups are the renters of assets and inflation increases the rental payments of these assets, lower income groups become poorer than before due to inflation.

Another channel is the imbalance between the borrower and the lender. Lenders transfer their resources to the borrower in exchange for a certain monetary benefit over a certain period of time. This monetary benefit includes expectations that arise when the act of lending takes place. However, if there is an increase in the rate of inflation, the increase in both actual and expected inflation causes the real return to the lender to decrease over time. This situation represents a transfer of resources from the lender to the borrower (Wolff, 2010; Mason and Jayadev, 2014; Kumhof et al., 2015).

When the relationship between inflation and INCI is assessed from a public finance perspective, several important issues emerge. The first is the relationship between inflation and the public budget. The real value of public claims declines due to the Olivera-Tanzi effect, especially in periods of high inflation. This phenomenon, which can cause a decrease in public revenues, also leads to budget deficits (Ruge-Murcia, 1999: 333). The occurrence of budget deficits can push policymakers toward contractionary fiscal policies. This means new taxes on individuals and firms. It is accepted that the increase in taxes has a distorting effect on income distribution and that low tax rates have a positive effect on income (Agranov and Palfrey, 2020: 1). The reason for this is that individuals in the high-income group have high wealth income and low wage income. On the contrary, low-income groups have high wage income and low wealth income (Taghizadeh-Hesary, 2020: 2605; Kim and Lin, 2023: 894). Since government revenue is generally collected from indirect taxes, the imposition of new taxes by the government will affect low-income people more. This situation highlights the possibility that changes in fiscal policy due to inflation may disrupt income equality. Larch (2012) provides evidence that INCI increases as a result of budget deficits.

2.2. Relationship between Economic Growth and Income Distribution

The impact of income distribution on growth has been a topic of interest to researchers for some time. It is based on the income-expenditure-production relationship predicted by the classical economic approach. A sufficient increase in income in the economy and the transformation of income into expenditure is a factor that triggers production. Income distribution refers to the fact that the income earned in the country is not distributed among the rich and the poor in certain percentages and according to the desired standards. Consequently, income is distributed to high-income groups, and production is not stimulated to the desired level. This transmission mechanism is generally based on the assumption that a deterioration in income distribution will negatively affect EG. Barro (2000: 6) makes a similar point, emphasizing in particular the low borrowing capacity of the segment negatively affected by income distribution. Barro states that the deterioration of the financial system has a negative impact on income distribution and emphasizes that this situation will affect EG. It is argued that a flow of income and wealth from the rich to the poor will increase the efficiency of production as the poor benefit from the financial system through inflation. Hussain et al. (1994: 1947) emphasized that deterioration in income distribution has significant effects, especially on households. The study also found that INCI increases, and rural-urban households lag behind in development. Kravis (1960: 416) discussed the impact of deterioration in income distribution on tax revenue. In the study, it was stated that the deterioration in income distribution affects not only individual income such as wages, interest, rents, but also all types of income. Such a deterioration in income is expected to have a negative impact on EG, as it will have a negative impact on tax revenues.

Kuznets (1955: 8) brought a new hypothesis to the idea that the deterioration of the commonly accepted income distribution will have a negative impact on EG. In his study of the USA, England, and Germany, the author examined the effect of EG on INCI. It is found that INCI increases in the initial stage of EG, and after economic development reaches a certain level, INCI decreases. The sudden decrease in INCI and increase in EG in the US and England after World War I was the main motivation for Kuznets' work (Gallup, 2012: 1). While the agricultural sector initially dominated the economy, income in this sector was low, but inequality was low. Over time, industrialization increases. However, although income in industry is high, inequality is also high. As economies transition from agriculture to industry, EG increases, but inequality also increases. However, with continued growth, population growth, and technological development, the income from savings by high-income earners will decrease, and the income from production and entrepreneurship will increase. Thus, INCI will decline (Kuznets, 1955: 10). Over time, studies have emerged that support Kuznets' ideas (Paukert, 1973; Papanek and Kyn, 1986; Campano and Salvatore, 1988; Ram, 1995; Dawson, 1997; Zang, 1998; Huang and Lin, 2007). However, some studies show that INCI is not in an inverted U-shape as described by Kuznets. (Anand and Kanbur, 1993; Ogwang,1995; Jacobsen and Giles, 1998; Gallup, 2012; Huang et al., 2012).

3. Literature Review

Fischer and Modigliani (1978) state that inflation has a negative effect on INCI. In particular, the authors state that lower-income groups suffer more than higher-income groups, and that inflation has shifted income from the wage group, which is the lower-income group, to the wealth group, which is the higher-income group. Cardoso et al. (1995) conclude that high inflation

in Brazil in the 1980s significantly eroded the incomes of low-income people. Easterly and Fischer (2001) concluded that inflation is positively related to poverty, based on some 32,000 household observations in 38 countries. There are also studies that find the opposite of the above. Bach and Stephenson (1974) assessed the issue in terms of debtor-creditor relations. The authors state that income shifts occur due to a decline in the real value of debt during periods of high inflation. The authors state that this income transfer occurs from the business world to wage earners. The authors state that during the high inflation period during World War II, 1.2 trillion dollars in the USA was transferred to the lower income group in this way. Parkin and Laidler (1975) study on the USA found that inflation was negatively related to INCI. As a result, authors stated that lower- and upper-income groups were affected more than income groups. It was stated that the group that was relatively unharmed was middle-income earners. Blinder and Esaki (1978) examined how inflation affected incomes between income groups. As a result of the analysis made in 5 different percentiles, income shifts due to inflation were observed from the upper-income group to the middle-income group. However, similar results are not valid for lower-income groups. In the study, no income transition from the middle-income group to the lower-income group was observed. These results differ considerably from previous results. Romer and Romer (1998), in the relationship between monetary policy and the welfare of the poor, state that steadily growing aggregate demand and low levels of inflation increase the welfare of the poor. The interesting result is that expansionary monetary policy temporarily reduces poverty in the short run. The authors explain that the effects are temporary because expansionary policies cannot permanently increase output in the long run and cannot exceed the natural rate. On the contrary, it has been found that when contractionary policies are implemented, inflation falls, and this increases poverty.

Although it is generally accepted that inflation damages low-income groups, Doepke and Schneider (2006) have suggested that in the US, individuals in the low-income group are better protected than those in the high-income group because low-income group holds government bonds. Herradi et al. (2023) examined the impact of inflation on high-income households in 14 developed countries. The results show that inflation negatively affects high-income groups in developed countries. Another study, which concludes that lower-income groups are protected from INCI, was conducted by Adam and Zou (2016). It is parallel to the study of Parkin and Laidler (1975) in its approach and conclusion. As a result, it is stated that middle-class young people in the euro area are largely unaffected by inflation. In the study on China, Xu et al. (2024) conclude that the effect of expansionary and contractionary monetary policy on income distribution is neutral.

Some of the studies that examine the asymmetric relationship between inflation and income inequality indicate that the relationship is in the form of a "U" (Aktas and Dokuzoglu, 2022; Monnin, 2014). Aktas and Dokuzoglu (2022) investigated the relationship between inflation and income inequality in 40 developed and developing countries. The study examined the relationship according to different threshold levels. As a result, it was determined that it had a negative effect up to a certain threshold value and a positive effect after this threshold value. Monnin (2014) examined income inequality with the basic variables of income, unemployment, and inflation and control variables in a study on OECD countries. The square of the income and inflation variables was included in the model for the asymmetric effect. An important point that distinguishes this study from the examples in the literature is that the inflation and income variables were separated into components using the HP filter. Inflation trend, inflation cycle and inflation gap were

examined in three components. In addition, the GDP variable was separated into its components with the same method. As a result, it was determined that income inequality for OECD countries has a nonlinear structure in the form of an inverted U. In the first regression of the study, the square of inflation was not included in the model. In the second regression, it was included in the model. In the first model, income inequality is largely determined by economic growth. In the second model results, income inequality was obtained relatively close to each other by both inflation and economic growth.

Some studies indicate that the inflation-income inequality relationship is in the form of an inverted "U" (Balcilar, 2018; Uspri et al., 2023). Uspri et al. (2023) investigated the relationship between income inequality and inflation in Indonesia. In the study, the authors examined income inequality with inflation and growth variables. In addition, the authors used the square of inflation as an independent variable and investigated the asymmetric structure. The result obtained is that income inequality is in the form of an "inverted U". The effect of inflation on income inequality was determined as positive, while the effect of its square was determined as negative. Another important issue is that the effect of inflation on income inequality is higher than economic growth. Balcilar (2018) analyzed the US states with a semiparametric approach. As a result, a negative relationship was determined between the inflation rate and income inequality. The relationship was determined to be positive after a threshold value.

In the groundbreaking article published by Acemoglu and Robinson (2002), it is stated that the difference between the rich and the poor in countries is very large. It states that the possibility of people taking action and causing problems increases with the increasing course of inequality. It emphasizes that economic decision-makers tend to prevent inequality with monetary and fiscal policies during the period when inequality is at its highest. Thus, it states that the relationship is in the form of an “inverted U”. The meaning of the expression is that inequality first increases and then decreases with intervention.

There is evidence in the literature that economic growth and income inequality occur in an inverted U shape (Bulíř, 2001; Zhou and Li, 2011; Argun, 2017; Emek, 2019; Siami-Namini and Hudson, 2019). Siami-Namini and Hudson (2019) examined the relationship between income inequality and inflation in developed and developing countries. The econometric model and variables are parallel to the Monnin (2014) study. The difference is that separate regressions were created for the components of both inflation and economic growth variables. As a result, it was determined that income inequality had a nonlinear feature for both country groups. While the Kuznets hypothesis was not valid in developed countries, it was found to be valid in developing countries. Emek (2019) examined the macroeconomic factors affecting income inequality in 17 developing countries. As a result, the validity of the Kuznets hypothesis was confirmed. In addition, it was determined that inflation has a decreasing effect on income inequality, while unemployment has an increasing effect on income inequality. Argun (2017) conducted an analysis on 10 developing countries. As a result, it was determined that the Kuznets hypothesis was valid in these countries. In addition, it was stated in the study that inflation and trade volume also had a decreasing effect on income inequality. Zhou and Li (2011) conducted a semiparametric analysis of the relationship between inequality and development in 75 countries. As a result, it was determined that the Kuznets hypothesis was valid. In addition, it was stated in the study that trade and inflation increased inequality. Bulíř (2001) examined income inequality in the USA. In the study, the validity of the Augmented Kuznets Hypothesis was tested. In the regression model applied, economic growth and inflation variables expected to affect income inequality were used

together with control variables. For asymmetry effects, the square of the income variable was added to the model. As a result, it was determined that income inequality in the USA had a nonlinear structure in the form of an inverted U.

In the relationship between economic growth and income inequality, some studies have found a "U" shaped relationship (Monnin, 2014; Dincer, 2016; Akarsu, 2023; Herradi et al., 2023). Dincer (2016) investigated the relationship between inflation and income inequality in the USA. An econometric model was created in the study with the Kuznets approach. The square of the income and unemployment variables was used as explanatory variables. The result obtained is that income inequality is "U" shaped. The level value of the variables is positive, and their squares are negative. Another important result of the study is that the effect of economic growth on income inequality is higher than inflation and unemployment. Akarsu (2023) created an income inequality regression for the USA. The explanatory variables are economic growth, inflation and unemployment. The asymmetric effect was created with the square of economic growth. As a result, it was determined that income inequality has a U-shaped structure. Shahbaz et al. (2010) found that there is no asymmetric relationship between inflation and income inequality. Shahbaz et al. (2010) examined inflation, growth, and income inequality in Pakistan. In the study, the asymmetric relationship was investigated by including the squares of the economic growth and trade openness variables in the model. No asymmetric structure was found in the effect of inflation on income inequality. In the effect of trade openness, a relationship was found that first became positive and then negative.

It is seen that different results are obtained in the studies conducted for Türkiye. In the relationship between economic growth and income distribution, Takim et al. (2020), Ayla and Karis (2021), Durak and Akalin (2022) studies have determined that there is a positive relationship between economic growth and income inequality in Türkiye. These results show that economic growth is an important factor in reducing income inequality. However, Pece et al. (2016) and Yilmaz and Demirgil (2021) studies have determined a negative relationship between economic growth and income inequality. Some studies have addressed the situation with the Kuznets approach. Of these, Yeter and Demirgil (2024), Torusdag and Barut (2020), Akalin et al. (2018), Akinci and Akinci (2016) studies have concluded that the Kuznets hypothesis is valid for Türkiye. The common results of the studies are that increases in economic growth first positively affect income inequality, but after a threshold value, the effect becomes negative. Some studies have found findings that the Kuznets hypothesis is not valid in Türkiye. Gocen (2021), Abdioglu et al. (2019), Ak and Altıntas (2016) and Disbudak and Suslu (2009) found that increases in economic growth first negatively affected income inequality, and then the effect became positive. Another important issue is the effect of inflation on income inequality. In studies conducted on Türkiye, Naimoglu (2023), Ozbek and Ogul (2022), Pata (2020), Bayraktar et al. (2019), Destek et al. (2017) concluded that increases in inflation had an increasing effect on income inequality. Keskin (2022) and Kanberoglu and Arvas (2014) have found that inflation reduced income inequality. No studies investigating the relationship between inflation and income inequality within the framework of the Kuznets hypothesis were identified.

4. Empirical Analysis

4.1. Data and Hypothesis

The model to be used in the study was derived from the studies of Monnin (2014) and Siami-Namini and Hudson (2019). These are the studies that examine the asymmetric relationships between INCI, inflation and EG. These studies have adopted the same approach with examples from different countries. This study also examines the relationships in Türkiye with the same vision.

$$Gini_t = \beta_0 + \beta_1 Gdp_t + \beta_2 (Gdp)_t^2 + \beta_3 Inf_t + \beta_4 (Inf)_t^2 + \vartheta_T X_t + \mathrm{u}_t \quad (1)$$

The basic structure of the model to be used in the study is shown in equation (1). The basic model considers INCI as a dependent variable and EG and inflation as independent variables. Other variables were included in the model as control variables. The details of the variables used in the study are shown in Table 1. The study was conducted with the data of Türkiye for the period 1988-2022. The reason why the study is conducted in this period is because the Gini index data are available in this period from the WID database.

Table 1. Variables and Explanations

Variables	Explanations	Source
Gini	Gini Index	World Inequality Database (WID)
Gdp	Real GDP per capita (annual %) (current $)	World Bank, World Development Indicators Database (WDI)
Gdp^2	Square of GDP variable	
Inf	Consumer price index, CPI (annual %)	
Inf^2	Square of CPI variable	
Op	Trade openness (% of GDP)	
Un	Unemployment rate (% of total labor force)	
Inv	Gross fixed capital formation (% of GDP)	

The *Gini* coefficient is an index that generally measures INCI. The index in question takes a value between the numbers 0 and 1. As known from the Lorenz curve, when the index approaches 1, the inequality is high, and when it approaches 0, the INCI is decreasing. The *Gdp* variable represents EG, and the Gross Domestic Product per capita variable is used. A deflator has been used to make the data real. Gdp^2 is the square of the specified real GDP per capita variable. The *Inf* variable represents inflation. Percentage increases in the Consumer Price Index were used as inflation. The expression Inf^2 refers to the square of inflation. X denotes control variables. The control variables were defined as unemployment and trade openness and investment, following the original studies. Four different hypotheses are tested in this study.

H_{a1}: Economic growth has an impact on income inequality

H_{a2}: Inflation has an impact on income inequality.

H_{a3}: The relationship between economic growth and income inequality is asymmetrical.

The existence of the Kuznets inverted U-shape is determined according to the status of β_1 and β_2 coefficients specified in equation (1). If $\beta_1>0$ and $\beta_2<0$, the validity of the Kuznets hypothesis is confirmed. This result also indicates that there is an asymmetric relationship between INCI and EG (Siami-Namini and Hudson, 2019: 618).

H_{a4}: The relationship between inflation and income inequality is asymmetrical.

Depending on the status of β_2 and β_3 coefficients in equation (1), the existence of an asymmetric relationship between inflation and INCI is determined. It states that if $\beta_3<0$ and $\beta_4>0$, there is an asymmetric relationship between INCI and inflation (Shahbaz et al., 2010: 53).

Kuznets (1955) examined the relationship between INCI and growth. As a result, it is stated that INCI increases as a result of increasing EG and after a certain point, the relationship reverses. The literature refers to this asymmetric relationship as the inverted U-curve hypothesis. The positive effect of increasing EG on INCI in the early periods indicates the transition from an agricultural to an industrial society. Over time, EG transitions to a structure that reduces INCI due to the positive spillover effects of productivity growth in the industrial sector to both the agricultural, manufacturing, and service sectors (Amri, 2018: 10).

Table 2. Descriptive Statistics

	Gini	Inf	GDP	Un	Op	Inv
Mean	61.47	35.69	5.654	9.428	49.77	25.56
Median	61.23	15.75	6.273	9.290	48.79	26.19
Maximum	67.26	105.2	7.602	13.67	81.17	29.85
Minimum	57.68	6.250	3.062	6.260	30.47	17.95
St. Dev.	2.240	32.52	1.567	1.961	10.54	3.229

The maximum value of the *Gini* variable in the dataset, 67.26, belongs to 1988. The value, which was relatively high until the early 2000s, decreased from 2002 to 2015. In the following years, an increase can be observed. The lowest value, 57.68, belongs to 2007. The *Inf* variable expresses the percentage increase in consumer inflation. The value, which remained around 60% towards the 1990s, reached the highest value of the period with a maximum value of 105% in 1994. In the following periods, decreases in inflation are observed. In 2005, the annual increase reached 8%. The increasing value from year to year in the following periods is seen as 72% in 2022, which is the last year. The maximum value of EG is 7.60, the minimum value is 3.06 and the average value is 5.65. The *Un* variable represents the unemployment rate. Unemployment, which was around 8% in the 1990s, remained at values close to 10% in the 2000s and rose suddenly to 12.55 in 2009. Although it decreased in the following years, it reached its maximum value of 13.67 in 2019. Unemployment decreases in the following years. Trade Openness (*Op*) was seen at values close to 30% in the 1990s. There are relative increases from year to year. The highest value of 81.17% belongs to 2022. They show that Türkiye's trade volume is increasing steadily. The ratio of investment to national income (*Inv*), which was between 22-26% in the 1990s, reached its minimum value of 17.95% in 2001. The maximum value of 29.85% of the investment, which increased year by year in the following period, belongs to 2022, which is the last year.

4.2. Research Methodology

The Fourier ADL test is a cointegration test created using Fourier terms. This test is called F-ADL as used in the study of Banerjee et al. (2017). The working principle starts with the use of Fourier terms expressed in equation (2).

$$h(t) = \lambda_0 + \zeta_1 \sin\left(\frac{2\pi kt}{T}\right) + \zeta_1 \cos\left(\frac{2\pi kt}{T}\right) \quad (2)$$

In equation (2), the expression h represents the entirety of the deterministic terms. The Fourier terms to be used in the cointegration test are specified as sin and cos. In equation (2), k represents the optimum frequency value; t represents the trend; π represents the constant pi value; T represents the number of observations. The optimum frequency value is accepted as the value that minimizes the residual sum of squares (Yilanci et al., 2020: 21).

$$\Delta y_{1t} = \lambda_0 + \zeta_1 \sin\left(\frac{2\pi kt}{T}\right) + \zeta_1 \cos\left(\frac{2\pi kt}{T}\right) + \delta_1 y_{1,t-1} + \gamma'_2 y_{2,t-1} + \Phi' \Delta y_{2t} + \mu_t \quad (3)$$

The Fourier ADL test procedure is as specified in equation (3). γ, Φ and y_{2t} are explanatory variables and nx1 vectors of parameters. The frequency value expressed as k is used as an integer expression such that $1 \leq k \leq k_{max}$ and k_{max}=5. The procedure for using integers is based on the procedure envisaged in the study of Enders and Lee (2012). The null hypothesis is that there is no cointegration (H_0: $\delta_1 = 0$). The alternative hypothesis states that there is cointegration (H_1: $\delta_1 < 0$). This procedure is used in the use of the t-test. In the use of the F test, the null hypothesis is checked with a Wald test that the explanatory variables are equal to each other and to zero (H_0: $\delta_1 = \gamma = 0$). The obtained test statistic is compared with Table 1a for the model with constant, and with Table 1b for the models with constant and trend together. When the test statistic is greater than the table value, the alternative hypothesis is accepted to be valid (Banerjee et al., 2017: 117).

4.3. Findings

In this part of the study, firstly the results of a unit root test with a break for the variables and then the Fourier Unit Root test results will be given and compared. Then, the results of the F-ADL cointegration test, long-term coefficients, and short-term error correction model will be given respectively.

Table 3. Unit Root Test Results

Variables		Perron (1997) Unit Root test with breaks			
		Level		Δ	
		Constant	Constant & Trend	Constant	Constant & Trend
Gini	Stat.	-4.00	-3.51	-5.79***	-5.74***
	Break. Date	(2004)	(2003)	(2005)	(2005)
Inf	Stat.	-2.50	-2.65	-4.47**	-5.04***
	Break. Date	(1998)	(2021)	(2020)	(1994)
Inf^2	Stat.	11.94***	-5.90***	-7.61***	-9.47***
	Break. Date	(2021)	(2021)	(1994)	(1994)
Gdp	Stat.	-2.41	-1.67	-5.52***	-6.56***
	Break. Date	(2001)	(2002)	(2013)	(1998)
Gdp^2	Stat.	-2.15	-1.37	-5.97***	-6.69***
	Break. Date	(2021)	(2002)	(2013)	(2002)
Un	Stat.	-4.38*	-4.57	-4.96***	-4.93***
	Break. Date	(2000)	(2000)	(2009)	(2009)
Trd	Stat.	-1.56	-3.88	-5.26***	-5.66***
	Break. Date	(2017)	(2021)	(2015)	(1997)
Inv	Stat.	-4.16	-4.53	-6.81***	-6.64***
	Break. Date	(2010)	(1998)	(2009)	(1999)
Critical Values	1%	-4.94	-5.34	-4.94	-5.34
	5%	-4.44	-4.85	-4.44	-4.85
	10%	-4.19	-4.60	-4.19	-4.60

Note: ***, ** and * symbols refer to 1%, 5% and 10%.

Table 3 presents the unit root with structural break test result. The analysis was carried out in two structures: both constant and constant and trend. As a result of the test, it was determined that inf^2 and *Un* variables were I(0), stationary at the level; other variables were I(1), stationary in difference.

Table 4. Fourier Unit Root Test Results

Var.	co./ co+tr	k	Lag	SSR_{min}	Sin. t stat.	Cos. t stat.	F (Wald)	Linear/ Nonlinear	Fourier ADF Stat.	ADF Stat.	I(0)/ I(1)
Gini	co.	5	0	16.087	0.95	0.11	0.45	Linear	-	-2.04	I(1)
Gini	co+tr	1.6	6	15.177	-4.07[a]	-5.08[a]	10.75[a]	Nonlinear	-3.47	-	I(1)
Inf	co.	1	14	3837.8	10.97[a]	-9.32[a]	97.80[a]	Nonlinear	-9.67[a]	-	I(0)
Inf	co+tr	0.1	4	3613.4	-2.01[c]	1.54	9.37[b]	Nonlinear	-3.23	-	I(1)
Inf^2	co.	1	13	637462	-7.76[a]	6.81[a]	31.46[a]	Nonlinear	-5.29[a]	-	I(0)
Inf^2	co+tr	0.1	5	629325	-8.62[a]	-8.43[a]	24.28[a]	Nonlinear	-6.61[a]	-	I(0)
Gdp	co.	1	10	3.4341	-4.26[a]	3.11[b]	10.91[a]	Nonlinear	-4.60[a]	-	I(0)
Gdp	co+tr	0.9	10	394.92	-4.18[a]	1.20	12.06[a]	Nonlinear	-4.56[b]	-	I(0)
Gdp^2	co.	1	12	402.73	-4.94[a]	3.67[b]	24.76[a]	Nonlinear	-4.43[a]	-	I(0)
Gdp^2	co+tr	0.9	10	394.92	-3.70[a]	1.38	10.96[b]	Nonlinear	-4.88[a]	-	I(0)
Un	co.	2.4	9	32.600	5.39[a]	-1.20	15.04[a]	Nonlinear	-3.25[b]		I(0)
Un	co+tr	2.5	9	27.039	2.74[b]	-2.65[b]	13.88[a]	Nonlinear	-0.88	-	I(1)
Trd	co.	0.1	8	665.43	-2.99[a]	-3.13[a]	4.95	Linear	0.30	0.25	I(1)
Trd	co+tr	0.1	7	468.59	-3.25[a]	2.98[a]	13.58[a]	Nonlinear	-3.35	-	I(1)
Inv	co.	3.7	7	110.68	-3.28[a]	0.04	5.38	Linear	0.82	-1.89	I(1)
Inv	co+tr	3.5	0	90.303	3.13[a]	1.02	5.18	Linear	0.81	-3.02	I(1)

Note: The expressions a, b and c above the numbers indicate 1%, 5% and 10% statistical significance, respectively. In addition, co represents constant; co+tr represents constant and trend; k represents optimal frequency value; SSR represents minimum residual sum of squares.

In Table 4, the Fractional Frequency Fourier ADF test proposed by Bozoklu et al. (2020) was applied. Bozoklu et al. (2020) determined the frequency range as $0.1 \leq k \leq 5$. The frequency change value ($k_t - k_{t-1}$) is 0.1. Bozoklu et al. (2020) further developed the Fourier tests created before it. For example, the study of Enders and Lee (2012) used the frequency value as an integer, and the study of Omay (2015) accepted the maximum value of the frequency as 2 despite using fractional frequency. The test proposed by Bozoklu covers a wider frequency range than the previous tests.

The study of Enders and Lee (2012) was used for the maximum lag length ($p \leq T/2$) and the critical values used to test the validity of the F Wald test. Bozoklu et al. (2020: 10-11) Table A and Table B were used for the significance of the Fourier ADF statistics. In addition, Bozoklu et al. (2020: 6) state that at least one of the Fourier terms must be statistically significant for the validity of the test. For this reason, the t-statistic significances were given by adding the sin and cos columns to Table 4. Accordingly, it is seen that at least one of the trigonometric terms of the variables stated to have nonlinear properties in Table 4 is significant. This result is an important measure of the validity of the test.

Table 4 results show that *inf*, Inf^2, *Gdp*, Gdp^2, Un variables are I(0), stationary at the level. *Gini*, *Trd* and *Inv* variables are I(1), stationary at the difference. Unit root tests investigate whether variables can return to their mean. Since variables that are stationary at level return to their mean, it is accepted that the changes in the variable are temporary. In the opposite case, which is

differential stationarity, the changes experienced in the variables are evaluated as permanent. Accordingly, according to the structural break test results, only Inf^2 and *Un* variables are stationary in Türkiye. Thus, the effects on these variables are temporary. However, the Fourier test showed that *Inf*, Inf^2, *Gdp*, Gdp^2, *Un* variables are stationary. Thus, according to the Fourier test, these variables are temporary. These results show that Fourier tests make more sensitive measurements than traditional tests. According to the results obtained, when a policy is desired to be determined, it is not necessary to recommend a policy for variables whose changes are temporary, while it is necessary to recommend a policy for variables whose changes are permanent. Applying a policy to a variable whose changes are temporary may lead to unexpected results in economic terms. Therefore, it is vital for economic applications that the tests are accurate and up to date. In this example, where structural break and Fourier tests are applied, it is seen that Fourier tests provide more precise measurements when added to unit root tests.

Table 5. F-ADL Cointegration Test Results

		F test: 7.65* **	**Opt. Freq. V.**
Critical Values	1%	5.01	(2) AIC (1.33)
	5%	5.34"	

Note: *** symbol refers to 1%. The critical values were derived from the study by Banerjee et al. (2017).

Table 5 present F-ADL cointegration test result. If the F-test is greater than the specified critical values, it means that the null hypothesis that there is no cointegration is rejected. According to Table 5, since $F_{est}>f_{critic}$, the H_0 hypothesis has been rejected. It can be seen that there is a cointegration relationship between the variables.

Table 6. Long-run Coefficients of F-ADL Cointegration Test

Variables	**Coef.**	**St. E.**	**t. Stat**	**Prob.**
Gdp	4.039**	1.765	2.288	0.045
Gdp^2	-0.618***	0.149	-4.148	0.002
Inf	-0.136***	0.031	-4.356	0.001
Inf^2	0.0003*	0.000	2.085	0.063
Un	0.081	0.115	0.704	0.497
Op	-0.026*	0.012	-2.209	0.051
Inv	-0.028	0.019	-1.478	0.170

Note: ***, ** and * symbols refer to 1%, 5% and 10%.

Table 6 presents the long-run coefficients of cointegration. According to the table, other variables than *Un* and *Inv* are statistically significant. The variable that has the strongest effect on the dependent variable, *Gini*, is *Gdp*. The level value of the variable *Gdp* positively affects the dependent variable. Gdp^2 has a negative effect on the dependent variable. This indicates that the Kuznets hypothesis is valid. INCI first becomes positive, then reaches a certain level, and then becomes negative. This is the inverted U-shape described. Moreover, the fact that the *Gdp* variable has a positive coefficient and the *Gdp* variable has a negative coefficient and is statistically significant ($\beta_1>0$ and $\beta_2<0$) confirms the existence of an asymmetric relationship between growth and INCI. Another important result is related to the inflation variable. While the *Inf* variable had a negative impact on INCI, the Inf^2 variable had a positive impact on INCI. The structure of INCI predicts a U-shaped relationship, first negative and then positive. The fact that the *Inf* and Inf^2 variables have different coefficient signs and are statistically significant ($\beta_3<0$ and

$\beta_4>0$) confirms the asymmetry of the relationship. Among the control variables, only the *Op* variable is significant. It has a negative sign of the coefficient. This indicates that inequality in income distribution has decreased as a result of increasing trade volume. The leading frameworks addressing the relationship between trade and income inequality are the Heckscher-Ohlin and Stolper-Samuelson theorems. The Heckscher-Ohlin theorem assumes that countries export using the abundant factors of production available to them. Developing countries export unskilled labor-intensive goods and import skilled labor-intensive goods. Thus, with the increase in trade, export revenues shift more to the factor that produces unskilled goods. The Stolper-Samuelson theorem argues that the production factor used intensively to produce that product will benefit more from the increase in the price of a good. Thus, if the price of a labor-intensive good increases, the income from this price increase will again shift to the labor sector (Demir et al., 2012: 168; Lin and Fu, 2016: 129). The assumptions in both theories support each other and theoretically assume that trade can cause a decrease in income inequality. The negative relationship between trade and income inequality obtained for Türkiye is in line with theoretical expectations.

Table 7. Error Correction Model Results

Variables	Coef.	St. E.	t. Stat	Prob.
C	0.976***	0.096	10.16	0.000
@Trend	-0.113***	0.014	-7.632	0.000
ΔInf	-0.029	0.018	-1.594	0.141
ΔInf^2	-0.0002	0.0001	-1.507	0.162
ΔGdp	1.019	1.097	0.928	0.375
ΔGdp_{-1}	-0.763***	0.183	-4.155	0.002
ΔGdp^2	-0.298***	0.093	-3.206	0.009
ΔUn	-0.043	0.065	-0.659	0.524
ΔUn_{-1}	0.392***	0.069	5.623	0.000
ΔOp	0.010	0.016	0.659	0.524
@COS	-0.027***	0.002	-10.78	0.000
@SIN	-0.010***	0.001	-6.657	0.000
ECT	-1.473***	0.144	-10.20	0.000

Note: ***, ** and * symbols refer to 1%, 5% and 10%.

Table 7 presents the results of the error correction model created to detect short-term relationships. This is the error correction term, which is denoted by the abbreviation ECT. The fact that the sign of the coefficient is negative and statistically significant indicates the accuracy of the model. According to Table 7, the error correction term of -1.473 indicates that short-term errors fluctuate and reach long-term equilibrium. The terms Cos and Sin are significant. This indicates the validity of the Fourier model. When the coefficients are evaluated, statistically significant variables cannot be evaluated accurately because the variables exhibit a positive effect at one level and a negative effect at another level.

Table 8. Diagnostic Tests

Tests	Stat.	Prob.	Decision
Breusch-Pagan-Godfrey	14.80	0.73	No heteroscedasticity problem
Breusch-Godfrey	0.30	0.57	No autocorrelation problem.
Jarque-Bera	4.73	0.09	Have normal distribution properties
Ramsey RESET	0.96	0.33	Does not have excluded variables and no specification error
Cusum and $Cusum^2$	See Appendix-I for graphics.		No structural break

Table 8 presents the results of the diagnostic tests employed to assess the validity of the applied model. These results demonstrate that the model exhibits no autocorrelation or heteroscedasticity, is normally distributed, contains no excluded variables, and does not exhibit structural breaks.

The first finding obtained from the study is that economic growth has an increasing effect on income inequality. The finding is consistent with the results of the studies on Türkiye by Takim et al. (2020), Ayla and Karis (2021), Durak and Akalin (2022). The second finding is that the Kuznets hypothesis is valid. This finding is consistent with the results of Yeter and Demirgil (2024), Torusdag and Barut (2020), Akalin et al. (2018), Akinci and Akinci (2016). The third finding is that inflation has a reducing effect on income inequality. This finding is consistent with the results of Keskin (2022) and Kanberoglu and Arvas (2014). Since no study investigating the asymmetric relationships between inflation and income inequality could be identified, a comparison could not be made. The fourth finding is that trade volume reduces income inequality. This finding is consistent with the results of Kuscuoglu and Cicek (2021), Topuz and Dagdemir (2020), Disbudak and Suslu (2009).

5. Conclusion

The aim of this study is to determine the effects of asymmetric relations in economic growth and inflation on income distribution. Türkiye was selected for the study. The reason for choosing Türkiye is the high inflation. Within the scope of the issues explained in detail in the theoretical section, inflation is a fundamental factor affecting the general macroeconomic order and ultimately economic growth. In addition, as far as can be reached, an inflation-gini relationship created by inflation and the square of inflation has not been studied in Türkiye before. It is aimed to contribute to the literature in this respect. The data set created covers the period 1988-2022. The reason for the limitation in this date range is that the income inequality data was served in this date range. This issue is a limitation of the study.

The econometric model investigated in the study is derived from the studies of Bulíř (2001), Shahbaz et al. (2010), Dincer (2016), Siami-Namini and Hudson (2019), Monnin (2014), Uspri et al. (2023). These studies focused on the impact of asymmetry in inflation and economic growth on income inequality.

The study investigated the answers to 4 research questions. The first of these questions is the effect of economic growth on income inequality. According to the analysis results, economic growth increases income inequality. In addition, it has been determined that economic growth has a stronger effect than other factors affecting income inequality. When compared with the literature, it is consistent with the studies of Takim et al. (2020), Ayla and Karis (2021), Durak and Akalin (2022).

The second research question is the effect of inflation on income inequality. As a result of the study, it was determined that increases in inflation reduce income inequality. It is thought that the improving effect of inflation on income distribution is related to the recent period of low interest rates in Türkiye. It is known that low interest rates are an important opportunity for low-income groups to acquire wealth. As predicted by the studies of Wolff (2010), Mason and Jayadev (2014) and Kumhof et al. (2015), income transfers from lenders to borrowers may have occurred. For this reason, if such a relationship has occurred, the study of Barro (2000) that the changes in

the financial system improved their economic situation through inflation will be supported. The results are consistent with the studies of Keskin (2022) and Kanberoglu and Arvas (2014).

The third research question is the existence of an asymmetric relationship between economic growth and income inequality. The situation where economic growth positively affects income inequality, and the square of economic growth negatively affects income inequality supports Kuznet's inverted U-shaped hypothesis. The statistical significance of the coefficient signs of the applied cointegration test in the long run shows that economic growth affects income inequality in an inverted U-shaped structure for Türkiye. This situation also confirms the asymmetric relationship between economic growth and income inequality. The finding is consistent with the results of Yeter and Demirgil (2024), Torusdag and Barut (2020), Siami-Namini and Hudson (2019), Emek (2019), Akalin et al. (2018), Argun, (2017), Akinci and Akinci (2016), Zhou and Li (2011) and Bulíř (2001).

The fact that inflation negatively affects income inequality, and the square of inflation positively affects income inequality indicates that there is an asymmetric relationship between income inequality and inflation (Shahbaz et al., 2010: 53). The long-term coefficient signs of the applied cointegration test and the finding of statistical significance show that inflation affects income inequality in a U-shaped structure for Türkiye. This also confirms the asymmetric relationship between inflation and income inequality. When the empirical results of this study are compared with the following literature, it is seen that they are consistent with Aktaş and Dokuzoglu (2022) and Monnin (2014).

The results of the study contribute to the understanding of the complex relationships between income inequality, inflation, and economic growth. The analysis shows that there are significant relationships between income inequality, inflation, and economic growth. These results are consistent with the studies in the literature.

These findings highlight important issues to be considered in the formulation and implementation of economic policies. Inflation and economic growth should be taken into account in the implementation of policies aimed at reducing income inequality. We recommend that the strong relationship between economic growth and income inequality should be taken into account in the formulation and implementation of expansionary monetary and fiscal policies. The results of this study can guide future research and provide important guidance to policymakers.

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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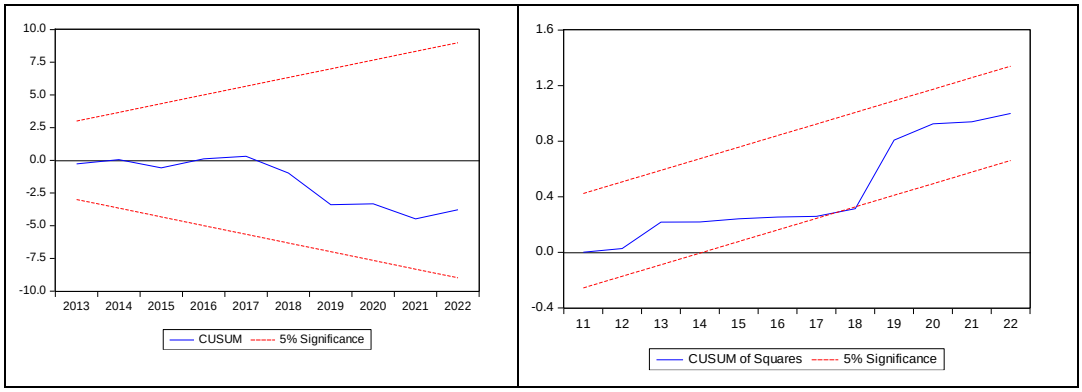
APPENDIX-I



Graph 1. CUSUM Tests Result

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THE NEXUS BETWEEN RENEWABLE ENERGY, ECONOMIC GROWTH, AND CARBON DIOXIDE EMISSIONS: EVIDENCE FROM MS-VAR AND MS-GRANGER CAUSALITY METHODS

Yenilenebilir Enerji, Ekonomik Büyüme ve Karbondioksit Emisyonları Arasındaki İlişki: MS-VAR ve MS-Granger Nedensellik Yöntemlerinden Kanıtlar

Ayça BÜYÜKYILMAZ ERCAN[*] & METEHAN ERCAN[**]

Keywords:
MS-VAR, MS-Granger Causality, Renewable Energy, Carbon Dioxide Emissions, Economic Growth, Regime Switching

JEL Codes:
Q53, C32, Q42

Abstract

This study aims to examine the dynamic relationship between carbon dioxide (CO_2) emissions, renewable energy consumption, and economic growth in Denmark, Sweden, and Chile. These countries were not randomly selected. They were chosen since they have the highest scores according to the Climate Change Performance Index (2023). In addition, Markov-switching vector autoregressive (MS-VAR) and Markov-switching Granger (MS-Granger) causality methods are applied to the annual data of the three countries over the period 1971–2021. Contrary to linear methods, MS-VAR and MS-Granger causality approaches allow us to estimate and interpret this relationship for different regimes, such as recession and expansion. These methods also provide insights into the likelihood and duration of the persistence of the current economic regime. The empirical results show that there is a two-way MS-Granger causality between renewable energy consumption and economic growth in all regimes for the three countries except for moderate and high expansion regimes for Chile. Moreover, in general, there is a two-way MS-Granger causality between economic growth and CO_2 emissions in all regimes. Furthermore, the findings from the estimated models indicate that there is a two-way MS-Granger causality between renewable energy consumption and CO_2 emissions in general, except for the second regime for Chile.

Anahtar Kelimeler:
MS-VAR, MS-Granger Nedensellik, Yenilenebilir Enerji, Karbondioksit Emisyonları, Ekonomik Büyüme, Rejim Değişimi

JEL Kodları:
Q53, C32, Q42

Öz

Bu çalışma, Danimarka, İsveç ve Şili'deki CO_2 emisyonları, yenilenebilir enerji tüketimi ve ekonomik büyüme arasındaki dinamik ilişkiyi incelemeyi amaçlamaktadır. Bu ülkeler rastgele belirlenmemiştir. İklim Değişikliği Performans Endeksi'ne (2023) göre en yüksek puanlara sahip ilk üç ülke oldukları için seçilmişlerdir. Ayrıca, üç ülkenin 1971-2021 yılları arası yıllık verilerine Markov rejim değişimli vektör otoregresif (MS-VAR) ve Markov rejim değişimli Granger (MS-Granger) nedensellik yöntemleri uygulanmıştır. Doğrusal yöntemlerin aksine, MS-VAR ve MS-Granger nedensellik yaklaşımları bu ilişkiyi durgunluk ve genişleme gibi farklı rejimler için tahmin etmemize ve yorumlamamıza olanak sağlamaktadır. Bu yöntemler aynı zamanda ülke ekonomisinin mevcut rejimde kalma olasılığı ve süresi hakkında da bilgiler sağlamaktadır. Ampirik sonuçlar, Şili için ılımlı ve hızlı büyüme rejimleri hariç, üç ülke için de tüm rejimlerde yenilenebilir enerji tüketimi ile ekonomik büyüme arasında iki yönlü MS-Granger nedenselliği olduğunu göstermektedir. Ayrıca, genel olarak, tüm rejimlerde ekonomik büyüme ve CO_2 emisyonları arasında iki yönlü bir MS-Granger nedenselliği bulunmuştur. Son olarak, tahmin edilen modellerden elde edilen bulgular, Şili için ikinci rejim hariç, genel olarak yenilenebilir enerji tüketimi ile CO_2 emisyonları arasında iki yönlü bir MS-Granger nedenselliği olduğunu göstermektedir.

[*] Asst. Prof. Dr., Akdeniz University, Faculty of Economics and Administrative Sciences, Department of Econometrics, Türkiye, abuyukyilmaz@akdeniz.edu.tr
[**] Res. Asst., Akdeniz University, Faculty of Economics and Administrative Sciences, Department of Econometrics, Türkiye, metehanercan@akdeniz.edu.tr (Corresponding Author)

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1. Introduction

The rapid rise of the world's population, industrialization, and living standards, together with technological improvements, contribute to an increase in energy usage. To meet increased energy demand, fossil fuels such as coal and oil are widely preferred. The use of fossil fuels causes greenhouse gas emissions. CO_2 has the largest share of greenhouse gases. Greenhouse gases play a major role in the issue of climate change caused by global warming, as they cause heat to be trapped in the atmosphere. Fossil fuels account for about 81% of all primary energy resources globally. Oil has a share of 38.2% of these fossil fuels, coal 35.5%, and natural gas 26.3% (IEA, 2015). According to the European Commission Joint Research Center assessment, 90% of worldwide CO_2 emissions are caused by the use of fossil fuels (Olivier et al., 2012). Concerns about the environmental impacts of CO_2 emissions have shifted the global energy search to clean and renewable energy sources. Renewable energy provides an alternate energy source while also reducing the impacts of climate change. In addition, the use of renewable energy is one of the most reliable approaches to meeting long-term development goals such as social and economic development, energy availability and security, and environmental and health effects reduction (IEA, 2016; Lee, 2019; Chen et al., 2020).

Environmental degradation has become a priority in global forums due to the negative impact of increasing CO_2 emissions on the environment. Accordingly, the Kyoto Protocol was signed in 1997, and the Paris Climate Agreement was signed in 2015. The central authorities of each nation were urged or compelled to reassess their energy policy under this approach (Bhattacharya et al., 2016). Both the Kyoto Protocol and the Paris Climate Agreement aim to encourage signatory countries to decrease CO_2 emissions and use renewable energy to tackle environmental challenges (Nguyen and Kakinaka, 2019). Following the drop in energy demand caused by the pandemic (COVID-19) in 2020, global economic activity recovered in 2021, resulting in a 4% increase in global energy usage and record CO_2 emissions. Following the United Nations Climate Change Conference (COP26) in 2021, nations responsible for more than 80% of today's CO_2 emissions have committed to reducing greenhouse gas emissions and, in certain cases, attaining net-zero emissions. Furthermore, fluctuating fossil fuel costs, energy security, and nations' efforts to decarbonize have increased interest in renewable energy sources (IEA, 2022; REN21, 2022). Therefore, understanding the relationship between renewable energy consumption, CO_2 emissions, and economic growth is critical for revealing the economy's reliance on energy, achieving the targets of economic development and sustainability, and fighting climate change. In this regard, four distinct hypotheses have been tested in the literature to identify the direction of the link between economic growth and energy consumption (Apergis and Payne, 2010a; Ocal and Aslan, 2013; Shahbaz et al., 2015). The growth hypothesis suggests a one-way causal relationship between economic growth and energy consumption. This demonstrates that the economy is dependent on energy, and so energy-saving initiatives negatively affect economic growth. The conservation hypothesis asserts a one-way causal relationship from economic growth to energy consumption; therefore, energy-saving policies will not adversely affect economic growth. The feedback hypothesis states that there is a two-way causal relationship between variables. Finally, the neutrality hypothesis refers to the lack of a causal relationship between variables. This indicates that energy-saving policies will have no effect on economic growth.

Many researchers have explored the causal relationship between renewable energy consumption, economic growth, and CO_2 emissions in the literature. The studies, however,

differ in terms of the countries studied, energy types, sample periods, econometric methodology, and outcomes. One of the most important points where these studies differ from each other is that while some of them analyze economic time series with linear models, others use nonlinear structures. However, the nonlinear nature of economic series should not be ignored due to shocks such as policy changes, economic crises, and energy crises. If the variables we used in our study include structural breakdowns or conjunctural fluctuations, using a fixed-parameter model during the sample period may produce misleading outcomes. To avoid the circumstances described above, it is more appropriate to examine the causal relationship between these variables using nonlinear models with changing parameters across the sample period.

In this paper, the MS-Granger causality method devised by Warne (2000) and Psaradakis et al. (2005) is applied to analyze the relationship between variables. This method is grounded in the view that the quantity and timing of changes in the causal relationship between the variables analyzed are stochastic and follow an unobservable Markov chain. In other words, contrary to standard VAR models, the parameters change over time. The MS-Granger causality approach was chosen because each economic regime has its own characteristics and provides regime-specific policy recommendations as well as important information about how the economy changes in different regimes. Traditional econometric methods suggest a common policy rather than a regime-specific policy (Fallahi, 2011).

This study aims to analyze the relationship between renewable energy consumption, economic growth, and CO_2 emissions for Denmark, Sweden, and Chile in 1971–2021 using the MS-VAR and MS-Granger causality methods. These countries are the top three with the best scores, according to the Climate Change Performance Index (CCPI) 2023 report. The CCPI assesses the 2030 objectives of nations in key areas, including greenhouse gas emissions, renewable energy, and energy, to see how close they are to the goal of below 2°C. Additionally, this index contains relative indicators that assess the present state and past trends in each of the three areas. In the calculation of the CCPI score, emission indicators account for 40%, renewable energy for 20%, and energy usage for 20%. The other 20% is composed of the climate policies of the related countries (CCPI, 2018). The CCPI appears to be an instrument designed to improve international climate policies' transparency. For this reason, it is a crucial scoring system to bring attention to the nations that implement the best climate policies (i.e., those with the highest CCPI ratings) and serve as an example for those that do not uphold their duties. Our study contributes to the literature in three ways. First, by applying the MS-VAR and MS-Granger causality methods, which offer policy suggestions that are particular to each regime by modeling the relationship between variables in separate regimes, our study introduces a novel analytical framework to this research area. These methods allow us to capture the dynamic and nonlinear relationships among the variables, which traditional linear models might overlook. The ability of MS-VAR to account for regime changes offers deeper insights into how these relationships evolve under different economic conditions. Second, we selected the top three countries in our research according to the CCPI, which is based on the weights of 14 metrics and four sub-indices. Thus, it is considered to provide valuable results that can inform policy decisions in other countries striving to improve their climate performance. Third, utilizing data spanning from 1971 to 2021, our study provides a comprehensive long-term analysis. This extensive temporal scope enables us to observe the structural changes and long-term trends in renewable energy consumption, CO_2 emissions, and economic growth, offering a

robust understanding of their interplay over half a century. The research is designed as follows: An overview of the relevant literature is provided in the second section. The third section provides an explanation of the data and the methodology. The empirical results of the MS-Granger causality and the linear Granger causality methods are presented and interpreted in the fourth section. The fifth section is composed of economic discussions and policy implications for each country. The conclusion is presented in the final section.

2. Literature Review

The current literature on the relationship between renewable energy consumption, CO_2 emissions, and economic growth falls into three categories. In the first, the relationship between economic growth and CO_2 emissions is examined. The main theory used to investigate this relationship is the Environmental Kuznets Curve (EKC). Grossman and Krueger (1991) have revealed that there is an inverted-U-shaped relationship between income and environmental pollution. Numerous studies (such as Lindmark, 2002; Ozturk and Acaravci, 2010; Tiwari et al., 2013; Can and Gozgor, 2017; Yao et al., 2019; Chen et al., 2020) have confirmed the validity of the EKC hypothesis for the nations of the European Union. However, Mazur et al. (2015) argued that the EKC hypothesis is not valid for the whole EU region. Dinda (2004) reviewed various studies in the literature that studied the EKC hypothesis and concluded that there is no single policy that can reduce CO_2 emission levels while the economy grows. Shahbaz and Sinha (2019) also tested the validity of the EKC hypothesis for the period 1991–2017. They concluded that the hypothesis does not have a definite validity and that it varies depending on the time period studied, the explanatory variables used, and the empirical method employed.

The dynamic linkages between economic growth and renewable energy comprise the second section of this literature review. Apergis and Payne (2010b) looked at this relationship for 20 OECD countries. The authors found a two-way relationship between these variables in both the short and long runs using panel cointegration and causality tests. Al-Mulali et al. (2014) assessed 18 Latin American countries, while Salim and Rafiq (2012) examined six important rising economies; both studies found a two-way (feedback hypothesis) relationship between the variables. Sadorsky (2009) suggested that there is a conservation hypothesis between these two variables in emerging economies. Similarly, Ocal and Aslan (2013) reported the same findings for Turkey, as did Cho et al. (2015) for 31 OECD countries. Payne (2009), on the other hand, used the Toda-Yamamoto causality approach and obtained results supporting the neutrality hypothesis for the United States. Menegaki (2011) also found no significant relationship (neutrality hypothesis) between variables in his analysis of 27 European countries. Inglesi-Lotz (2016) found evidence for the growth hypothesis in 34 OECD countries, Fang (2011) in China, and Kula (2014) in 19 OECD countries. Kocak and Sarkgunesi (2017) investigated the same variables using a panel data analysis that included all nine Black Sea and Balkan countries and found a two-way relationship (feedback hypothesis).

The third and final section of the literature review focuses on the relationship between renewable energy, CO_2 emissions, and economic growth. Apergis et al. (2010) added the nuclear energy variable to these three variables in their research. They examined the causal relationship for 19 developed and emerging countries using the panel causality and panel error correction methods. Although the results of the analysis do not show that renewable energy reduces CO_2 emissions in the short run, there is a statistically significant positive relationship

between them in the long run. Salim and Rafiq (2017) investigated the relationship between these three variables and oil prices in six important emerging countries, applying the panel Granger causality. The results of their study revealed that both CO_2 emissions and economic growth have a two-way causal relationship with renewable energy in the short run. Adewuyi and Awodumi (2017) studied these three variables for West African countries. They found a two-way relationship between renewable energy and CO_2 emissions in five West African countries and a partial relationship between three variables in the others. Dong et al. (2018) reviewed 128 countries across six major regional subgroups. Estimated results for European and Eurasian countries emphasize that there is a two-way causal relationship between CO_2 emissions and economic growth, while there is a one-way causal relationship from renewable energy to CO_2 emissions. Musah et al. (2020) used the Dumitrescu-Hurlin panel causality test for 16 West African countries. Across the panel, they found that there is a one-way causal relationship from renewable energy to economic growth (growth hypothesis), and both renewable energy and economic growth have a two-way causal relationship with CO_2 emissions. Also, Radmehr et al. (2021) analyzed European Union countries. Their findings demonstrate that economic growth has a two-way causal relationship with both CO_2 emissions and renewable energy.

3. Methodology and Data

3.1. Data

In our study, we included the top three countries (Denmark, Sweden, and Chile) with the highest scores according to the CCPI in the empirical analysis for factors such as data availability and common time periods between countries. The analyzed variable GDP represents GDP per capita (constant, 2015 US dollars), the variable REN represents renewable energy consumption (PJ), and the variable CO_2 represents CO_2 emissions (Mt CO_2). Yearly data covers the period 1971–2021. The GDP data was taken from the World Bank Development Indicators (WDI, 2023); CO_2 and REN data were gathered from the British Petroleum and International Energy Agency (IEA), respectively. In the study, all variables are subject to logarithmic transformation. The logarithmic GDP per capita, renewable energy consumption, and CO_2 emissions are denoted as LGDP, LREN, and LCO_2, respectively. Furthermore, the first differences are denoted as DLGDP, DLREN, and $DLCO_2$.

3.2. Methodology

3.2.1. MS-VAR Analysis

If the variables analyzed change their behavior over time, that is, across regimes, it would be incorrect to use vector autoregressive (VAR) models in the estimation. To investigate the relationship between these variables, MS-VAR models can be utilized (Fallahi, 2011). The studies of Goldfeld and Quandt (1973) have introduced the Markov-switching regression model to the literature on econometrics. Hamilton (1989) developed a Markov switching autoregressive (MS-AR) model. In Hamilton's MS-AR model, a single variable is utilized, and transitions between regimes have constant probability. Thus, Krolzig (1997) evolved the MS-VAR model, in which the VAR model's autoregressive parameters vary depending on the unobserved regime variable.

Krolzig (2003) defines the p th-order MS-VAR model as:

$$y_t = \mu(s_t) + A_1(s_t)y_{t-1} + \cdots + A_p(s_t)y_{t-p} + u_t \quad (1)$$

where, $\mu(.)$ represents the intercept coefficient in each regime, whereas $A(.)$ and Σ represent the variable's autoregressive coefficients in different regimes and the error term's variance, respectively. In the MS-VAR model, the unobserved regime variable (s_t) is generated by the Markov chain.

$$Pr\left(s_t \middle| \{s_{t-j}\}_{j=1}^{\infty}, \{y_{t-j}\}_{j=1}^{\infty}\right) = Pr(s_t|s_{t-1};\rho) \quad (2)$$

Here, ρ contains the probability parameters. That is, the regime at time t will depend only on the regime at time $t-1$. However, as seen in the equation $P(y_t|Y_{t-1}, s_{t-1}) = P(y_t|Y_{t-1})$, the conditional probability distribution of y_t is independent of s_{t-1}. Since the observable y_t series contains information about its situation, statistical inferences can be made about the unobservable s_t (Krolzig, 1998: 3).

$$Pr(s_t = j|s_{t-1} = i, s_{t-2} = k, \dots) = Pr(s_t = j|s_{t-1} = i) = p_{ij} \quad (3)$$

$$\sum_{j=1}^{M} p_{ij} = 1, \quad i,j \in \{1,\dots,M\} \quad (4)$$

Here, p_{ij} gives the probability of transition from state i to state j, and $0 \leq p_{ij} \leq 1$. The transition probabilities matrix is seen here (Hamilton, 1994: 679):

$$P = \begin{bmatrix} p_{11} & \cdots & p_{1M} \\ \vdots & \ddots & \vdots \\ p_{M1} & \cdots & p_{MM} \end{bmatrix} \quad (5)$$

For the estimation of MS models, Hamilton (1989) suggested two methods: Maximum Likelihood (ML) and Expectation Maximization (EM). Dempster et al. (1977) developed the EM technique based on an iterative ML method due to the large number of parameters estimated in the MS-VAR model. The EM approach is intended to estimate the parameters of models in which observed time series are dependent on unobserved stochastic variables (Krolzig, 1997: 103).

3.2.2. MS-Granger Causality Analysis

Warne (2000) and Psaradakis et al. (2005) introduced the MS-Granger causality method to the literature for cases where causal relationships can change along the period of interest. This causality method is based on the MS-VAR model in which the parameters of the VAR model change over time. The time variation of the parameters of the model varies according to the existence and direction of causality. The MS-Granger causality method can be applied to MSIA(.)-VAR(.) and/or MSIAH(.)-VAR(.) models (Fallahi, 2011: 4168). By considering the estimated variables, the MS-VAR Granger causality approach can be described by using the following equation vector:

$$\begin{bmatrix} LGDP_t \\ LREN_t \\ LCO2_t \end{bmatrix} = \begin{bmatrix} \mu_{1,st} \\ \mu_{2,st} \\ \mu_{3,st} \end{bmatrix} + \sum_{k=1}^{q} \begin{bmatrix} A_{11}^{(k)} s_t & A_{12}^{(k)} s_t & A_{13}^{(k)} s_t \\ A_{21}^{(k)} s_t & A_{22}^{(k)} s_t & A_{23}^{(k)} s_t \\ A_{31}^{(k)} s_t & A_{32}^{(k)} s_t & A_{33}^{(k)} s_t \end{bmatrix} \begin{bmatrix} LGDP_{t-k} \\ LREN_{t-k} \\ LCO2_{t-k} \end{bmatrix} + \begin{bmatrix} e_t \\ \varepsilon_t \\ \xi_t \end{bmatrix} \quad (6)$$

The coefficients of the lagged values of LGDP, LREN, and LCO_2 for each variable can be used to assess the existence of a causal relationship between the variables. For the LGDP vector, it means that LREN is the cause of LGDP if any of the coefficients of the lagged values of LREN are significantly different from zero in any regime. It is same for the coefficients of the lagged values of LCO_2 in the LGDP vector. Testing the hypotheses $H_0 = A_{12}^{(k)} = 0$ and $H_0 = A_{21}^{(k)} = 0$; $H_0 = A_{13}^{(k)} = 0$ and $H_0 = A_{31}^{(k)} = 0$; $H_0 = A_{23}^{(k)} = 0$ and $H_0 = A_{32}^{(k)} = 0$ will determine MS-Granger causality (Psaradakis et al., 2005:6).

4. Empirical Results

The first step before doing causality tests is to determine the LGDP, LREN, and LCO_2 series integration levels. We used the ADF test proposed by Dickey and Fuller (1981) and the PP test proposed by Phillips and Perron (1988) for this purpose. Table 1 shows the results of unit root tests. Due to the results, there is a unit root at the level for these variables in all countries. However, the first differences of LGDP, LREN, and LCO_2 appear to be stationary. As a result, we can say that LGDP, LREN, and LCO_2 are integrated into order one, I(1).

Table 1. Results from Unit Root Tests

		Denmark	**Sweden**	**Chile**
LGDP	PP-stat	-1.4368	-2.6274	-2.9783
DLGDP		-5.9082***	-5.3575***	-5.0583***
LREN		1.5225	-2.5673	-1.2053
DLREN		-8.5061***	-8.5748***	-5.6090***
LCO_2		-0.9503	-3.1794	-2.2055
$DLCO_2$		-8.3924***	-7.6043***	-4.9906***
LGDP	ADF-stat	-1.3391	-2.6274	-3.2357
DLGDP		-5.9631***	-5.3575***	-5.0747***
LREN		-1.1208	-2.6016	-0.7012
DLREN		-11.4044***	-8.5748***	-5.5155***
LCO_2		-1.1141	-3.0787	-2.5013
$DLCO_2$		-8.2594***	-7.0648***	-4.9833***

Note: ***, ** and * denote 1%, 5% and 10% significant level.

The cointegration relationship between the variables is shown in Table 2. We used the maximum likelihood approach suggested by Johansen (1988, 1995). Based on these results, the null hypothesis is accepted. It means there is no cointegration, and the variables' innovations or first differences can be used for the MS-Granger causality approach.

Table 2. Results from Cointegration Test

Country	Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	Max-Eigen Statistic
Denmark	None	0.3706	30.1179	22.6921
	At most 1	0.0963	7.4257	4.9641
Sweden	None	0.3159	34.3831	18.6096
	At most 1	0.2455	15.7734	13.8029
Chile	None	0.2388	24.3459	13.3762
	At most 1	0.1524	10.9697	8.1028

Note: The critical values for trace statistic at 5% are 35.1927 and 20.2618 respectively. The critical values for max-eigen statistic at 5% are 22.2996 and 15.8921 respectively.

Following the likelihood ratio (LR) test approach proposed by Ang and Bekaert (1998) for regime-switching models, LR test statistics and Akaike information criterion (AIC) were used to test linearity and determine the number of regimes. Table 3 provides the LR test statistics. First, the linear VAR model was tested against the two-regime MS-VAR model and the null hypothesis was rejected at all significance levels for all countries. In other words, all the statistics support the existence of nonlinearity. Then, the LR test was applied again between the two-regime models and the three-regime model. According to the test results, the null hypothesis was rejected, and the three-regime MS-VAR model is appropriate for all countries. Regimes 1, 2, and 3 represent recession, moderate expansion, and high expansion, respectively. As a result, the MSIA(3)-VAR(4) model was selected for Denmark and Sweden, while the MSIA(3)-VAR(3) model was found to be the best model for Chile.

Table 3. LR Test Results

		Distribution	Statistics
Denmark	H_0: Linear VAR(4) H_1: MSIA(2)-VAR(4)	$\chi^2(41)$	139.0718
	H_0: MSIA(2)-VAR(4) H_1: MSIA(3)-VAR(4)	$\chi^2(45)$	279.9968
Sweden	H_0: Linear VAR(4) H_1: MSIA(2)-VAR(4)	$\chi^2(41)$	89.6602
	H_0: MSIA(2)-VAR(4) H_1: MSIA(3)-VAR(4)	$\chi^2(45)$	314.7942
Chile	H_0: Linear VAR(3) H_1: MSIA(2)-VAR(3)	$\chi^2(32)$	91.8032
	H_0: MSIA(2)-VAR(3) H_1: MSIA(3)-VAR(3)	$\chi^2(36)$	118.4912

Table 4 shows the estimated model findings for Denmark. The transition probabilities show that regime one has the highest persistency, with $p_{11} = 0.7265$. The average duration of this regime is 3.66 years. When the economy is in the moderate expansion phase, it has a higher possibility of switching to the high expansion phase than to the recession phase ($p_{21} = 0.1315$; $p_{23} = 0.2112$). This phase has a duration of 2.92 years on average, which is the shortest predicted. However, the probability of shifting to the recession regime is 12.75%, and to the moderate expansion regime is 19.13% when the economy is in the high expansion regime. In addition, according to the results of the diagnostic tests, the error terms of the model are normally distributed with constant variance at all significance levels and are also not autocorrelated at the 1% significance level.

Table 4. MSIA(3)-VAR(4) Model Estimation Results for Denmark

Variables	Regime 1			Regime 2			Regime 3		
	$DLCO_2$	**DLGDP**	**DLREN**	**$DLCO_2$**	**DLGDP**	**DLREN**	**$DLCO_2$**	**DLGDP**	**DLREN**
Intercept	-0.053***	0.003***	0.002	0.111***	0.002	-0.026	-0.065***	0.025***	0.084***
	(-3.542)	(2.651)	(0.226)	(3.519)	(0.809)	(-1.336)	(-4.561)	(21.466)	(9.702)
$DLCO_2$ (-1)	0.148	0.056***	0.239***	-0.337**	0.027**	-0.231***	-0.234**	-0.033***	-0.123**
	(1.389)	(6.556)	(3.707)	(-2.642)	(2.650)	(-2.985)	(-2.613)	(-4.610)	(-2.254)
$DLCO_2$ (-2)	-0.510**	-0.384***	0.413***	0.077	-0.029***	-0.269***	-0.352***	0.077***	0.896***
	(-2.630)	(-24.539)	(3.510)	(1.029)	(-4.757)	(-5.916)	(-2.747)	(7.496)	(11.541)
$DLCO_2$ (-3)	0.608***	0.052***	0.080	-0.981***	0.077***	-0.559***	0.847***	0.133***	-0.269***
	(4.199)	(4.424)	(0.906)	(-9.251)	(9.000)	(-8.691)	(8.304)	(16.197)	(-4.346)
$DLCO_2$ (-4)	0.378***	0.119***	0.550***	-0.625***	0.032**	-0.685***	-0.667***	0.011	0.166
	(2.796)	(10.897)	(6.702)	(-3.383)	(2.124)	(-6.105)	(-3.666)	(0.724)	(1.507)
DLGDP (-1)	1.024**	0.737***	0.341	-2.308*	0.586***	1.054	2.016***	0.088***	-1.034***
	(2.044)	(18.236)	(1.123)	(-1.770)	(5.576)	(1.332)	(5.403)	(2.936)	(-4.566)
DLGDP (-2)	0.938**	0.489***	0.146	2.973***	-0.077	-0.424	0.887***	0.092***	0.682***
	(2.307)	(14.917)	(0.592)	(4.279)	(-1.371)	(-1.006)	(2.741)	(3.536)	(3.475)
DLGDP (-3)	-1.771***	-0.986***	-0.489	-2.207***	0.101*	3.251***	-1.107***	0.340***	-0.127
	(-3.376)	(-23.331)	(-1.537)	(-3.377)	(1.925)	(8.197)	(-2.765)	(10.532)	(-0.521)
DLGDP (-4)	0.008	0.736***	-1.575***	-3.564***	0.161***	-1.152***	1.303***	0.337***	-0.660**
	(0.016)	(18.913)	(-5.377)	(-5.929)	(3.320)	(-3.159)	(2.871)	(9.213)	(-2.396)
DLREN (-1)	0.823***	0.404***	0.111	-1.254***	0.066***	-0.336***	0.027	-0.117***	1.383***
	(3.510)	(21.406)	(0.783)	(-9.782)	(6.426)	(-4.316)	(0.237)	(-12.826)	(20.149)
DLREN (-2)	-0.837***	-0.495***	-0.021	-0.021	-0.169***	-0.743***	-0.227	-0.124***	-0.896***
	(-4.254)	(-31.182)	(-0.176)	(-0.094)	(-9.285)	(-5.411)	(-1.376)	(-9.296)	(-8.942)
DLREN (-3)	1.568***	0.418***	0.465***	-0.107	0.149***	0.472**	0.145	0.162***	-0.141*
	(7.191)	(23.785)	(3.514)	(-0.335)	(5.796)	(2.442)	(1.220)	(16.848)	(-1.943)
DLREN (-4)	-0.899***	-0.368***	0.463***	0.579*	-0.061**	0.268	0.219***	0.017***	0.020
	(-5.107)	(-25.917)	(4.338)	(1.875)	(-2.432)	(1.430)	(7.103)	(6.86)	(1.082)
Standard error	0.020	0.002	0.012	0.020	0.002	0.012	0.020	0.002	0.012

Transition Probabilities				**Duration**	**Diagnostic Tests**	
Regime 1	0.7265	0.1321	0.1414	3.66	Vector Portmanteau(9)	$\chi^2(45)$=61.9975 [0.0471]
Regime 2	0.1315	0.6573	0.2112	2.92	Vector Normality Test	$\chi^2(6)$=7.1445 [0.3077]
Regime 3	0.1275	0.1913	0.6811	3.14	Vector Hetero Test	$\chi^2(144)$=136.1158 [0.6678]
					Vector Hetero-X Test	$\chi^2(270)$=276.0000 [0.3878]

Note: ***, ** and * denote 1%, 5% and 10% significant level. In the part where the statistics of the diagnostic tests are given, the values in brackets denote p-values.

Table 5. MSIA(3)-VAR(4) Model Estimation Results for Sweden

Variables	Regime 1			Regime 2			Regime 3		
	$DLCO_2$	**DLGDP**	**DLREN**	**$DLCO_2$**	**DLGDP**	**DLREN**	**$DLCO_2$**	**DLGDP**	**DLREN**
Intercept	-0.068***	-0.004	0.020**	-0.036**	0.033***	0.056***	0.009	0.066***	0.002
	(-5.869)	(-0.950)	(2.617)	(-2.198)	(5.449)	(5.116)	(0.316)	(6.353)	(0.108)
$DLCO_2$ (-1)	-0.761***	-0.115***	0.377***	-0.297**	0.088*	-0.109	0.820**	-0.641***	0.460*
	(-7.296)	(-2.951)	(5.397)	(-2.287)	(1.808)	(-1.255)	(2.362)	(-4.944)	(1.978)
$DLCO_2$ (-2)	-0.141*	0.026	-0.066	-0.724***	0.113***	0.242***	0.403	-0.389***	0.576***
	(-1.739)	(0.857)	(-1.220)	(-9.640)	(4.043)	(4.812)	(1.249)	(-3.23)	(2.661)
$DLCO_2$ (-3)	-0.393***	0.082**	0.093	-0.044	0.059	-0.723***	0.087	0.480***	-0.317*
	(-4.339)	(2.430)	(1.535)	(-0.401)	(1.435)	(-9.832)	(0.318)	(4.723)	(-1.736)
$DLCO_2$ (-4)	0.078	0.054	-0.154**	-0.603***	0.027	0.063	-0.604***	0.314***	-0.494***
	(0.836)	(1.545)	(-2.461)	(-4.109)	(0.498)	(0.641)	(-2.898)	(4.038)	(-3.540)
DLGDP (-1)	-0.666*	0.886***	1.051***	-0.581*	-0.271**	0.346	-2.139***	-0.559***	1.272***
	(-1.996)	(7.121)	(4.702)	(-1.725)	(-2.155)	(1.531)	(-4.419)	(-3.093)	(3.920)
DLGDP (-2)	-0.402	-0.208**	-0.204	0.961**	0.318**	-1.385***	1.000	-2.310***	3.172***
	(-1.614)	(-2.232)	(-1.224)	(2.541)	(2.252)	(-5.464)	(0.684)	(-4.232)	(3.236)
DLGDP (-3)	-0.521	0.082	-0.301	-1.214***	-0.428***	-0.507**	-4.137***	1.568***	-1.337**
	(-1.377)	(0.584)	(-1.188)	(-3.383)	(-3.192)	(-2.107)	(-4.310)	(4.374)	(-2.079)
DLGDP (-4)	0.094	-0.226	0.282	0.964***	0.063	-1.674***	6.646***	-1.132***	1.099**
	(0.177)	(-1.147)	(0.796)	(3.140)	(0.547)	(-8.135)	(8.913)	(-4.065)	(2.200)
DLREN (-1)	-0.782***	-0.082	-0.087	-0.240*	-0.080	-0.336***	0.661***	0.120***	-0.316***
	(-3.427)	(-0.960)	(-0.566)	(-1.743)	(-1.555)	(-3.633)	(5.584)	(2.718)	(-3.987)
DLREN (-2)	0.637***	-0.149*	-0.418***	-0.027	-0.094**	-0.027	2.358***	0.047	-0.858***
	(3.150)	(-1.974)	(-3.087)	(-0.214)	(-2.001)	(-0.317)	(9.486)	(0.509)	(-5.150)
DLREN (-3)	-0.638***	-0.280***	0.592***	0.196**	0.016	-0.289***	0.745***	-0.343***	-0.202
	(-3.051)	(-3.581)	(4.222)	(2.097)	(0.447)	(-4.613)	(3.826)	(-4.719)	(-1.55)
DLREN (-4)	0.287**	0.016	-0.392***	-0.584***	0.043	0.148**	-1.956*	-1.070***	2.402***
	(2.485)	(0.365)	(-5.068)	(-6.579)	(1.295)	(2.491)	(-1.971)	(-2.886)	(3.611)
Standard error	0.017	0.006	0.011	0.017	0.006	0.011	0.017	0.006	0.011

	Transition Probabilities			**Duration**	**Diagnostic Tests**	
Regime 1	0.5890	0.1309	0.2801	2.43	Vector Portmanteau(9)	$\chi^2(45)$=50.6353 [0.2609]
Regime 2	0.1245	0.8091	0.0664	5.24	Vector Normality Test	$\chi^2(6) = 5.6369$ [0.4651]
Regime 3	0.2742	0.1371	0.5887	2.43	Vector Hetero Test	$\chi^2(144) =$119.3824 [0.9335]
					Vector Hetero-X Test	$\chi^2(270) =$276.0000 [0.3878]

Note: ***, ** and * denote 1%, 5% and 10% significant level. In the part where the statistics of the diagnostic tests are given, the values in brackets denote p-values.

The estimated model for Sweden is MSIA(3)-VAR(4), and the analysis results are given in Table 5. According to the results, regime 2 represents the most persistent period with a duration of 5.24 years, and the probability of staying in this regime is quite high at 80.9%, as expected. The average duration of recession and high expansion regimes is identical at 2.43 years. However, the possibilities of staying in the same regime are almost equal, with 58.90% for the recession phase and 58.87% for the high expansion phase. For this country, when the economy is in one of the expansion regimes, it seems more likely to switch to the recessionary regime than switch to the other expansion regime. The probabilities of moving to the recessionary regime are $p_{21} = 0.1245$ and $p_{31} = 0.2742$. Finally, when the economy is in the recessionary phase, the probability of switching to the moderate expansion phase is 13.09%, while the probability of switching to the high expansion phase is 28.01%. Furthermore, diagnostic test findings demonstrate that the model's error terms have a normal distribution, a constant variance, and no autocorrelation.

The empirical findings for Chile are shown in Table 6. The MSIA(3)-VAR(3) model was selected as the best model for this country. The probabilities of staying in the same phase are $p_{11} = 0.6841$, $p_{22} = 0.5954$, and $p_{33} = 0.6427$. The average length of each regime corresponds with these findings. When the transition probabilities obtained for regime 1 are examined, it is seen that switching to regime 2 is more likely than switching to regime 3 ($p_{12} = 0.2370$; $p_{13} = 0.0789$). When the Chilean economy is in the high expansion phase, the probability of moving to the recessionary phase is highly low, with $p_{31} = 2.136e - 11$, while it is $p_{32} = 0.3573$ for moving to the moderate expansion phase. In addition, the possibility of shifting to the recessionary regime is 15.66%, and to the high expansion regime is 24.79% when the economy is in the moderate expansion regime. Additionally, the model's error terms have no autocorrelation, or constant variance, and are normally distributed, according to the findings of diagnostic tests.

Table 6. MSIA(3)-VAR(3) Model Estimation Results for Chile

Variables	Regime 1			Regime 2			Regime 3		
	$DLCO_2$	**DLGDP**	**DLREN**	**$DLCO_2$**	**DLGDP**	**DLREN**	**$DLCO_2$**	**DLGDP**	**DLREN**
Intercept	-0.018	-0.018**	-0.001	0.000	0.033***	0.026**	0.130***	0.093***	0.078***
	(-1.481)	(-2.360)	(-0.090)	(-0.010)	(3.798)	(2.236)	(4.270)	(4.802)	(3.082)
$DLCO_2$ (-1)	2.000***	2.390***	1.343***	-0.144	-0.068	-0.328**	0.424	0.330*	0.776***
	(4.864)	(9.171)	(3.905)	(-0.855)	(-0.639)	(-2.324)	(1.395)	(1.714)	(3.052)
$DLCO_2$ (-2)	0.880***	0.822***	0.619**	-0.283*	-0.271***	-0.037	-0.466**	-0.063	-0.135
	(2.774)	(4.089)	(2.332)	(-1.799)	(-2.724)	(-0.284)	(-2.035)	(-0.438)	(-0.707)
$DLCO_2$ (-3)	1.028***	1.377***	-0.141	0.351	0.084	0.291	0.366*	0.082	0.134
	(3.036)	(6.413)	(-0.499)	(1.665)	(0.626)	(1.651)	(1.910)	(0.677)	(0.833)
DLGDP (-1)	-1.758***	-1.761***	-1.239***	0.977**	0.356	0.424	-0.559	0.067	0.260
	(-4.943)	(-7.815)	(-4.167)	(2.428)	(1.395)	(1.259)	(-0.926)	(0.176)	(0.515)
DLGDP (-2)	-0.574*	-0.490**	-0.225	-0.241	0.071	-0.366*	1.811***	-0.518	-0.666
	(-1.783)	(-2.399)	(-0.836)	(-0.942)	(0.441)	(-1.711)	(3.336)	(-1.504)	(-1.466)
DLGDP (-3)	-0.064	-0.346**	0.399*	0.009	0.082	-0.006	-0.134	-0.882	-1.119
	(-0.234)	(-2.002)	(1.746)	(0.039)	(0.587)	(-0.031)	(-0.159)	(-1.647)	(-1.582)
DLREN (-1)	-1.701***	-1.737***	-0.975***	-0.135	0.253	0.055	0.309	-0.578	-0.901
	(-4.323)	(-6.964)	(-2.965)	(-0.462)	(1.361)	(0.224)	(0.420)	(-1.239)	(-1.463)
DLREN (-2)	-1.143***	-0.703***	-0.702**	0.453	-0.057	0.261	-1.248***	-0.221	0.304
	(-3.162)	(-3.067)	(-2.321)	(1.602)	(-0.317)	(1.103)	(-3.523)	(-0.984)	(1.025)
DLREN (-3)	0.116	-0.194	0.429	-0.382	-0.255	-0.230	-1.014	0.903**	0.809
	(0.339)	(-0.893)	(1.494)	(-1.479)	(-1.558)	(-1.061)	(-1.603)	(2.252)	(1.530)
Standard error	0.028	0.018	0.023	0.028	0.018	0.023	0.028	0.018	0.023

	Transation probabilities			**Duration**	**Diagnostic Tests**	
Regime 1	0.6841	0.2370	0.0789	3.17	Vector Portmanteau(9)	$\chi^2(36)$=41.6687 [0.2377]
Regime 2	0.1566	0.5954	0.2479	2.47	Vector Normality Test	$\chi^2(6) = 9.6520$ [0.1401]
Regime 3	2.136e-11	0.3573	0.6427	2.80	Vector Hetero Test	$\chi^2(108) =$65.1578 [0.9996]
					Vector Hetero-X Test	$\chi^2(276) =$282.0000 [0.3890]

Note: ***, ** and * denote 1%, 5% and 10% significant level. In the part where the statistics of the diagnostic tests are given, the values in brackets denote p-values.

4.1. MS-VAR and MS-Granger Causality Results

Table 4 shows the analysis findings for the MSIA(3)-VAR(4) model, which was found to be statistically appropriate for Denmark. According to these findings, in the first equation, where $DLCO_2$ (i.e., CO_2 innovation) is the dependent variable, the coefficients of all estimated for DLREN and DLGDP are statistically significant, but for DLGDP(-4) in the first regime, DLREN(-1) in the third regime, and both DLREN(-2) and DLREN(-3) in the second and third regimes. In addition, in all regimes, it was found that economic growth and renewable energy consumption are Granger causes of CO_2. All $DLCO_2$ and DLREN coefficients except $DLCO_2$(-4) in regime three were found to be statistically significant in the equation where GDP innovation is the dependent variable. Hence, CO_2 emissions and renewable energy consumption are the Granger causes of economic growth in all regimes. According to the third equation, where REN innovation is the dependent variable, all $DLCO_2$ coefficients are significant at conventional levels of significance, but $DLCO_2$(-3) in regime one and $DLCO_2$(-4) in regime three. When the estimated coefficients for DLGDP are considered, it can be seen from the results that DLGDP(-4) in regime one and DLGDP(-3) and DLGDP(-4) in regime two are statistically different from zero. Moreover, the only coefficient that is not statistically significant in regime three is DLGDP(-3). As a result, there is evidence of two-way Granger causality between renewable energy consumption and CO_2 emissions. Furthermore, it seems that economic growth is Granger cause of CO_2 emissions, while CO_2 is Granger cause of economic growth in the reverse direction. Additionally, results suggest evidence that there is two-way Granger causality between GDP and REN. It should also be noted that all Granger causality interpretations are valid for all regimes.

The MSIA(3)-VAR(4) model was chosen for Sweden, and Table 5 shows the results. When the GDP coefficients in the first model are examined, where $DLCO_2$ is the dependent variable, it seems to be that DLGDP(-1) in regime one, all in regime two, and all except DLGDP(-2) in regime three are statistically significant. Except for DLREN(-2) in the second regime, the REN coefficients of innovations are statistically different from zero in all regimes. When the significant coefficients of this equation are considered, we can say that economic growth innovations and renewable energy consumption innovations are the Granger causes of CO_2 emissions. All $DLCO_2$ coefficients in the DLGDP equation are significantly different from zero except $DLCO_2$(-2) and $DLCO_2$(-4) in regime one, $DLCO_2$(-3), and $DLCO_2$(-4) in regime two. Meanwhile, DLREN(-2) and DLREN(-3) in the first regime, DLREN(-2) in the second regime, and all DLREN coefficients in the third regime are also statistically significant. According to the results of this country, CO_2 and REN are Granger causes of GDP. Except for $DLCO_2$(-2) and $DLCO_2$(-3) in regime one and for $DLCO_2$(-1) and $DLCO_2$(-4) in regime two, all CO_2 innovations for DLREN are significantly different from zero in the third equation. On the other hand, DLGDP(-1) in regime one and all DLGDP coefficients except DLGDP(-1) in the second regime are statistically significant in the second and third regimes. Finally, as in Denmark, the findings of the study point out two-way Granger causality in all regimes between economic growth and renewable energy consumption, as well as between renewable energy consumption and CO_2 emissions and between economic growth and CO_2 emissions.

The best model for Chile was determined to be the MSIA(3)-VAR(3) model, as seen in Table 6. The coefficients of DLGDP(-1) and DLGDP(-2) in regime one, DLGDP(-1) in regime two, and DLGDP(-2) in regime three are significantly different from zero in the first model,

where CO_2 innovation is the dependent variable. This means that there is Granger causality from GDP to CO_2. Also, the coefficients of DLREN(-1) and DLREN(-2) in regime one and DLREN(-2) in regime three are statistically significant. Hence, we may claim that Granger causality exists from REN to CO_2. But also, there is no evidence of a causal relationship between REN and CO_2 when the Chilean economy is in the moderate expansion regime. The second equation is the model, where gdp is the explained variable. All coefficients of CO_2 innovations in the first regime, $DLCO_2$(-2) in the second regime, and $DLCO_2$(-1) in the third regime are significantly different from zero. In the same equation, the coefficients of DLREN(-1) and DLREN(-2) in regime one and DLREN(-3) in regime three are statistically significant, while there is no Granger causality from REN to GDP in regime two. Additionally, in the third equation, the explained variable of which is REN innovation, $DLCO_2$ coefficients are statistically different from zero except $DLCO_2$(-3) in regime one, $DLCO_2$(-2) and $DLCO_2$(-3) in both regimes two and three. Also, the coefficients of DLGDP(-1) and DLGDP(-3) in regime one and DLGDP(-2) in regime two are statistically significant, but there is also no Granger causality from GDP to REN. As a result, the findings show two-way Granger causality between economic growth and CO_2 emissions in all regimes, renewable energy consumption and CO_2 emissions in the first and third regimes, and one-way Granger causality from CO_2 emissions to renewable energy consumption in the moderate expansion regime. Consequently, for this country, it can be said that there is two-way Granger causality in the first regime, one-way Granger causality from GDP to REN in the second regime, and one-way Granger causality from REN to GDP in the third regime when the causal relationship between renewable energy and economic growth is considered.

4.2. Standard Linear Granger Causality Results

This section compares the causality obtained by two alternative approaches. The knowledge of the direction of causality is critically important for accurately determining the energy hypothesis and hence energy policy strategies. Therefore, we also applied the standard Granger causality method to the same data set and presented the results in Table 7. Our purpose is to compare the test results with the findings of the MS-Granger causality. When we examined the findings, we found that the results of the two tests completely contradicted each other. According to the results of the standard Granger causality method, there is no causality between renewable energy consumption and economic growth in any regime. It means the neutrality hypothesis holds for all three countries analyzed. In contrast to the results of the MS-Granger causality approach, we did not find evidence of the causality between CO_2 emissions and economic growth for any of the countries we studied when we applied the standard Granger causality method. In conclusion, MS-Granger findings differ greatly from standard Granger results because, while the first technique takes structural breaks or cyclical variations into account, the second one does not.

Table 7. Standard Linear Granger Causality Results

Countries	Causality Direction	χ^2	Prob.	Causality Decision
Denmark	DLGDP→DLCO$_2$	1.6996	0.4275	No
	DLREN→DLCO$_2$	2.1650	0.3387	No
	DLCO$_2$→DLGDP	1.9715	0.3732	No
	DLREN→DLGDP	3.3874	0.1838	No
	DLCO$_2$→DLREN	0.1952	0.9070	No
	DLGDP→DLREN	0.2829	0.8681	No
Sweden	DLGDP→DLCO$_2$	1.8978	0.1683	No
	DLREN→DLCO$_2$	0.8585	0.3541	No
	DLCO$_2$→DLGDP	0.1876	0.6649	No
	DLREN→DLGDP	0.2603	0.6099	No
	DLCO$_2$→DLREN	0.3629	0.5469	No
	DLGDP→DLREN	0.0298	0.8629	No
Chile	DLGDP→DLCO$_2$	0.0006	0.9802	No
	DLREN→DLCO$_2$	0.3742	0.5407	No
	DLCO$_2$→DLGDP	0.1551	0.6937	No
	DLREN→DLGDP	0.5493	0.4586	No
	DLCO$_2$→DLREN	0.2605	0.6098	No
	DLGDP→DLREN	0.0777	0.7803	No

5. Discussions and Policy Recommendations

In this section, we will discuss the empirical results of the MS-Granger causality method developed by Psaradakis et al. (2005). We found a two-way causal relationship between economic growth and CO_2 emissions for all three countries in all three regimes, which is consistent with Saidi and Omri (2020) and Radmehr et al. (2021) in Denmark and Sweden. Furthermore, there is evidence for a two-way causal relationship between renewable energy consumption and CO_2 emissions in all three regimes for all three countries but a one-way causal relationship from CO_2 to REN in the moderate expansion regime for Chile. These results comply with the results of Irandoust (2016) in Sweden. When the causality between economic growth and renewable energy consumption is considered, the results of our study show that there is evidence of a two-way causality between renewable energy consumption and economic growth in the recessionary regime for Chile and in all three regimes for Denmark and Sweden. Also, there is a one-way causal relationship from economic growth to renewable energy consumption in the moderate expansion regime and from REN to GDP in the high expansion regime for Chile. These conclusions are consistent with the results of Saidi and Mbarek (2016) in Sweden, Jebli et al. (2020) for Sweden and Denmark in the long run and for Chile in the short run, and Radmehr et al. (2021) in Denmark and Sweden. According to these findings, we concluded that the feedback hypothesis is valid in the recessionary regime, the conservation hypothesis in the moderate expansion regime, and the growth hypothesis in the high expansion regime for Chile, which is consistent with Joo et al. (2015) in Chile, while the feedback hypothesis is valid in all regimes for Denmark and Sweden.

According to the results for Denmark, there is a two-way causal relationship between CO_2 emissions and economic growth during times of recession. Based on IEA data, the fact that fossil fuels accounted for the majority of total energy usage for the years included in the analysis further supports this conclusion. At the same time, we found a two-way causal relationship between renewable energy consumption and CO_2 emissions. In addition, for both the moderate expansion and high expansion regimes, CO_2 emissions and renewable energy

consumption cause economic growth, such as during times of recession. These results show that the feedback hypothesis is valid in all regimes for Denmark. However, the Danish government announced a net-zero by 2045 plan in 2022, with the goal of reducing emissions by 110% by 2050. In contrast to the MS-Granger causality findings, standard Granger causality results for Denmark suggest no relationship between economic growth and renewable energy consumption. Both causality approaches have completely different policy consequences, but the MS-Granger causality method is more reliable than the standard Granger causality because it takes into account the dynamics of the economy. Consequently, in order to reach its goals, the government should put in place incentive programs that encourage the use of renewable energy sources while keeping current regulations.

Sweden has the lowest CO_2 emissions, with 3.304 metric tons per capita in 2021. Also, according to the IEA (2019) report, the transport sector, which is still primarily reliant on oil, is the main source of greenhouse gas emissions. From 2010 to 2030, the government has set a goal to cut transportation-related emissions by 70%. They also intend to decrease carbon emissions by 59% in 2030 compared to 2005 and to have a net-zero carbon economy in 2045. The results obtained for Sweden show that there is a two-way causal relationship between CO_2 emissions and economic growth in all regimes. At the same time, we found a two-way causal relationship between renewable energy consumption and economic growth in the Swedish economy, while standard Granger causality results suggest that there is no relationship between them. For Sweden, the feedback hypothesis holds in all regimes, as in Denmark. These results emphasize the importance of sustainable energy policies in balancing economic development with environmental concerns. Thus, Swedish policymakers should focus on developing policies that promote the use of clean fuels in the transport sector.

In Chile, there is a two-way causal relationship between economic growth and CO_2 emissions in all regimes. CO_2 emissions have increased significantly as a result of rapid industrialization and increasing energy demand. According to the IEA (2018) report, the percentage of fossil energy sources in overall energy usage was 73.2% in 2016, which confirms these findings. This situation is also reflected in the level of the country's CO_2 emissions. Also, there is no two-way causal relationship between renewable energy and CO_2 emissions in the moderate expansion regime. Thus, increasing the share of renewable energy could reduce the value of CO_2 emissions. Furthermore, in the same regime, we found a one-way causal relationship from economic growth to renewable energy consumption, while this causality for the other direction exists in the high expansion regime. Despite the fact that standard Granger causality results support the neutrality hypothesis, MS-Granger findings suggest the conservation hypothesis and growth hypothesis in the moderate expansion regime and the high expansion regime, respectively. The Chilean government, which has committed to achieving net-zero emissions by 2050, has put in place a variety of policies and laws to encourage the production and use of renewable energy. Also, we recommend expanding incentives for renewable energy production and consumption, as well as investing in research and development to further improve renewable energy technologies.

Consequently, in the case of Denmark and Sweden, the feedback hypothesis, which holds in all three regimes, suggests that both countries have aligned environmental sustainability with economic growth. For these countries, we recommend that they keep investing more in renewable energy and promote technological innovation. For Chile, the different causal relationships between the regimes suggest that the Chilean government should regulate its

energy policies in a flexible manner. During a recessionary regime, the validity of the feedback hypothesis implies that economic recovery requires increased investment in clean energy. Policymakers should invest in renewable energy infrastructure and provide incentives for both businesses and households to adopt renewable energy sources. In the moderate expansion regime, there is a one-way relationship from economic growth to renewable energy consumption. This finding may indicate that policymakers have not invested enough in renewable energy infrastructure while supporting economic growth or that these investments have been insufficient in the presence of economic growth. Therefore, we can say that during this regime, subsidies, tax incentives, and grants should be made more pronounced both to increase renewable energy investments and to incentivize renewable energy. The finding that renewable energy investments contribute to growth in the high expansion regime suggests that the development of renewable energy technologies and infrastructure is critical for sustainable economic growth in this regime. Besides this, given the two-way MS-Granger causality between economic growth and CO_2 emissions in all regimes, it is essential to develop strategies for sustainable economic growth that prioritize low-carbon development. Investing in green technologies, enhancing public transportation systems, and encouraging sustainable agricultural practices can help reach this goal. Finally, the two-way MS-Granger causality between renewable energy consumption and CO_2 emissions suggests that increasing renewable energy usage can directly reduce carbon emissions. Policies should therefore focus on scaling up renewable energy production and facilitating its adoption.

6. Conclusion

This study analyzes the relationship between CO_2 emissions, renewable energy consumption, and economic growth in different economic regimes for Denmark, Sweden, and Chile, the countries with the highest scores according to the CCPI (2023). For this purpose, MS-VAR and MS-Granger causality methods were applied to annual data for the period of 1971 to 2021. The MS-VAR and the MS-Granger causality approaches provide us the opportunity to estimate and interpret separately for different regimes of the economy, such as recession and expansion. In reality, the recession and expansion regimes of the economy have their own specific structure. These nonlinear methods are superior to linear ones because nonlinear methods take into account these specific structures of the economy. However, this is the first study that examines the relationships between the variables mentioned above by using MS-VAR and MS-Granger causality approaches. So it enriches the literature in this respect.

The results of this study show that there is a two-way causality between CO_2 emissions and economic growth in all regimes and for all countries. As expected, we found that CO_2 emissions were the cause of economic growth. This finding can be associated with the validity of the EKC hypothesis, which suggests that environmental pollution increases in the early phases of economic growth but decreases after a certain level of prosperity is reached as environmental awareness increases and cleaner technologies are adopted. Also, due to the findings, there is a two-way MS-Granger causality between renewable energy consumption and CO_2 emissions in general, except in the moderate expansion regime for Chile. The existence of this relationship in Denmark and Sweden, across all three regimes, indicates that these countries' energy policies promote the shift towards renewable energy. This result also supports sustainable growth theory while means that green economy transition strategies are effectively

utilized. Additionally, when the relationship between renewable energy and economic growth is considered, our findings point to two-way causality for Denmark and Sweden. This implies that renewable energy investments are both a consequence and a propulsion of growth. This is consistent with long-term sustainable development goals, showing that growth increases energy demand, while energy efficiency and technology improvements contribute to economic growth. In all regimes for the three countries except moderate and high expansion regimes for Chile, the results support the feedback hypothesis that renewable energy and economic growth in general play a complementary role. However, for Chile, we also found evidence for the conservation hypothesis in the moderate expansion regime and for the growth hypothesis that renewable energy is the cause of economic growth in the high expansion regime. Standard Granger causality results assert neutrality between these variables. This means that an increase in GDP is not related to renewable energy use, and policy changes linked to renewable energy consumption will have no effect on economic growth. This is completely in contrast to the findings of the MS-Granger method. Given the fact that business cycles characterize economies, the development and implementation of regime-specific policies are critical for the proper management of resources. Therefore, if policymakers follow the findings of the standard causality tests, policies to be implemented could negatively impact the economy and the environment.

Consequently, all three countries attach great importance to the share of renewable energy sources and the reduction of CO_2 emissions, as evidenced by their high scores in the CCPI (2023) report. However, renewable energy consumption has a two-way causal relationship with both economic growth and CO_2 emissions in some regimes, while there is a one-way causal relationship in others, according to the research. Therefore, determining the existence and direction of the causal relationship between renewable energy and other variables separately for each regime is critical for developing accurate and effective environmental policies, taking into account the economic regime in which the country is located. In this respect, increasing investment in renewable energy technologies that do not cause climate change and environmental degradation, considering the transition phases between economic regimes, is a necessity for all countries to create a cleaner, healthier environment for current and future generations.

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 first author of the study contributed to the conceptualization, methodology, data curation, writing-original draft preparation, and formal analysis of the research; the second and corresponding author of the study contributed to the conceptualization, reviewing of literature, writing-review and editing, visualization, and design of the discussion and results sections.

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

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DIGITAL FINANCIAL INCLUSION AND ITS DETERMINANTS: EVIDENCE FROM TÜRKİYE*

Dijital Finansal Kapsayıcılık ve Belirleyicileri: Türkiye Örneği

Tuğba GÜZ** & **Gülden POYRAZ*****

Keywords: Digital Financial Inclusion, Digital Technologies, Digital Finance, Banking Sector

JEL Codes: O11, O30, O39, E44

Abstract

Facilitating participation in the financial system through digital technologies became important to identify the determinants of Digital Financial Inclusion (DFI). In this context, the study aims to examine the use and accessibility of DFI and measure it specifically for Türkiye. The data is divided into two categories: demographic variables (gender, age, income, and education level) and variables related to DFI (account ownership, ownership of mobile money account, saving, and borrowing) and was compiled from the Global Findex Database 2021. Considering the binary structure of the dependent variable, the probit model was used in the study. Although our model findings indicate that demographic characteristics such as gender, education, and income have a significant effect on account ownership and savings, when marginal effects are taken into account, education is the strongest determinant of DFI. Regarding the income level, the coefficient estimates for the four income quintiles were found statistically significant. However, for lower-income quintiles, particularly the poorest 20 percent and the second 20 percent, the probability of being financially included was found to be significantly lower. When all variables are taken into consideration, women are more financially excluded than men, and there is significant gender inequality, especially in terms of account ownership.

Anahtar Kelimeler: Dijital Finansal Kapsayıcılık, Dijital Teknolojiler, Dijital Finans, Bankacılık Sektörü

JEL Kodları: O11, O30, O39, E44

Öz

Dijital teknolojiler aracılığı ile finansal sisteme katılımın kolaylaşması, Dijital Finansal Kapsayıcılığın (DFK) belirleyicilerinin tespit edilmesi açısından önemli hale gelmiştir. Bu kapsamda çalışmada, DFK'nın kullanımı ve erişebilirliği incelenerek, Türkiye özelinde ölçülmesi amaçlanmıştır. Veriler, demografik değişkenler (cinsiyet, yaş, gelir ve eğitim düzeyi) ve DFK ilgili değişkenler (hesap sahipliği, mobil para hesap sahipliği, tasarruf ve borçlanma) olmak üzere iki kategoriye ayrılmış olup Global Findex Database 2021 veri tabanından derlenmiştir. Bağımlı değişkenin binary yapısı göz önüne alındığında çalışmada probit model kullanılmıştır. Model bulgularımız cinsiyet, eğitim ve gelir gibi demografik özelliklerin, hesap sahipliği ve tasarruf üzerinde önemli bir etkiye sahip olduğunu işaret etse de marjinal etkiler dikkate alındığında DFK'nın en güçlü belirleyicisinin eğitim olduğunu göstermektedir. Gelir düzeyine ilişkin olarak dört gelir dilimine ilişkin katsayı tahminleri istatistiksel olarak anlamlı bulunmuştur. Bununla birlikte, daha düşük gelir dilimleri için, özellikle en yoksul %20'lik kesim ile ikinci %20'lik kesimin finansal açıdan dahil olma olasılıkları önemli ölçüde düşük bulunmuştur. Tüm değişkenler göz önüne alındığında, kadınların finansal olarak erkeklere göre daha fazla dışlandığı, özellikle hesap sahipliği açısından önemli bir cinsiyet eşitsizliğinin var olduğu görülmektedir.

* This study is an extended version of the oral presentation titled "Determinants of Digital Financial Inclusion: An Empirical Study for Türkiye" presented at the congress The Economic Research and Financial Markets Congress (IERFM) on 27-29 April 2023.

**Asst. Prof. Dr., Istanbul Yeni Yüzyıl University, Faculty of Health Sciences, Department of Healthcare Management, Türkiye, tugbaguz@gmail.com

***Asst. Prof. Dr., Bandırma Onyedi Eylül University, Department of Foreign Trade, Türkiye, poyrazgulden06@gmail.com

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1. Introduction

The spread of digitalization worldwide has led to revolutionary transformations by showing its effect in the economic and social fields. In this transformation, creating value with digital technologies has come to the fore and has an impact on all sectors. One of the sectors in which the influence of digital technologies is increasing gradually has been the financial services sector. In this sector; advanced technologies such as artificial intelligence and smart automation technologies have started to be used widely. Digital technologies included in the financial system have led to the emergence of digital financial products and services and digital identities, payment systems have become digital and diversified, and digital platforms that support the formation of digital infrastructure have emerged and become a part of digital transformation (Thathsarani and Jianguo, 2022). Along with the digital transformation, which is especially effective in the banking sector, digital formations such as Internet banking, mobile banking, branchless banking, and mobile wallets, where artificial intelligence applications are used, have been included in the financial system (Babarinde et al., 2020). Digital platforms and services have facilitated the participation and access of all segments of society to the financial system through mobile devices with widely used digital technologies.

Digital financial services, which have an important role in the growth of financial inclusion, have revealed the concept of "Digital Financial Inclusion (DFI)", which is a combination of digital technology and digital inclusive finance. “DFI comprises the financial services that meet the needs through digital tools of the population who are financially excluded, have difficulty accessing financial services, and cannot benefit from financial services adequately. It also involves financial services that are affordable for customers, sustainable for providers, and cost-saving (World Bank Group, 2014; Nandru et al., 2021). Among the reasons for exclusion of the financially excluded people are having not sufficient financial possibilities, religious reasons, not needing any financial services, having an account from one of a family member, physical distance from bank branches, expensive financial services, and lack of trust (Allen et al., 2016). Another reason for financial exclusion could be inequalities in access to digital services both nationally and internationally. In UNDP's Sustainable Development Goals, it is stated that almost more than four billion people, ninety percent of whom are in developing countries, still do not have access to the internet and therefore cannot access to digital services (Nandru et al., 2021). It is widely accepted that DFI should be ensured in order to remove the barriers to access to digital services and close the digital gap and that digital financial services will contribute to growth by promoting the growth of financial inclusion (Ghosh and Chaudhury, 2020). Digital technologies play an important role in the development of banking and financial services penetration, especially in developing countries, and pave the way for DFI (Nandru et al., 2021).

Financial and banking systems have become more efficient with digital financial technologies. Digital finance which causes transformation in the finance and banking industry refers to financial services offered through personal computers, mobile phones, other wearable and mobile technological devices, the internet, and digital payment systems. The digitalization of financial services can ensure that the transaction costs of these services are more convenient and economical compared to traditional banking services. Thereby, low-income and poor people particularly in developing countries, can be included in the official financial system and benefit from more comfortable and safe banking services. Thus, these people who are included in the financial system may save money and have easier access to credit. Digital finance also provides

many advantages to customers in terms of making financial decisions faster, having more control over personal finance, and providing the ability to receive and make faster and easier payments. However, in order to provide a digital financial environment, different actors such as financial technology providers, finance-banking institutions, agencies, mobile network operators, necessary technological infrastructure, retail chains, customers, and their participation in the system should be ensured (Durai and Stella, 2019).

The study conducted by Boston Consulting Group (BCG) stated that especially mobile financial services have a positive effect on financial inclusion, but this effect varies from country to country (BCG, 2011). Making the financial system more inclusive and accessible will also secure the people who have been financially excluded and have difficulties accessing the financial system, thereby facilitating their access to official finance. In this case, these financially excluded people will be able to increase their income, establish a business, make investments and save, contribute to economic activities, and thus support economic growth (Ghosh and Chaudhury, 2020).

High participation and inclusiveness in the financial system provide advantages such as lower bank account costs, stronger legal rights, and the creation of more politically stable environments (Allen et al., 2016). Despite the advantages of financial inclusion, a large proportion of the adult population still does not have a bank account (Ghosh and Chaudhury, 2020). There can be various negative effects of not having a bank account. For example, if not having a bank account, difficulties may be experienced in liquidity management and payments, and high fees may be incurred in the use of services such as money orders and checks to cash (Lusardi, 2011). The fact that approximately two-thirds of the adult population who do not have a bank account in the world have at least one mobile phone can facilitate access to mobile financial services and contribute to the growth of financial inclusion (Demirgüc-Kunt et al., 2018). In addition, increasing banking penetration with the help of digital platforms, mobile banking services, and other digital technologies, and providing the necessary infrastructure to use all these factors will increase financial inclusion (Ghosh and Chaudhury, 2020).

The issue of financial inclusion has become one of the priority agenda items, attracting the attention of both countries and international organizations on a global scale. For example, financial inclusion, which was accepted as one of the important components of global development at the G20 summit in 2010, emerged as a tool for inclusive economic growth (GPFI, 2015; Ghosh and Chaudhury, 2020). Also at the summit, the "Financial Inclusion Action Plan" was approved for financial inclusion, which is accepted as the main agenda of global development, and the establishment of the "Global Partnership for Financial Inclusion" was announced (GPFI, 2015). Afterward, financial inclusion has been among the official goals of more than sixty governments around the world and has been adopted as the main objective in the Development Agenda of the United Nations member states after 2015 (Sahay et al., 2015). In 2014, "Financial Access, Financial Education, Financial Consumer Protection Strategy, and Action Plans" came into effect in relation to financial inclusion, which has been internalized by being among the official targets in Türkiye as a developing market. This strategy and action plan which is in line with the innovative financial inclusion principles determined in the G20 intended to be developed financial inclusion. In this respect, it is aimed that financial products and services are spread more inclusively to all individuals and businesses, financially excluded people are included in the financial system, and financial inclusion is increased by increasing the quality and use of financial products and services (CBRT, 2014). This action plan also

focused on two issues, namely, that financial education should be inclusive of the whole society and the protection of consumers. In addition, Türkiye also took some important steps to increase the diversity of financial products and services with the "Istanbul International Financial Center Strategy and Action Plan" prepared by the State Planning Organization in 2009 (Bozkurt and Karakus, 2020). In this direction, issues related to identifying the determinants of financial inclusion and ensuring access to financial services by all the people of society have started to take place among the development goals.

According to the World Bank Global Findex data, it is stated the proportion of the adult population holding an account in an official financial institution in Türkiye increased between 2011 and 2017. This rate increased from 58 percent in 2011 to 57 percent in 2014 and to 68 percent in 2017. While Türkiye was slightly above the developing country average of 61 percent as of 2017, it remained close to the world average of 67 percent. Despite this, it is seen that Türkiye remains below OECD countries and upper-middle-income countries. However, the number of people actively using digital banking services has reached 90 million 579 thousand individuals both individual and corporate in 2022 in Türkiye. It is observed that there has been a significant increase in the number of those actively using digital banking services between 2017 and 2022. The number of people, which was 35 million in 2017, increased to 91 million in 2022 and increased by approximately 62 percent. The increase in mobile banking services was remarkable in this increase (TBB, 2022).

The purpose of this study is to examine and measure the use and accessibility of DFI in Türkiye. To that end, the data is divided into two categories: demographic variables and variables related to DFI, and was compiled from the Global Findex Database 2021. Considering the binary structure of the dependent variable, the probit model was used in the study.

This study aims to contribute to the empirical literature on financial inclusion in Türkiye by using a rich individual-level data set. It is thought that the research findings will be beneficial to policymakers and service providers in improving the current status of DFI and identifying the barriers in front of it. In addition, since it is observed that a wide variety of variables are used in most of the studies in the financial inclusion literature, which is the subject of studies at macro and micro scales, and mostly indices created and country comparisons are made, it is thought that determining the main determinants of DFI and evaluating them in a country-specific manner will contribute to the literature.

The rest of the study is organized as follows. In the second part of the study, the literature on DFI will be mentioned, in the third part, the data set and method will be emphasized, this part will be followed by the findings, and finally, the conclusion part will be given.

2. Literature Review

Financial inclusion, especially DFI, has become one of the determinants of development in developing countries. Moreover, the new term development goals focus on the development of these countries, the issue of financial inclusion has become an increasing area of interest for various researchers, policymakers, and financial sector stakeholders, and has been examined in many aspects in the literature. The subject of financial inclusion has also been included in various studies in Türkiye. However, to the best of our knowledge, there is a limited number of studies in the empirical literature on the determinants of DFI, especially in Türkiye.

Ozsuca (2019) analyzed the level and main determinants of financial inclusion for Türkiye by using the 2017 World Bank Global Findex individual level of data. The study focused on how the relationship between formal financial services usage and individual characteristics such as education, age, gender, and income. Moreover, explored how individual characteristics affect financially excluded people in Türkiye's perceived barriers to owning accounts. The results of the study reveal that the probability of having an official account and savings increases according to the characteristics of being more educated, richer, older, and a male. The other result of the study is the individual traits that drive the use of other traditional formal financial services and mobile banking are the same.

Gunduz and Ozyildirim (2019) calculated a financial inclusion index for the 81 provinces in Türkiye in the period 2011-2018. They aimed to reveal the proportion of people who don't use financial market instruments for various reasons and how wide the range of financial products and services can reach in Türkiye. They found that the index values that depict the financial system dimensions exhibit significant regional variations. For instance, while the provinces such as İstanbul, İzmir, Ankara, Antalya, and Muğla had the highest financial inclusion index value, Bingol, Şanlıurfa, Şırnak, Batman, and Muş were in the lowest index value category.

Dar and Ahmed (2020) aimed to reveal financial inclusion determinants, the barriers to the determinants of financial inclusion, and the informal financial activities' determinants in India. They used independent variables such as education, age, gender, and income and used the Probit model for the analysis. According to their results, education, income, gender, and age have a substantially effect on variety of financial inclusion factors. These factors also have an essential effect on borrowing and informal savings.

Rahimyar ve Curuk (2021) examined the determinants and current situation of financial inclusion in Türkiye by using a questionnaire method on 480 people. They analyzed the obtained data with Probit regression. According to their findings, the rate of account ownership which is the fundamental indicator for financial inclusion is the percentage of 89.8. They also indicated that people most commonly prefer borrowing from family members or friends and using a formal account in order to save their money. Moreover, they stated that a percentage of 69.8 of people benefited from insurance services the other factor of financial inclusion. In accordance with the regression results, the level of education and income of the people considerably affect formal savings and account ownership.

Habesoglu (2021) aimed to investigate financial inclusion specifically with regard to women in Türkiye. Within this scope, he aimed to answer the questions; of whether gender is an obstacle to financial inclusion and if the answer is yes, whether women's income level affects financial inclusion. He aimed to find with these questions whether women were excluded from the financial system in Türkiye. As a result, he found that approximately more than half of the women are excluded financially in Türkiye and there is a substantial divergence between men and women.

Sarigul (2021) analyzed the level of financial inclusion development of regions and provinces in Türkiye in the period from 2011-2018. In this analysis, he developed a financial inclusion index by using access and usage dimensions. According to the result of the study, the regions evaluated as very high, high, medium, low, and very low, and found that Istanbul has a very high index value in the years considered. The index values of the Aegean, Western

Marmara, and Western Anatolia were in the high index value category. While, the Mediterranean, Eastern Marmara, and Eastern Black Sea were in the medium index value, Western Black Sea was in a low category. Lastly, Southeast Anatolia and Middle East Anatolia were in the very low index values category of financial inclusion. Provinces' financial index values found that consistent with their included index values of regional.

Nandru et al. (2021) investigated DFI determinants in India and the effect of characteristics of the demographic on the usage and accessibility of DFI. They measured the usage and accessibility of DFI in relation to demographic properties such as gender, education, employment status, income, and age. They found that the factors of employment status, age, income, gender, and education have a substantial effect on accessibility. Moreover, these factors have a considerable impact on the use of the digital environment for financial transactions such as made payments and receipts through mobile devices or internet usage.

Anane and Nie (2022) examined determinants of the adoption of financial services by using the Logit model. They evaluated the level of adoption among the key socio-demographics. The result of the Logit model stated that factors such as awareness, transaction cost, effort expectancy, facilitating conditions, privacy, security, and self-efficacy affect the adoption of digital financial services positively and also increase the adoption of digital financial services in several ratios. Moreover, the findings showed a substantial disparity in adoption rates across important socio-demographic factors, such as education level, gender, place of residence (urban vs. rural), and administrative areas of Ghana.

3. Data and Methodology

In this study, we aimed to identify the determinants of DFI in Türkiye and determine how individual characteristics (gender, age, income, and education level) are related to account ownership, ownership of mobile money accounts, saving, and borrowing. To that end, the data was obtained from The World Bank Global Findex (2021) database published in June 2023. The data were collected from nationally representative surveys of about 128,000 adults over 15 years of age in more than 120 economies including the Türkiye during the COVID-19 pandemic.

The previous versions are from 2011, 2014, and 2017 and also include a variety of new series that measure financial resilience and health in addition to the use and accessibility of formal and informal financial services. Moreover, the data identifies the gaps in the usage and access to financial services by poor adults and women. The sample size is 1,000 individuals for Türkiye.

As the dependent variables are binary, we use the Probit models that have been estimated along with marginal effects to analyze the determinants of DFI. In an econometric model, if the dependent variable has a normal distribution, analyses can be performed with linear models. When the dependent variable is not normally distributed, the assumptions cannot be met if the variable has two or more categories. Therefore, analysis with linear models is insufficient. Approaches such as the linear probability model, logit, and probit models are used to estimate models with this structure.

Logit or probit models are generally preferred when the dependent variable is categorical. The main difference between these two models is that the tail of the logit distribution is slightly fatter than the probit model. That is, in the probit model, the conditional probability of Pi

approaches 0 or 1 more quickly than in the logit model (Gujarati, 2004; Gujarati and Porter, 2009). The standard normal distributions, which form the basis of probit, and the standard logistic, which form the basis of logit, both have a mean value of zero, but their variances differ; 1 for the standard normal (Gujarati, 2004). In other words, the main difference between the two models is that the logistic cumulative distribution function is used in the logit model, while the normal cumulative distribution function is used in the probit model. This is because in the probit model, the basic dependent variable, which is the non-binary version of the dependent variable "y", is assumed to have a normal distribution, while in the logit model, the basic dependent variable is distributed in the form of a logistic curve. This hypothetical variable Y* is transformed by the cumulative normal in probit or the logistic transformation in logit (Aldrich and Nelson, 1984). Another difference of the probit model is that the results obtained from the analyses made with the same data are closer to the asymptotes, which is more consistent, than the logit model.

The probit model, based on utility theory or rational choice approach developed by Mc Fadden, is one of the regression models in which the dependent variable takes values of 0 and 1 such as successful-unsuccessful, yes-no, present-absent, observed-not observed, that is, it has two categories (Gujarati, 2004; Gujarati and Porter 2009). If the dependent variable is binary structure and normally distributed, a probit model using the cumulative normal distribution function is needed. In the probit model, when interpreting the estimated parameter coefficients, marginal effects are usually taken into account to measure the effects of the independent variable on the expected value of the dependent variable. In other words, the instantaneous effect of a one-unit change in the independent variable on the estimated probability, when other variables are held constant, is measured by the marginal effect.

Accordingly, the following specification is employed in the empirical analysis:

$$DFI = \propto + \beta_1 Gender + \beta_2 Age + \beta_3 Income + \beta_4 Education + \varepsilon \quad (1)$$

In equation 1, DFI is a proxy represented by four different financial inclusion measures, namely, ‘ownership of bank account’, ‘mobile money account’, ‘formal savings’, and ‘borrowing’. The independent variables are individual characteristics that are expected to determine the DFI. Individual characteristics are mainly ‘gender’, ‘age’, ‘income’, and ‘education’. These variables are constructed as dummy variables, except for the variable age. Gender variable, for example, is measured using two categories; equal to one if an individual is a female and zero otherwise. Regarding income, we consider five different income quintiles and use four different dummy variables, each one measured using two categories. The dummy variable for the richest quintile is omitted. In an indicator divided into five equal groups, each group is known as a quintile. Each of quintile represents 20% or 1/5 of the indicator's value range. The lowest 1/5 of values from 0–20% of the range are represented by the first quintile. In other words, the first quintile group represents 20% of the population with the lowest income and the fifth quintile group represents the 20% of the population with the highest income. The values from 20–40% are included in the second quintile; 40–60% are included in the third quintile; 60–80% are included in the fourth quintile; and the top 1/5 of values from 80–100% are included in the fifth quintile. When data is regarded as a quintile, users can quickly compare indicator values by comparing an economy's position to other economies for which data is

available by quintile[1]. For instance, when income falls into the first income quintile-1, it equals one; otherwise, it equals zero; and so on for the remaining other dummies (Gosh and Chaudhury, 2020).

For education variables, we use two different dummies that are incorporated into the specification and omit primary education. The dummy variable is equal to 1 if the individual has completed secondary education, and 0 otherwise. The dummy variable is equal to 1 if the individual has completed tertiary education or more, 0 otherwise. We used the International Standard Classification of Education (ISCED 2011) for the classification in the education levels.

Finally, the individual's age (AGE) is included as an explanatory variable because it is assumed to have an effect accessing to financial inclusion. The age is measured parametrically using 'age in the number of years'. Moreover, the 'Agesquare' variable is included in the model as a control variable to determine whether it has a linear effect on DFI. Four probit regression equations are developed in order to study patterns of financial inclusion in Türkiye based on these individual-level data and analyzed using the Stata 17 software. The description of these variables and summary statistics are given in Table 1 and Table 2, respectively.

Table 1. Description of the Variables Used in The Estimation

Variable	Definition
Main Indicator of DFI	
Account ownership	The dummy variable equals one if the individual has an account in a financial institution, zero for otherwise
Ownership of mobile money account	The dummy variable equals one if the individual has a mobile money account, zero for otherwise
Saving	The dummy variable equals one if the individual saved using an account at a financial institution, zero for otherwise
Borrowing	The dummy variable equals one if the individual borrowed in the past year, zero for otherwise
Individual Characteristics	
Female	The dummy variable equals one if the individual is a female, zero for otherwise
Age	Age of the individual
Age squared	Square of the age of the individual
Income quintile 1 -poorest 20%	The dummy variable equals one if income is in the first quintile, zero for otherwise
Income quintile 2 – second 20%	The dummy variable equals one if income is in the second quintile, zero for otherwise
Income quintile 3 – third 20%	The dummy variable equals one if income is in the third quintile, zero for otherwise
Income quintile 4 – fourth 20%	The dummy variable equals one if income is in the fourth quintile, zero for otherwise
Secondary education	The dummy variable equals one if the individual has completed secondary education, zero for otherwise
Tertiary education	The dummy variable equals one if the individual has completed tertiary education or more, zero for otherwise

[1]Eurostat (2024), World Bank (2024).

Table 2. Descriptive Statistics of the Variables Used in the Estimation

Variable	Observations	Mean	Std. dev.
Account ownership	1000	0.798	0.4016
Ownership of mobile money account	1000	0.228	0.4197
Saving	1000	0.264	0.4410
Borrowing	1000	0.684	0.4651
Income quintile 1 – poorest 20%	1000	0.156	0.3630
Income quintile 2 – second 20%	1000	0.166	0.3722
Income quintile 3 – third 20%	1000	0.185	0.3884
Income quintile 4 – fourth 20%	1000	0.212	0.4089
Female	1000	0.448	0.4975
Age	1000	37.862	14.8167
Age square	1000	1652.848	1294.05
Secondary education	1000	0.487	0.5000
Tertiary education	1000	0.294	0.4558

Source: World Bank Global Findex Database.

4. Findings

The probit regression estimation for the influence of individual characteristics on DFI is presented in Table 3. The columns in the table represent the dependent variables as separate models (Model I, II, III, IV), and the rows represent the independent variables consisting of individual characteristics.

Table 3. Determinants of Financial Inclusion in Türkiye

	Model I	Model II	Model III	Model IV
	Account Ownership	Ownership of Mobile Money Account	Saving	Borrowing
Female	-0.1445***	-0.0744***	-0.0630**	-0.1353***
	(0.0253)	(0.0261)	(0.0280)	(0.0304)
Age	-0.0053	-0.0018	-0.0225***	0.0214***
	(0.0045)	(0.0051)	(0.0049)	(0.0054)
Age square	0.0001	-0.0000	0.0002***	-0.0002***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Income quintile 1 – poorest 20%	-0.2843***	-0.1215***	-0.2263***	0.0532
	(0.0580)	(0.0329)	(0.0256)	(0.0466)
Income quintile 2 – second 20%	-0.2076***	-0.0985***	-0.1994***	0.0199
	(0.0554)	(0.0342)	(0.0280)	(0.0472)
Income quintile 3 – third 20%	-0.1472***	-0.0451	-0.1433***	0.0380
	(0.0517)	(0.0355)	(0.0308)	(0.0446)
Income quintile 4 – fourth 20%	-0.1189**	-0.0135	-0.0928***	-0.0510
	(0.0486)	(0.0350)	(0.0322)	(0.0450)
Secondary education	0.1281***	0.1287***	0.0951**	0.1685***
	(0.0313)	(0.0423)	(0.0443)	(0.0405)
Tertiary education	0.1811***	0.1510***	0.1098**	0.2532***
	(0.0258)	(0.0511)	(0.051)	(0.0363)
Observations	1000	1000	1000	1000
Pseudo R2	0.1553	0.0667	0.1097	0.0658
Log likelihood	-424.9991	-501.0635	-513.9057	-582.7790

Note: The estimated coefficients are the marginal effects and numbers in parentheses indicate the standard error. ***, **, * denote the statistical significance at 1%, 5% and 10% levels, respectively.

Considering the results, all the financial inclusion indicators indicate a significant relationship with the gender of an individual. Being female is found to be negatively significant for all of the financial inclusion indicators, implying the existence of a gender gap in the access and usage of financial services. While this result aligns with previous studies by Dar and Ahmed (2020), Ozsuca (2019), and Zins and Weill (2016), it differs from the findings of Rahimyar and Curuk (2021), who state that there is no statistically significant difference between women and men in terms of account ownership. Additionally, our findings that women are much less likely than men to have an account in Türkiye are consistent with the results found by Fungácová and Weill (2015) in China. Women's accounts ownership, savings, and borrowing rates in an official financial institution are lower than men's in Türkiye. Particularly, women in Türkiye are roughly 13% less likely than men to have formal borrowing, while they are 14% less likely than men to have an account at a financial institution. Among the reasons are lower rates of women's labor force participation, insufficient financial means, and generally being economically dependent on their families or spouses. In addition to these reasons, religious reasons, not needing any financial services, having an account from a family member, and expensive financial services can also be cited. Our findings regarding gender shows that gender has a significant impact on financial inclusion. It also confirms the fact that women tend to be more financially excluded than men due to barriers to entry into the formal financial system.

Considering the relationship between the age of the individuals and the DFI, it is seen that the age of an individual has a significant effect on 'Saving' and 'Borrowing'. People who have reached a certain age have a higher probability of borrowing in Türkiye than younger individuals. This means that the probability of saving is lower. However, the coefficient estimates for the 'Agesquare' variable are significant with positive and negative signs for the 'Saving' and 'Borrowing' variables, respectively. This result indicates that an individual's age has a significant effect on the probability of saving and borrowing but this relationship is not linear.

Regarding the level of income, the coefficient estimates for the four income quintiles are found to be negative and statistically significant. However, all income quintiles become statistically insignificant for the specification employing borrowing (Model IV) as the dependent variable. In the account ownership (Model I) and saving (Model III) with larger negative coefficients for lower income quintiles, the poorest 20 percent, second 20 percent, and third 20 percent, are found a significantly lower probability of being financially included.

The results obtained from Models I to IV show that coefficient estimates for education are positively significant for all financial inclusion variables. The dummy variable for tertiary education that has the highest coefficient value is a major significant determinant for all financial inclusion measures. It was observed that the value of coefficients increases with higher education level. In other words, individuals being tertiary education are considerably less likely to be financially excluded than individuals with secondary education. This result is similar to the studies investigated by Dar and Ahmed (2020), Nandru et.al. (2021), and Ozsuca (2019). They also stated in their studies that the level of higher education significantly affects higher financial inclusion.

Moreover, in this study, those with a tertiary degree or higher, in example, are roughly 18% more likely to have a formal account and 11% more likely to have saved using formal

methods. On the other hand, having a bank account and formal savings are 14 and 6 % less likely, respectively, if you're a woman.

Considering the relationship between the secondary and tertiary education levels of the individuals and the DFI, it is seen that both of education level also has a significant effect on the ownership of mobile money accounts. The individual has tertiary education or higher are approximately 18% more likely to have a formal account, 15% ownership of a mobile money account, 11% saving, and 25% borrowing. On the other hand, the individual who has secondary education is approximately 13% more likely to have a formal account, 13% ownership of mobile money account, 9% saving, and 17% borrowing. When comparing both education levels, especially in terms of borrowing, the individual who has a tertiary education level is more likely to have borrowing. Meanwhile considering the age, as individuals age, financial difficulties appear to be less of an issue, but new concerns for older adults include cost, trust, distance, and religion.

Based on the findings above, the regression analysis on overall samples emerges that gender, education, and income level are significantly related to financial inclusion. In terms of all the measures of financial inclusion aspects, females are significantly more financially excluded than males. In conclusion, individual characteristics seem to have a greater impact on account ownership and saving in particular, yet education is revealed as the most powerful predictor when the marginal effects are considered.

5. Conclusion

The main goal of this study is to identify the determinants of DFI in Türkiye and determine how individual characteristics (gender, age, income, and education level) are related to account ownership, ownership of mobile money accounts, saving, and borrowing. In this context, we measured DFI by examining the accessibility and usage of DFI in relation to selected demographic characteristics such as gender, age, income, and education. Variables in the study were broadly grouped into two categories demographic variables and variables related to DFI, and the data was collected from the Global Findex database to specify the determinants of DFI from Türkiye's perspective. Considering the binary nature of the dependent variable, the probit model was used to make inferences in the study. The findings of the study showed that individual characteristics such as gender, education, and income have a significant impact on DFI.

Education, more specifically tertiary education, was revealed as the most important determinant for all financial inclusion indicators. Regarding the level of income, for lower-income quintiles, in particular, the poorest 20 percent and the second 20 percent are found a significantly lower probability of being financially included.

Another important finding is that the probability of being financially included is lower for women. Women's accounts ownership, savings, and borrowing rates in an official financial institution are lower than men's in Türkiye. Among the reasons are lower rates of women's labor force participation, insufficient financial means, and generally being economically dependent on their families or spouses. In addition, considering the traditional role of Turkish women, it can be said that they have informal savings, which are called "under the pillow", especially in terms of savings. In addition to these reasons, religious reasons, not needing any financial services,

having an account from a family member, and expensive financial services can also be cited. Based on our gender-related findings, steps to be taken to remove the barriers to women's entry into the official financial system for various reasons in Türkiye will increase financial inclusion. These steps may include increasing women's employment, making policies to encourage women's participation in the financial system, increasing the level of formal education, and providing various pieces of training to increase financial literacy.

Türkiye has a significant potential to increase financial inclusion. Factors such as the high number of young people in Türkiye, the high rate of adaptation of these young people to new technologies, and the widespread use of mobile technologies and social media are influential in increasing this potential. Moreover, the increase in online shopping, mobile banking transactions and mobile payment platforms, and digital banking, especially with the COVID-19 pandemic, can be counted among the factors that increase the potential for high financial inclusion in Türkiye. The increase in Internet access from 42% to 88% between 2010 and 2019 in Türkiye, and significant increases in the use of services such as e-commerce, e-government, and Internet banking can also increase this potential.

The study's findings may contribute to the development of better policies to improve financial sector outreach by showing how different individual traits affect financial inclusion. In addition, developing policies to increase income and education levels and removing barriers related to income and education could help expand formal financial services, participation in these services, and use of these services. In this context, it is important to first increase formal education at all levels of education by reorganizing it according to the requirements of the digital age and to develop policies to ensure that girls are more included in the education and training system. Furthermore, importance should be given to campaigns to increase awareness of access to financial products and financial resources, to increase women's employment potential, and to develop policies to ensure the participation of women and the young population in the financial system.

In addition to this, whereas there may be various barriers to financial inclusion in some societies or countries, exclusion from financial inclusion may be voluntary or involuntary, as stated by Allen et al. (2016). Therefore, it is important to explain the difference between this voluntary and involuntary exclusion. For instance, in some societies, people may voluntarily excluded from financial inclusion due to “not having enough income,” “religious reasons,” or “having a family member own an account.” Involuntary exclusion can be expressed as a market failure. For example, distance to financial institutions, high financial transaction costs, excessive document requirements, and lack of trust can be expressed as involuntary exclusion. This distinction between exclusion from financial inclusion due to voluntary and involuntary barriers will also help in creating policy recommendations and will help develop policies that are appropriate to the structure of society. In addition, there may be cultural reasons behind the exclusion of women, in particular from financial inclusion in some societies. In such a case, the long distance of the bank, high costs, excessive document requirements, lack of trust, and religious reasons appear as less important obstacles for women. In this case, it can be concluded that the exclusion of women from financial inclusion is voluntary. Thus, as Aterido et al. (2013) have stated, in such a case, the gender gap in finance is not due to the finance sector itself but to the inclusion of women in the economy. Demirgüc-Kunt et al. (2013) also asserted that the gender gap in formal financial services access is caused by social and legal norms; additionally, Aterido et al. (2013) discoursed that female participation in the economy through formal

employment and education highlights the role of country characteristics influencing financial exclusion.

Lastly, the policymakers can develop efficient strategies that promote campaigns related to digital literacy or "d-literacy". This can be accomplished by raising awareness through the financial institutions' or service providers' embrace of digital payments. Both users and service providers will benefit from increased capacity building as a result of this program. Moreover, the providers of service must improve the users' ability to access their credit, debit, and mobile money accounts as well as their ability to use these accounts to pay for and receive services through card-based and mobile-based financial transactions. This can be enhanced with efficient support systems, sufficient technology infrastructure, and reasonable user fees.

Although there are many studies in the literature on financial inclusion and its potential benefits, due to the limited number of studies that reveal the main determinants of DFI for Türkiye, this study will contribute to the limited number of empirical literature and be an expansionist. For this reason, it is crucial to identify the determinants of financial inclusion in Türkiye and to expand financial services to include the whole society. The study findings will also guide developing and promoting financial inclusion in developing countries.

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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SOVEREIGN RISK AND IMPLICATION OF MONETARY POLICY: EVIDENCE FROM PANEL DATA

Ülkelerin Krize Düşme Riski ve Para Politikasının Etkileri: Panel Veri Analizi

Parla ONUK*

Keywords:
External Debt,
Interest Rate,
Monetary Policy,
Debt Distress

JEL Codes:
H63, E43, E52, F43

Abstract

This paper reopens the discussion on the main dynamics behind the sovereign debt crisis focusing on global monetary policy. A panel logit model was applied using data from twenty countries between 1975 and 2022. According to the model, an increase in the U.S. interest rate is one of the significant factors fueling the likelihood of debt distress in developing countries. With this finding, we emphasize the dependency of developing countries on external factors through the interest rate and the importance of external dynamics. Additionally, an increase in short-term debt to total reserves and the ratio of international reserves to imports strengthens the likelihood of debt distress. Another important factor is the possibility that countries may fall into debt distress due to high inflation and low growth. Although these two variables are considered internal dynamics of countries, there is a strong direct relationship between the performance of production and expenditure in periphery countries and foreign capital. In this context, various recommendations are presented in the conclusion section for reconsidering debt crises and implementing appropriate policies.

Anahtar Kelimeler:
Dış Borç,
Faiz Oranı,
Para Politikası
Borç Bunalımı

JEL Kodları:
H63, E43, E52, F43.

Öz

Bu çalışma, gelişmekte olan ülkelerin borç krizinin arkasındaki ana dinamikleri küresel para politikası açısından yeniden tartışmaya açmaktadır. 1975 ile 2022 yılları arasında 20 ülkeden elde edilen veriler kullanılarak bir panel logit modeli tahmin edilmiştir. Modele göre, ABD'deki faiz oranlarındaki bir artış, gelişmekte olan ülkelerde borç sıkıntısının olasılığını artıran önemli faktörlerden biridir. Bu bulgu ile, gelişmekte olan ülkelerin faiz oranları aracılığıyla dışsal faktörlere olan bağımlılığını ve dışsal dinamiklerin önemi vurgulanmaktadır. Ayrıca, kısa vadeli borçların toplam rezervlere oranındaki artış ve uluslararası rezervlerin ithalata oranı, borç sıkıntısı olasılığını güçlendirmektedir. Bir diğer önemli faktör ise ülkelerin yüksek enflasyon ve düşük büyüme nedeniyle borç sıkıntısına düşme olasılığıdır. Bu iki değişken, ülkelerin içsel dinamikleri olarak değerlendirilse de gelişmekte olan ülkelerdeki üretim ve harcama performansı ile yabancı sermaye arasında güçlü bir doğrudan ilişkiyi gözler önüne sermektedir. Bu bağlamda, borç krizlerini yeniden değerlendirmek ve uygun politikaları uygulamak için sonuç bölümünde çeşitli öneriler sunulmaktadır.

* Asst. Prof. Dr., İstanbul Nişantaşı University, Faculty of Economics, Administrative and Social Sciences, Department of Economics and Finance, Türkiye, parla.onuk@nisantasi.edu.tr

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1. Introduction

As external debt figures rapidly escalate worldwide, the future of developing countries, with their fragile structures, has been re-examined, particularly during the pandemic. Prior to this, the world was facing a global inflation threat, prompting a shift towards monetary tightening. However, with the onset of the pandemic, the need to increase money supply became almost a necessity. This situation appeared to be a remedy for developing countries that had become increasingly dependent on international liquidity. Nevertheless, in recent years, these high-debt countries have faced economic turbulence due to renewed tightening measures. The extent to which they can sustain this situation has become a significant puzzle.

On the other hand, previous studies on external debt crises have generally focused on the question of "why do countries repay their debts?" and have been significantly lacking in comprehensively examining the underlying dynamics of crises (Eaton and Gersovitz, 1981; Sachs and Cohen, 1982; Bulow and Rogoff, 1989; Cole and Kehoe, 2000). These studies focus on the internal dynamics of debtor countries, examining the motivations for repayments to avoid losing access to international liquidity. This perspective is highly inadequate to explain the series of global debt crises that have occurred since the 1980s. For instance, there is a clear need for more comprehensive studies to better understand the broader picture of the 1997-98 Asian financial crisis, the 2010-11 European debt crisis, and recent debt distress involving Lebanon and other countries.

This paper challenges the prevailing understanding by arguing that the fundamental causes of debt crises are primarily related to asymmetric power relations between core and peripheral countries. If the primary issue is to understand the debtor-creditor relationship, it is crucial to thoroughly understand the dynamics of countries that accumulate capital and export it globally versus those that, despite their internal dynamics, are unable to generate capital and remain perpetually dependent on it. In this context, the paper aims to elucidate how all processes related to borrowing are connected to the dominance of capitalist countries at the core.

The paper posits that the asymmetric power structure in the creditor-debtor relationship is both exacerbated and highly influential in the external borrowing processes (including high levels of borrowing, crises, and restructuring) by the monetary policies implemented by developed countries. Specifically, when interest rates in core countries start to decline, there is an increased tendency for capital to flow towards peripheral countries. Conversely, when interest rates rise, capital flows back to the core, leading to debt distress in peripheral countries. The extent of damage caused during the return process to peripheral countries also reflects this trend.

To test this hypothesis econometrically, the paper analyzes annual data from 20 highly indebted countries for the period 1975-2022. It employs a panel logit model to examine not only the impact of monetary policy but also the influence of other external and internal dynamics. Also, the period from 1975 to 2022 represents a phase of heightened international capital flows. Moreover, it coincides with a time when the International Monetary Fund (IMF) actively intervened in the fiscal autonomy of countries experiencing debt crises. Given this context, identifying the underlying dynamics of sovereign debt crises during this period could help eliminate the potential for external intervention and facilitate more effective domestic policy maneuvers. This study seeks to address this gap in the literature by examining these dynamics.

In line with this perspective, the paper is organized into five sections. Section 1 outlines the rationale for the study, its objectives, and its contribution to the literature. Section 2 reviews both theoretical and empirical literature on external borrowing, with a particular focus on studies related to early warning systems for countries, discussing their findings and criticizing their shortcomings. Section 3 covers the empirical analysis. Details of the model, variables, and findings are explained in this section. Section 4 discusses the results of the model. Finally, Section 5 explores the impact of international monetary policy and other identified dynamics on the debt crises of developing countries within the framework of economic policy and presents various policy recommendations for discussion.

2. Literature Review

In literature, many studies addressing external borrowing and debt repayment difficulties in peripheral countries are largely unrelated and often limited in scope. A significant portion of these studies focuses on short time periods, specific geographic areas, or countries. Clearly, these works remain constrained to the temporal and spatial events when external borrowing became a significant and problematic issue in international relations.

To understand debt crises, it is crucial to outline a roadmap. Firstly, it is important to comprehend the structure and dynamics of the asymmetric power relationship between core and peripheral countries. Therefore, Imperialism Theories, which interpret the global economy through the lens of capital accumulation, and Dependency Theories, which explain debt relationships between core and peripheral countries, largely fill this gap.

According to Marx (2011), capitalism is fundamentally a system characterized by global operations and a tendency towards monopolization. Marx posits that the diminishing profit rates in capitalist production are merely a tendency, and capitalists will inevitably turn to foreign trade to increase their profits. Hobson, a pioneer of Imperialism Theory, argues that capital export is a result of the distribution of domestic purchasing power, highlighting a flaw in capitalism's development (Hobson, 1961). Hilferding (1981) views capital export as an inevitable outcome of monopoly financial capitalism and identifies banks as a key factor in capitalism. Additionally, thinkers such as Bukharin (1987) and Amin (1991) emphasize the dependency relationship established through capital between core and peripheral countries, giving particular importance to the role of borrowing.

Frank (1984) viewing external borrowing as a significant tool in the dependency relationship between core and peripheral countries, has argued that the growth of indebtedness in peripheral countries is crucial for core nations. During periods of economic crises in core countries, authorities tend to resort to printing money and attempting to overcome the crisis by extending more credit. This strategy is successful in sustaining growth for a short period. However, over time, the accumulation of debt leads to a collapse in the financial system, affecting both core and peripheral countries.

Suter (1992) proposes approaches to dependency theory by advancing the argument that the indebtedness of peripheral countries may be related to the long-term economic cycles in core countries. In his analysis, he first defined peripheral indebtedness as a separate wave and examined its structure. He then attempted to illustrate the dependency relationship between core and peripheral countries through the dynamics of these waves, shedding light on the economic

and political determinants behind borrowing. Suter identified the hegemonic power in core countries and global economic growth as the primary dynamics shaping the movement of these waves.

Imperialism theories and dependency approaches make an important observation by analyzing the asymmetric power relationships in the creditor-debtor relationship and how borrowing will lead peripheral countries to become even more economically and politically dependent on core countries. In recent years, with the dominance of empirical analyses in economic literature, this study seeks to identify the dynamics behind the debt crises by utilizing both these theories and the perspective offered by econometric studies.

Over the past 30 years, empirical studies on debt crises have virtually dominated the field. Before examining the empirical method to be used in this study, it is important to review the works in this area. As empirical analyses have advanced, researchers have investigated the existence of early warning systems for predicting debt crises and the variables involved in their interactions. Consequently, a range of studies incorporating macroeconomic, political, and even institutional variables have emerged in the literature.

This paper empirically investigates how heavily indebted peripheral countries are dependent on external factors from this perspective. Before diving into the analysis, it will be beneficial to examine the methods and variables used in empirical analyses of debt crises. As empirical analyses have developed, researchers have investigated the existence of early warning systems for predicting debt crises and the variables involved in their interactions. Consequently, a range of studies have emerged that incorporate macroeconomic, political, and even institutional variables into the literature.

There is no single experimental definition of default and debt crisis metrics in empirical studies. Some studies have maintained lists of default and restructuring periods based on case examples or anecdotal records (Suter, 1992; Beers and Bhatia, 1999; Reinhart and Rogoff, 2009). Reinhart et al. (2003) have associated debt crises with specific thresholds based on the ratio of external debt to GDP. In another study, Detragiache and Spilimbergo (2001) indicated that a country is in debt distress if its external obligations to commercial creditors exceed 5% of its commercial debt or if a restructuring agreement with creditors has been made. Manasse et al. (2003) analyzed situations where countries might experience debt crises when the ratio of total external debt to GDP exceeds 50%. Another data set on defaults is provided by Standard & Poor’s (2002), which has also been frequently utilized by researchers.

Other variables include whether a state is unable to resolve its debt payments, and these are related to GDP, exports, or government revenues, which represent debt repayment capability. Low inflation is also included in models as it significantly affects policy credibility and country risk. Additionally, liquidity metrics such as the ratio of short-term debt or money supply to reserves are frequently used in models. Institutional and political factors have also been added to models to test policy credibility and whether the government is willing to pursue consistent policies through sustainable debt (Manasse et al., 2003: 6).

Using these variables, the determinants of debt crises have been analyzed through probit/logit regressions or signal models. Most studies have focused on the major debt crises of the 1980s and 1990s. In this context, the first empirical study introduced to the literature was by Eaton and Gersovitz (1981), who examined 45 developing countries. Their study addresses a

situation where the government conducts public investments through external borrowing. The authors assume that a country's willingness to borrow is a determinant of debt. Using a logit model, the authors found that this borrowing demand is positively related to income instability, export/GDP, and income level.

Two other significant studies in this field are by McFadden et al. (1985) and Hajivassiliou (1987). They argue that the connection between debt repayment performance and macroeconomic dynamics may vary between countries and over time. For countries with fewer capital controls or more open to global trade, external economic signals may be more decisive in terms of debt crisis. Additionally, various institutions (government and religious institutions) may explain the reasons for a country's default.

In contrast to approaches that focus on inter-country heterogeneity, Reinhart (2002) found that in 84% of cases, a currency crisis precedes a debt crisis. Therefore, he emphasizes that variables suitable for predicting currency crises also have explanatory power for default models. Another critical study by Detragiache and Spilimbergo (2001) found that including short-term debt, debt service, and reserves separately in the model rendered it meaningless. Hence, they do not find it appropriate to use variables such as the ratio of short-term debt to reserves.

Although most studies use macroeconomic variables, Catão and Sutton (2002) address volatility measures in their models. Using panel analysis methods with data from 25 countries for the period 1970-2001, they highlight that adding measures of commercial volatility, fiscal policy, monetary policy, and exchange rate policy volatility to a model with variables such as U.S. interest rates, real effective exchange rates, fiscal balance, real GDP growth, and debt service to export ratio increases the likelihood of default.

Another relationship explored is the impact of countries' credit ratings on currency crises and defaults. Studies on this topic analyze the determinants of credit ratings (Larraín et al., 1997; Rojas-Suarez, 2001; Reinhart, 2002). Some research tests whether credit ratings are significantly related to a range of economic factors. In this regard, it has been found that external debt metrics and default history, along with other macroeconomic and political variables, are related to debt crises (Haque et al., 1998).

Manasse et al. (2003), use Standard & Poor's default dataset to analyze the likelihood of debt crises in less developed countries using a panel logit regression model. This study, which uses a substantial number of variables, highlights that a ratio of external debt to GDP exceeding 50% and high inflation levels are significant determinants of default. Conversely, it is suggested that the ratio of short-term debt to reserves and maintaining low external debt burdens are necessary to reduce the likelihood of default. Additionally, external shocks, such as U.S. interest rates, are emphasized as significant dynamics of default (Manasse et al., 2003: 30).

Another study analyzing the determinants of debt distress, in addition to default, is by Kraay and Nehru (2006). Using a probit model, the authors highlight three variables: debt burden, the quality of institutions and policies, and shocks, which are considered the strongest determinants of debt distress. The results are largely consistent with those in Manasse et al. (2003), which used similar variables.

Fuertes and Kalotychou (2006) analyze 96 developing countries from 1983 to 2002 using a logit model. The authors found that the determinants of default include trade, external debt,

the ratio of private sector credit to GDP, the ratio of IMF credits to exports, and the ratio of official credits to total debt (Fuertes and Kalotychou, 2006: 1434).

Suter (1992), representing the dependency approach, analyzed the determinants of default and restructuring over two periods, 1931-33 and 1978-85. Using a logit regression model, the author noted that the capacity to service debt is a strong variable. The significance of exports and growth rates was also emphasized (Suter, 1992: 78).

However, these studies have focused more on identifying early warning signals to prevent countries from sliding into a debt crisis, rather than providing a comprehensive picture of the crisis itself. While these identifications are indeed crucial and can help uncover the root causes of the problem with the right perspective, this study aims to address the gap in the literature from this standpoint.

3. Data and Methodology

3.1. Data

The number of countries used in this paper, as dictated by availability of data, is 20. Latin America has always been one of the most favored destinations for foreign investment. For this reason, we include Bolivia, Brazil, the Dominican Republic, Ecuador, El Salvador, Guatemala, Honduras, Colombia, Costa Rica, Mexico, Peru, and Paraguay. In addition, the analysis includes Indonesia, the Philippines, India, and Thailand from East and Southeast Asia; Türkiye from Europe; and Morocco, Egypt, and Nigeria from Africa—countries that are favored by investors. The annual time series spans 1975–2022; therefore, the dataset includes periods when capital transfers are intense. Data for the countries were obtained from the World Bank dataset.

To prevent potential issues in the analysis, special attention was given to ensuring the completeness of the datasets for the countries. Consequently, certain countries were excluded from the analysis and the period from 1975 to 2022, characterized by the highest capital mobility, was used in the analysis. Two key considerations were taken into account when selecting the countries included in the analysis. First, countries characterized by the highest inflows of foreign capital and those frequently affected by debt crises were included in the analysis. Second, particular attention was paid to ensuring that the data used were as complete as possible. For this reason, some countries were excluded from the analysis. Furthermore, when it comes to debt, some countries may present macroeconomic statistics in a biased manner in order to secure more borrowing (e.g., Argentina). Therefore, countries with the most reliable data were selected for the analysis.

It is important to use a balanced panel model for the correct interpretation of the model results. However, the absence of data for certain years is a common issue in economic studies, and unbalanced panels are typically employed. In this study, data for some years are missing for two variables (see Table 1). An ordinary fixed effects model has been applied in this case.

Table 1 shows the descriptive statistics of variables. Our dependent variable is external debt distress. This variable was designed based on the study of Manasse et al. (2003). The debt distress variable was obtained by assigning 1 to cases where the ratio of total external debt (public + private) to GDP was greater than or equal to 50 percent, and 0 to other years.

Table 1. Descriptive Statistics

Variables	Obs.	Mean	S.D.	Min.	Max.
External debt distress (edgdp)	960	0.32	0.47	0	1
Total reserves in months of imports (rsrvimp)	932	4.92	3.00	0.23	19.21
Fed funds rate (fedfnd)	960	4.68	3.90	0.08	16.38
GDP growth (gdpgrwth)	960	3.81	3.84	-13.13	15.33
Exports of goods and services/GDP (expgdp)	960	25.42	12.23	3.22	71.42
Foreign direct investment/GDP (fdigdp)	958	1.87	1.85	-5.09	12.2
High inflation (hghinf)	960	0.09	0.28	0	1
Short-term debt /Total reserves (shrtrsrv)	960	15.53	9.59	0	68.69

Our independent variables have been determined within the framework of both literature and historical analysis. The first of these is the interest rates in core countries. Given that our analysis covers the period from 1975 to 2022, it has been deemed more appropriate to use the real interest rate of the United States, the most influential country in shaping global capital flows. The Federal funds rate (fedfnd) has concentrated around an average of 4.68%, with values ranging from 0.08% to 16.38%. This distribution suggests a tendency for rates to cluster near the mean.

The second variable is the annual growth rate of GDP. This variable serves as a significant indicator of a country's creditworthiness. It reflects that countries can not only borrow more but also face fewer serious issues in repaying their debts. To investigate whether this variable is a crucial determinant on the path to a debt crisis, it was decided to include it in the model.

The average GDP growth rate across the sample period is 3.81%, indicating moderate overall economic expansion. However, the relatively high standard deviation of 3.84% suggests considerable variability in growth across the observations. The range from -13.13% to 15.33% further underscores this variability, with some countries or periods experiencing negative growth (contractions), while others saw significant economic expansions. The negative minimum value highlights the presence of severe economic downturns or crises during the period under review, while the positive maximum indicates periods of robust growth.

Another variable is the share of short-term debt within total reserves. Over the past 25 years, short-term debt has been a major factor behind the debt crises in peripheral countries. Creditors prefer to lend short-term to peripheral countries that they perceive as risky. This situation has periodically led to crises in these peripheral countries, which have become increasingly dependent on capital from core economies. When interest rates in the core rise, in addition to a reduction in foreign capital, short-term debt has led to significant liquidity crises in peripheral countries. Consequently, countries facing funding shortages have experienced inevitable debt crises. Therefore, this variable, which plays a crucial role in explaining debt crises, has been included in the model. The average ratio of short-term debt to total reserves is 15.53%, suggesting that, on average, countries maintain a relatively low level of short-term debt relative to their total reserves. The standard deviation of 9.59% indicates a notable degree of variability in this ratio across the sample, with some countries showing significantly higher levels of short-term debt compared to their reserves. The range from 0% to 68.69% further emphasizes this variability, showing that some countries have minimal or no short-term debt relative to reserves, while others exhibit a higher dependence on short-term borrowing.

The average ratio of exports of goods and services to GDP is 25.42%, indicating that, on average, a significant portion of economic activity is driven by external trade. However, the relatively high standard deviation of 12.23% suggests considerable variability in the degree of export dependence across the sample, with some countries being more reliant on international trade than others. The range from 3.22% to 71.42% further highlights this variation, indicating that some countries have very low export-to-GDP ratios, while others have a disproportionately high share of their GDP coming from exports.

Another variable that has gained importance in recent years is high inflation. This variable is designed as a dummy variable. It is coded as 1 for years in which inflation rates exceed 50% and 0 for other years. The ratio of foreign direct investment to GDP and the share of international reserves in imports are additional independent variables. It is believed that decreases in these two variables could significantly impact the likelihood of falling into a debt crisis or experiencing financial distress. Also, the standard error values are quite low, there is little variation between the countries.

3.2. Panel Logit Model

In this paper, the impact of macroeconomic variables on the likelihood of countries experiencing debt distress will be analyzed using a panel logit model. In binary models, namely logit, probit, and log-log regression models, the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) were used to determine which model is the most appropriate. Based on these criteria, the logit model was selected as the best-fitting model. A panel logit model deals with data observed over time and across different units and is used when the dependent variable is binary (0 or 1). This model is a type of panel data analysis, which includes data observed from a set of individuals, countries, etc., over a certain period. The panel logit model aims to provide more accurate predictions by accounting for heterogeneity among units and changes over time.

The dependent variable is formulated as a binary choice model. In binary choice models, the dependent variable takes the value of 1 if an event has occurred for unit i at time t, and 0 if it has not. In this case, the expected value of the dependent variable is:

$$E(Y_{it}) = 1.P_{it} + 0.(1 - P_{it}) = P_{it} \quad (1)$$

$E(Y_{it})$: The expected value of the dependent variable (Y) for unit i at time t.

P_{it}: The probability of event i occurring at time t. It typically represents the probability of a binary outcome.

The expression is essentially a way of modeling expected outcomes for a binary variable, where the outcome takes the value 1 with probability P_{it} and 0 with probability 1 - P_{it}. If the probability of the event occurring for unit i at time t is given, then:

$$P_{it} = Prob(Y_{it} = 1) = E(Y_{it} I\, X_{it}) = F(\beta' X_{it}) \quad (2)$$

β’ is a vector of coefficients and X_{it} is a vector of the independent variables (covariates) for unit i at time t.

$E(Y_{it} \; I \; X_{it})$: The conditional expectation of Y_{it} given the values of the independent variables X_{it} for unit i at time t. This represents the expected value of Y_{it}, given the covariates or predictors X_{it}.

$F(\beta'X_{it})$: A cumulative distribution function (CDF) applied to the linear predictor $\beta'X_{it}$. The function F could represent different distributions, such as the logit function (logistic regression), the probit function (standard normal cumulative distribution), or other suitable distributions depending on the model.

In our study, the analysis will be conducted using the logit model. The logit model utilizes the logistic distribution, and its formula is as follows;

$$L_i = \ln\left[\frac{P_i(Y_i = 1)}{1 - P_i(Y_i = 1)}\right] = \ln(e^{\beta' X_i}) = \beta' X_i \quad (3)$$

$P_i/1\text{-}P_i$ represents the odds ratio. The left side of the equation represents the logarithm of the odds ratio (Lardaro, 1993: 408). Here, $Y_i = 1$ denotes the years of debt distress, while $Y_i = 0$ denotes the years without debt distress.

4. Results

To identify the dynamics underlying debt distress, a panel logit model has been applied. Before applying the model, the stationarity of the variables was tested. The Levin, Lin, and Chu test has been used. Structural breaks have been disregarded. Ignoring structural breaks indicates that important events, such as crises or external shocks, have not been incorporated into the analysis. However, such events could potentially influence the model. This represents one of the key limitations of the study. The results of the stationarity tests are summarized in Table 2. Since edgdp and hghinf are dummy variables, their stationarity is not tested. Also, to examine multicollinearity among the variables, the variance inflation factor (VIF) was applied, and the result was 1.17. Since this value is less than 5, it indicates that there is no multicollinearity among the variables. The expgdp variable is the only one that is non-stationary. However, it becomes stationary after applying the first difference.

Table 2. Levin, Lin, and Chu Unit Root Test Result

	t statistics
fedfnd	-4.9315*
rsrvimp	-2.7923*
gdpgrwth	-11.1621*
d.expgdp	-15.5004*
fdigdp	-4.6060*
shrtrsrv	-4.1277*

Note: * denote significance at the $p < 0.01$.

After testing the stationarity of the variables, it is necessary to investigate the presence of unit effects in the data before applying the panel logit model, as the existence of such effects complicates predictions. According to the results of the LR test, unit effects were

detected.[1] To determine whether these effects are fixed or random, a robust Hausman test was conducted. The probability value as a result of the applied Hausman test is less than 0.05, it is necessary to establish the model with fixed effects. The probability value is 0.0025. The results of this test indicated that the assumption of fixed effects was valid for the model. The estimation results obtained through this method are presented in Table 3. Table 3 shows that, according to the results of the Wald test, all variables except for Foreign direct investment/GDP are significant in explaining the dependent variable. The direction of the coefficients is also as expected.

Table 3. Panel Logit Regression Result

Independent Variables	Dependent Variable: External Debt Distress		
	Odds ratio	Coeff.	z
fedfnd	1.135128	0.126*	4.79
hghinf	2.255446	0.813**	1.98
fdigdp	1.045731	0.044	0.84
rsrvimp	0.807710	-0.213*	-4.83
gdpgrwth	0.951845	-0.049**	-2.01
shrtrsrv	0.950328	0.050*	-4.27
expgdp	1.071013	-0.068*	2.77
Wald	98.67		
LR	125.09		

Note: *, ** denote significance at the $p < 0.01$, $p<0.05$.

Regression results indicate that a one-unit increase in the real interest rate in the United States raises the odds of reporting into debt distress by 13%. This finding is highly significant as it highlights the impact of core country interest rates on debtor nations and is one of the strongest relationships identified in the model.

Another variable explaining debt distress is high inflation. The model indicates that countries experiencing high inflation are 2.25 times more likely to enter debt distress compared to those with lower inflation. High inflation can erode the real value of debt repayments and destabilize economies, making them more vulnerable to financial crises. This result emphasizes the detrimental impact of inflation on debt sustainability and highlights why peripheral countries often face severe economic challenges when inflation rates are high. As is well known, high inflation has been one of the major problems for peripheral countries, especially since the 1970s. Given that peripheral countries experience high and frequently changing inflation rates, creditors have preferred short-term debt contracts to mitigate this risk. Additionally, to hedge against inflation, there has often been a tendency to borrow in foreign currencies. However, when these two factors combined with the fixed exchange rate system, a popular practice at the time, peripheral economies were dragged into significant contractions.

[1] Unit effects can introduce several complications in panel data models, especially when these effects are not properly accounted for or when their presence leads to certain assumptions being violated. Omitted variable bias, endogeneity, and multicollinearity are important issues. The inclusion of unit effects makes it challenging to interpret the effects of the independent variables on the dependent variable because the model now accounts for the unit-specific characteristics that could influence the outcome. To address these complications, various techniques such as fixed effects or random effects models are commonly used to control for unit effects. The choice between these methods depends on the assumption about the correlation between the unit effects and the explanatory variables.

Therefore, high inflation is a critical factor that exacerbates the financial difficulties of debtor countries.

Moreover, creditors' preference for short-term debt contracts due to inflation risk is also a crucial factor leading to debt crises. A one-unit increase in the ratio of short-term debt to reserves raises the probability of debt distress by 0.9%. This suggests that a higher proportion of short-term debt relative to reserves increases the likelihood of financial distress. Short-term debt is typically more vulnerable to shifts in market conditions and can lead to liquidity problems if not adequately supported by reserves. This finding reinforces the importance of maintaining a balanced debt structure to mitigate crisis risk.

Another variable is GDP growth. The results show that a one-unit decrease in GDP growth increases the likelihood of a debt crisis by 0.95 times. This reflects the role of economic performance in debt sustainability. Sluggish GDP growth can impair a country's ability to service its debt and increase the risk of a crisis. Strong economic growth is crucial for maintaining fiscal health and preventing debt distress. The share of international reserves in imports also has a similar effect. A one-unit decrease in the ratio of international reserves to imports increases the likelihood of debt distress by 0.80 times. This indicates that lower reserves relative to import needs can weaken a country's ability to manage external shocks and service its debt. Adequate reserves are essential for buffering against sudden changes in the external environment and for ensuring debt servicing capacity.

The analysis finds that a one-unit decrease in the ratio of exports to GDP increases the probability of debt distress by 7%. Export performance is crucial for generating foreign exchange earnings and maintaining debt serviceability.

In this model, which investigates the dynamics behind falling into debt distress, the results are consistent with the findings of Manasse et al. (2003) and Kraay and Nehru (2006). Also, the most significant variable is the interest rates in the United States. This finding underscores the impact of external dynamics on the debt distress experienced by developing countries. Additionally, high inflation, along with short-term debt imposed by creditors in debt contracts, is also a crucial factor contributing to the onset of debt distress.

5. Conclusion

When a country falls into a debt crisis, it typically turns to the IMF, which imposes austerity policies. This occurs because the country has mismanaged its debt and has been driven into crisis by its internal dynamics. This study challenges this prevailing view by demonstrating that developing debtor countries are more vulnerable to external dynamics than to their own internal dynamics. A panel logit model was applied to twenty debtor countries to investigate this.

The results of the model, which substantiate the claims, show that debtor countries are highly sensitive to the interest rates of the dominant country shaping the monetary policy of the period. Although the data analysis focuses primarily on crisis and turmoil periods, it is plausible to predict similar sensitivity during periods of intense capital export and debt accumulation. Therefore, the dependency established through capital in the core-periphery relationship and the underlying dynamics are critically important and cannot be overlooked. This relationship also influences other internal dynamics. For instance, during periods of monetary expansion when

interest rates are kept low in the core, foreign capital flows into peripheral countries, affecting their production and spending performance. These countries can also be driven into high inflation trends due to either misguided policies or uncontrolled capital flows during these periods. High inflation, in turn, impacts the country's credibility and can lead to a lack of international liquidity for debtor countries.

For these reasons, the debt crises and periods of turmoil faced by developing countries, both historically and in the present day, necessitate approaching the problem of borrowing from accurate perspectives. Considering the decisive impact of interest rates in core countries, state intervention to redirect funds towards production during periods of high external borrowing and intense capital flows will be an extremely effective strategy. In this context, implementing incentive policies is essential. It is crucial to remember that there is a limit to increased capital transfers. Therefore, it is imperative to implement policies that strengthen the production dynamics of the national economy. Additionally, dependence on external interest rates can sometimes lead to a decrease in international liquidity. If this dependency can be mitigated through state-led production mechanisms, debtor countries will be able to take more secure steps into the future.

During periods of high foreign capital inflows into developing countries, these resources can be directed towards infrastructure investments that will enhance the countries' future production capacity. At the same time, during such periods, peripheral countries should implement structural reforms to develop a skilled workforce capable of supporting a high-value-added production structure, through comprehensive educational initiatives. Additionally, it is crucial to regulate capital movements through counter-cyclical policies. Tax policies should be implemented to prevent an increase in luxury consumption and dependence on imported goods in production. Furthermore, appropriate incentive policies should be applied to channel foreign capital inflows into productive investments.

The findings of this paper provide significant and timely contributions to the literature by uncovering the dynamics behind debt crises. However, in its current form, the study can only analyze debt crisis processes due to data limitations. Historical studies are needed for comparative analysis in this context. Future research could enrich the field by incorporating additional variables into the model and examining debt processes in a more comprehensive manner. Indeed, there are still many unanswered questions in this literature.

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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THE LINKAGE BETWEEN ECONOMIC DEVELOPMENT AND INCOME DISTRIBUTION IN MIST COUNTRIES: PANEL ARDL ANALYSIS

MIST Ülkelerinde Ekonomik Kalkınma ve Gelir Dağılımı İlişkisi: Panel ARDL Analizi

Ayşenur TARAKCIOĞLU ALTINAY*, Mustafa Batuhan TUFANER & İlyas SÖZEN*****

Abstract

Economic development and income distribution are central issues in economics, with their relationship being critical for sustainable development. Imbalances in income distribution can slow economic growth and reduce societal welfare. Thus, development policies should prioritize not just growth but also equitable income distribution. A balanced income distribution enhances social acceptance and ensures the sustainability of development. This study examines the relationship between economic development and income distribution in MIST countries (Mexico, Indonesia, South Korea, and Turkey) from 1990 to 2022, as classified by economist Jim O'Neill. Using a panel ARDL model, the findings show that economic development reduces income inequality. However, industrialization, a marker of technological progress, tends to increase inequality. These insights have significant policy implications. To mitigate income inequality, MIST countries should emphasize the three pillars of economic development: education, health, and growth. Policymakers must reassess industrialization strategies, promoting renewable energy while addressing inequality. Subsidies to non-renewable sectors and improved vocational training for unskilled labor can reduce the dual economic structure created by technological advancements. By implementing vocational programs and orientation initiatives, governments can limit the adverse effects of industrialization on unskilled workers, ensuring more equitable growth.

Keywords: Economic Development, Income Distribution, Panel ARDL Model.

JEL Codes: O10, O15, C35.

Öz

Ekonomik kalkınma ve gelir dağılımı, ekonomide merkezi konulardır ve aralarındaki ilişki sürdürülebilir kalkınma için kritik öneme sahiptir. Gelir dağılımındaki dengesizlikler ekonomik büyümeyi yavaşlatabilir ve toplumsal refahı azaltabilir. Bu nedenle, kalkınma politikaları sadece büyümeye değil aynı zamanda adil gelir dağılımına da öncelik vermelidir. Dengeli bir gelir dağılımı toplumsal kabulü artırır ve kalkınmanın sürdürülebilirliğini sağlar. Bu çalışma, ekonomist Jim O'Neill tarafından sınıflandırılan MIST ülkelerinde (Meksika, Endonezya, Güney Kore ve Türkiye) 1990-2022 yılları arasında ekonomik kalkınma ve gelir dağılımı arasındaki ilişkiyi incelemektedir. Panel ARDL modeli kullanılarak elde edilen bulgular, ekonomik kalkınmanın gelir eşitsizliğini azalttığını göstermektedir. Bununla birlikte, teknolojik ilerlemenin bir göstergesi olan sanayileşme, eşitsizliği artırma eğilimindedir. Bu görüşler önemli politika çıkarımlarına sahiptir. Gelir eşitsizliğini azaltmak için MIST ülkeleri ekonomik kalkınmanın üç ayağına vurgu yapmalıdır: eğitim, sağlık ve büyüme. Politika yapıcılar sanayileşme stratejilerini yeniden değerlendirmeli, eşitsizliği ele alırken yenilenebilir enerjiyi teşvik etmelidir. Yenilenemeyen sektörlere yönelik sübvansiyonlar ve vasıfsız işgücüne yönelik mesleki eğitimin iyileştirilmesi, teknolojik ilerlemelerin yarattığı ikili ekonomik yapıyı azaltabilir. Hükümetler mesleki programlar ve oryantasyon girişimleri uygulayarak sanayileşmenin vasıfsız işçiler üzerindeki olumsuz etkilerini sınırlayabilir ve daha adil bir büyüme sağlayabilir.

Anahtar Kelimeler: Ekonomik Kalkınma, Gelir Dağılımı, Panel ARDL Model.

JEL Kodları: O10, O15, C35.

* Assoc. Prof. Dr., Usak University, Civil Aviation Vocational High School, Türkiye, aysenur.altinay@usak.edu.tr

** Assoc. Prof. Dr., Beykent University, Faculty of Economics and Administrative Sciences, Türkiye, batuhantufaner@beykent.edu.tr

*** Prof. Dr., Dokuz Eylül University, School of Applied Sciences, Türkiye, ilyas.sozen@deu.edu.tr

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1. Introduction

Economic development is a complex and multidimensional process encompassing various aspects, characteristics, and objectives. While traditional measures, such as economic growth, remain significant, they do not fully capture other critical dimensions of development, such as reducing poverty, inequality, and unemployment (Seers, 1979). Broader development objectives include improving education, enhancing health and nutrition standards, promoting environmental sustainability, ensuring equal opportunities, expanding individual freedoms, and enriching cultural experiences (World Bank, 1991: 4). To maintain conceptual clarity, it is essential to distinguish between economic development and the broader concept of development, which incorporates non-economic values and goals. The additional objectives are better aligned with this broader perspective.

Economic development can be described as improving society's living standards in areas such as education and healthcare, along with enhancing the overall income level. While economic growth and economic development are occasionally used synonymously in economic theory, the concept of economic development encompasses a significantly broader scope. Therefore, a country's high per capita income does not reflect that country's development alone. In the literature, the phenomenon of development is generally measured through the HDI (Human Development Index) prepared by the UNDP (United Nations Development Programme). HDI is a measurement prepared by taking the geometric mean of life expectancy, education, and income index sub-indicators.

Although economic growth and economic development are sometimes treated as interchangeable terms in economic theory, economic development covers a much wider scope. Income distribution can be expressed as the distribution of the income obtained as a result of the goods and services produced in a country to the society (Kuştepeli and Halaç, 2004: 144). The widely used criterion to measure fairness in income distribution is the "Gini coefficient". The Gini coefficient, derived from the Lorenz curve, ranges between 0 and 1. When the Gini coefficient is close to 1, it means that the equality in the income distribution decreases, and when it approaches 0, the equality in the income distribution increases.

Traditional development theory argues that the development process does not start at the same time in all areas of the economy, and therefore balanced development is not realistic (Lewis, 1976: 26). Accordingly, economies realize their growth by using more advanced production techniques. However, only a limited number of labor forces can be transferred to advanced production techniques, while others may be left behind while waiting their turn (Lydall, 1977: 13-14). Development moves by expanding the "modern sector" using advanced production techniques. During this process, the labor force transitions from the traditional sector to the modern sector, leading to an increase in average incomes within the modern sector. As a result, although inequality is greater within the traditional sector, the overall level of inequality initially rises and then falls as the modern sector expands (Gagliani, 1987: 315). Because the development process necessitates the expansion of certain modern sectors, an inverted U-shaped relationship may form between per capita income and income inequality.

Kuznets (1955) examined the link between economic development and income inequality by drawing a distinction between the rural population and those living in urban areas. At the early stages of development, income inequality rises, and after reaching a certain point, it begins to decline. According to Kuznets, while the incomes of the labor force in the agricultural sector are

lower than those in the industrial sector, they are distributed more equally than in the industrial sector. As a result, the movement of labor from the agricultural sector to the industrial sector raises individual incomes but also results in greater inequality. Swamy (1967), Knight (1976), Robinson (1976), and Fields (1980) have extended this version using sectoral shifts and various distribution indices.

Lewis (1976) has suggested some possibilities that urban development can reduce incomes in the traditional sector. These are the destruction of traditional trade through product-price or wage competition, geographic polarization, and acceleration of population growth due to a decrease in mortality. However, governments can take action to prevent most, if not all, of these negativities. The share of profits and rents in the urban sector is likely to increase at first. However, after a threshold, the expansion of the middle-income group and the tightening of the labor market will put downward pressure on income inequality.

Economic development is not a concept that can be measured only by economic growth or gross domestic product (GDP). As a multidimensional process, development encompasses elements such as welfare, education, health, employment, political participation, governance, social relations, and environment, which directly affect the quality of life of individuals. These elements reveal that development should be evaluated in a broader framework. The HDI, one of the most common indicators used to measure economic development, reflects this multidimensional approach. HDI is a measure that takes education, health, and income levels together. Therefore, in addition to GDP, it also includes other critical factors affecting the welfare of individuals. This index, first developed by Amartya Sen and Mahbub ul Haq in 1990, allows for a more holistic analysis of economic development.

Based on these recent developments, there is an increasing number of articles discussing the effects of economic growth on income distribution. However, there has been relatively little progress in understanding the effects of economic development on income distribution. In the study, the relationship between economic development and income distribution was analyzed for MIST countries (Mexico, Indonesia, South Korea, and Türkiye). MIST countries stand out in terms of economic development. The common features of these four countries are; having a large population, having a GDP equivalent to more than 1% of the global economy, and being members of the G-20. Figure 1 shows the course of economic development and income distribution in MIST countries. In the context of the research, we address the question of whether there is a relationship between economic development and income distribution.

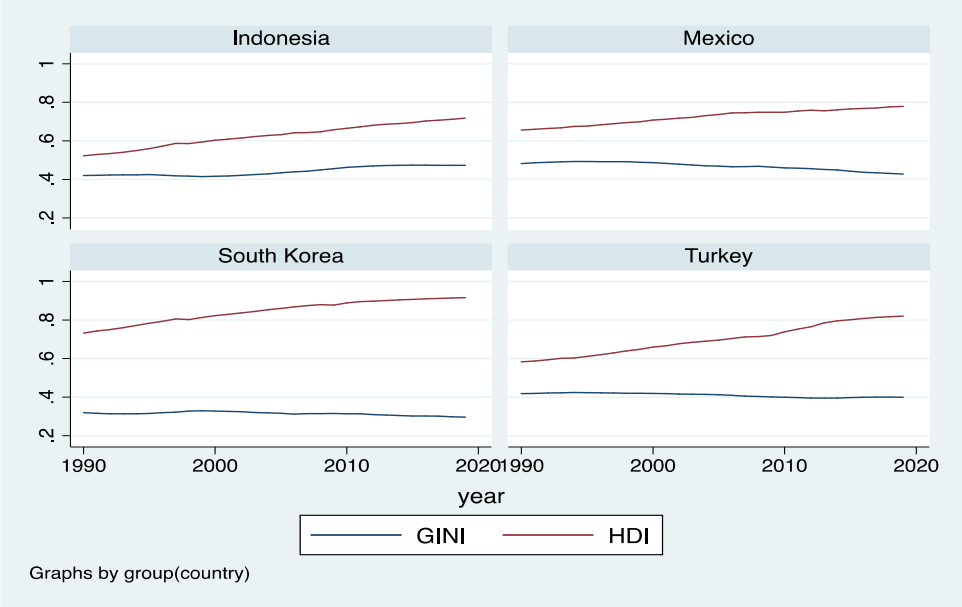

Figure 1. Economic Development and Income Distribution in MIST Countries (1990-2022)
Source: Compiled from Harvard University and United Nations data.

In the study, first of all, the empirical literature explaining the relationship between economic development and income distribution will be discussed. Next, the data and method part will be presented. Lastly, the findings of the econometric analysis will be evaluated.

2. Literature Review

The relationship between economic growth and income distribution is a frequently discussed topic in the economics literature. It is seen that the concept of economic growth is discussed together with the concepts of income distribution, inequality in income distribution, human development index, financial development and rural development (Kılıç and Gökçeli, 2024; Batmaz et al., 2023; Opuala et al., 2023; Uche et al., 2024; Gonese et al., 2023; Wang et al., 2023). Income inequality and economic development have always been an important topic of debate for both economists and policymakers. These two concepts are also critical for economic sustainability. In the literature, there are many studies on the relationship between economic development and income inequality. In this context, the theory of economic development by Kuznets (1955) is recognized as one of the pioneering studies making a significant contribution to the literature on inequality and development. According to this hypothesis, known as the Kuznets curve, income inequality increases in the initial stages of economic development, while inequality tends to decrease when a certain level is reached. This theory has been one of the main approaches aiming to explain inequality dynamics in development processes.

After Kuznets (1955), studies similar to the framework of our study have investigated the relationship between economic development and income distribution using different methods.

Deininger and Squire (1998) explain the relationship between economic growth and income inequality through political processes. According to this approach, the median voter shapes income distribution policies through political mechanisms. Tribble (1999), on the other

hand, expresses this relationship with two turning points and defines the Kuznets curve as an S-curve rather than an inverted-U shape. While the first turning point represents the transition from the agricultural sector to the industrial sector at lower levels of economic development, the second turning point represents the transition from the industrial sector to the service sector at a more advanced stage of development. In this framework, the cubic function is used to explain the S-curve hypothesis. In order to test the Kuznets hypothesis, US time series data for the period 1947-1990 were analyzed. The results showed that the relationship between income inequality and economic growth is consistent with the S-curve hypothesis. Accordingly, while income inequality increases in the initial stages of economic development, it then tends to decrease and increases again with advanced development. Using a different methodology, List and Gallet (1999) also obtained findings supporting this S-curve hypothesis. Human development stands out as both a tool and the ultimate goal of the development process. In this context, human development contributes to the formation of human capital by increasing the levels of knowledge, skills, creativity, and productivity of individuals. This approach refers to the empowerment of individuals to take an active role in improving their living conditions, i.e. the realization of human potential through the expansion of their capabilities and opportunities for choice. The main objective of human development within a macroeconomic policy framework is to ensure that economic growth is directly reflected in the living standards of individuals.

Although economic growth is recognized as a necessary condition for human development, it is not sufficient on its own. Therefore, it is emphasized that the focus should not only be on quantitative growth but also on qualitative growth. The human development approach aims to bring together economic growth and the quality of life of individuals, noting that the relationship between economic growth and human development is not direct. In this framework, improving the capabilities of individuals, increasing their participation in economic growth, and assessing the extent to which they benefit from the gains derived from the growth process are among the main priorities of human development (Griffin and McKinley, 1994). Different studies have examined the relationship between human development and income inequality in various dimensions. Özden et al. (2022) analyzed the relationship between income inequality, human development, urbanization, and female employment rate in MIST countries between 1990 and 2019 using the support vector regression method and found that these variables had improving effects on income distribution. Similarly, Avcı (2022) analyzed the effects of income inequality, education, and health expenditures on human development in Turkey for the period 2000-2019. The findings show that education expenditures and income inequality do not have a significant effect, while health expenditures have a negative impact on human development. Ngoc and Hai (2022), in their analysis with the wavelet method for the period 1978-2019 in Singapore, found that human development decreases income inequality at medium frequency, but developments in tourism have an increasing effect on inequality. Bucak and Saygılı (2022) examined the relationship between trade openness, income inequality, and HDI in the 2004-2016 period covering 15 OECD countries and found that an increase in human development reduces income inequality according to the results of panel cointegration analysis. In addition, causality analysis showed that there is a unidirectional causality from human development to income inequality.

In recent years, the concept of economic development has been discussed with the concept of sustainable development, carbon footprint, ecological transformation and technological development (Banna et al., 2020; Cetin et al., 2021; Mahalik et al., 2021; Wang et al., 2021;

Afshan and Yagoop, 2022; Handayani et al., 2022; Hossain et al., 2022; Khanal et al., 2022; Li et al., 2022; Mehrjo et al., 2022; Uzar and Eyuboglu, 2023; Abate et al., 2024; Jula et al., 2024).

In the literature, technological development is accepted as one of the most important determinants of income inequality. In the studies, it is seen that many variables are included in the model as a proxy for technological development. Acemoglu et al. (2001) found that skill-based technical change had a direct positive effect on income inequality. Mehic (2018) found that industrial employment negatively affects income inequality and that middle-income people are the biggest burden in terms of inequality increases. Le et al. (2020) and Lee et al. (2022) found that industrialization has a negative effect on income inequality. Kharlamova et al. (2018) revealed that technological development reduces income inequality in some countries and increases it in others, and they determined that this effect varies according to the size of the country and the level of development. In the academic literature, studies on the relationship between sustainability, carbon emissions, energy consumption, and economic development show that these factors interact with each other. In general, it is emphasized that economic development leads to an increase in energy consumption, which in turn increases carbon emissions and has negative impacts on environmental sustainability. However, the use of renewable energy sources and the adoption of energy efficiency technologies are considered important strategies that contribute to both reducing carbon emissions and achieving sustainable development goals (Akadiri et al., 2020; Chandio et al., 2021; Khan et al., 2021; Ali, 2022; Shakoor et al., 2023). Moreover, some studies reveal that there is a bidirectional causality relationship between energy consumption and economic growth, suggesting that energy policies should be designed without adversely affecting economic growth. In this context, the transition to renewable energy, reduction of carbon footprint, and transition to a green economy is suggested as a critical pathway to ensure both environmental sustainability and support long-term economic development (Tangworachai et al., 2023; Artekin and Kalayci, 2024).

A review of the literature on the MIST countries (Mexico, Indonesia, South Korea, Turkey), which constitute the sample of the study, reveals that there are studies that address financial markets in MIST countries, focus on stock price forecasting, and address the link between energy consumption and sustainable economic development (Pao et. al., 2014; Danis et. al., 2015; Gemici and Polat, 2018; Sevinç, 2022). A review of the literature on the MIST countries (Mexico, Indonesia, South Korea, Turkey), which constitute the sample of the study, reveals that there are studies that address financial markets in MIST countries, focus on stock price forecasting, and address the link between energy consumption and sustainable economic development (Pao et. al., 2014; Danis et. al., 2015; Gemici and Polat, 2018; Sevinç, 2022). We believe that this study will contribute to the literature by analyzing the relationship between economic development and income distribution in MIST countries.

3. Data and Methodology

3.1. Data

In this study, the relationship between human development and income inequality was examined for MIST countries (Mexico, Indonesia, South Korea and Türkiye) between 1990 and 2022. In regressions, economic development is measured by Gross Domestic Product per capita and also by the HDI in the literature. Gross Domestic Product and HDI are explained in this

section. Gross Domestic Product: It is measured based on different approaches such as production, expenditure and income. According to the production approach, it is the monetary value of final goods and services produced in a country at a given time. HDI: It is used to measure development. HDI is a composite index measuring human development, which is a long and healthy life, knowledge, and a good standard of living. The main explanatory variable is GINI. Industry value added (IND) and urbanization (URB) are included in the model as instrumental variables. Definitions and resources of the variables are given in Table 1 and descriptive statistics in Table 2 below.

Table 1. Definitions and Resources of Variables

Variable	Definition	Resource
GINI	GINI coefficient	Standardized World Income Inequality Database
HDI	Human development index	United Nations
IND	Industry value added (current USD)	World Bank, World Development Indicators
URB	Urban population	World Bank, World Development Indicators

The number of observations is 132 for all variables. The minimum value of the HDI variable is 0.526, the maximum value is 0.929 and the mean value is 0.734. The minimum value of the GINI variable is 0.301, the maximum value is 0.512 and the mean value is 0.416. The minimum of the IND variable is 4.18e+10 and the maximum is 5.90e+11. The URB variable has a minimum value of 3.17e+07 and a maximum value of 1.60e+08.

Table 2. Descriptive Statistics

Variable	Observation	Mean	Std. Dev.	Min	Max
GINI	132	0.4160682	0.0580817	0.301	0.512
HDI	132	0.7349091	0.0995522	0.526	0.929
IND	132	2.50e+11	1.51e+11	4.18e+10	5.90e+11
URB	132	6.93e+07	3.31e+07	3.17e+07	1.60e+08

3.2. Econometric Methodology

As in time series, the stationarity of variables is important in panel data analysis. In order for the analysis results to be consistent and unbiased, the series must be made stationary. Unit root tests are applied to test the stationarity of the series. In the analysis, Levin et al. (2002) panel unit root test (LLC) was preferred. The LLC panel unit root test assumes that all units have the same autoregressive parameter (ρ). In addition, the constant and trend parameters vary by unit. The LLC test is based on Augmented Dickey Fuller (ADF) regression;

$$\Delta Y_{it} = \rho Y_{it-1} + \sum_{L=1}^{\rho_i} \theta_{iL} \Delta Y_{it-L} + \alpha_{mi} d_{mt} + \varepsilon_{it} \qquad m = 1, 2, 3 \tag{1}$$

where d_{mt} represents the vector of deterministic variables and a_{mi} represents its parameters. The null hypothesis of the test is established as "panels contain unit roots". If the t-statistic value is

greater than the table value, the null hypothesis is rejected and the series is accepted to be stationary.

After the panel unit root test, the relationship between the variables is estimated. After the panel unit root test, the relationship between the variables is estimated. Since some of the variables are stationary at the level and some become stationary when their first differences are taken, the panel ARDL method can be applied.

The determinants of GINI in MIST countries are assessed with the panel ARDL framework. The following estimators are used in the long-term ARDL models: the DFE (dynamic fixed effect) estimator (Weinhold, 1999) and the PMG (pooled mean group) estimator (Pesaran et al., 1999). The PMG estimator restrains the long-term coefficients to be the same but allows slope coefficients and short-term coefficients to vary across groups. The general ARDL (p, q1,…,qk) can be derived as an error correction estimator that captures short- and long-term effects;

$$\Delta GINI_{i,t} = ECT_{i,t} + \sum_{j=1}^{p-1} \vartheta_j^i \, \Delta GINI_{i,t-j} + \sum_{j=0}^{q-1} \theta_j^i \Delta X_{i,t-j} + \varepsilon_{i,t} \qquad (2)$$

i and t in Equation (5) represent the unit and time dimensions, respectively. Δ is the first difference operator and ECT is the error correction term. Xi,t is a vector of the independent variable (HDI, IND, and URB), ϑ_j^i and θ_j^i are the dependent and independent variable short-run coefficients, respectively. On the other hand, $\varepsilon_{i,t}$ represents the error term.

4. Findings

First, a panel unit root test was applied to test the stationarity of the variables. Table 3 reports the panel unit root test results. According to the findings, GINI and URB have a unit root process at the level but become stationary at the first difference. This indicates that they are integrated of I(1) process. HDI and IND variables are stationary at level I(0).

Table 3. Levin, Lin and Chu Test Results

Variable	Level		First Difference	
	Constant	Constant and Trend	Constant	Constant and Trend
GINI	0.2430	-1.2470	-6.6944	-5.5889
	(0.5960)	(0.1062)	(0.0000)***	(0.0000)***
HDI	0.6377	-1.6820	-3.0982	-2.1038
	(0.7382)	(0.0463)**	(0.0010)***	(0.0177)**
IND	-0.4423	-1.7710	-4.3454	-3.4114
	(0.3291)	(0.0383)**	(0.0000)***	(0.0003)***
URB	-1.2869	-0.9990	-1.6974	-1.9553
	(0.0991)*	(0.1589)	(0.0448)**	(0.0253)**

Since the variables are stationary at different degrees, the panel ARDL approach is adopted in this study. The panel ARDL approach (DFE and PMG) is more appropriate than traditional cointegration techniques because the dependent and independent variables are a mixture of I(0) and I(1) (Pesaran et al., 2001). The Hausman test was used to determine the estimator. According to the Hausman test results, the PMG estimator outperforms the DFE estimator. Table 4 displays the ARDL test results.

Since the ECT coefficient is statistically significant, it is understood that there is a stable long-term relationship between GINI and the independent variables. The findings reveal that HDI is negatively and URB is positively correlated with GINI, with a statistical significance level of 1%. IND does not have a significant coefficient.

Table 4. Panel ARDL Estimations

Variable	DFE	PMG
ECT	-0.0756582 (0.085)*	-0.3169646 (0.025)**
HDI	-0.027498 (0.950)	-0.1937699 (0.007)***
IND	-1.44e-13 (0.531)	4.69e-14 (0.410)
URB	1.55e-09 (0.210)	1.40e-09 (0.008)***
C	0.0368552 (0.219)	0.1641865 (0.045)**
DFE vs PMG	0.15 (0.7022)	
Unit	4	
Observation	124	

Note: ***, **, * denote the statistical significance at 1%, 5% and 10% levels, respectively.

5. Conclusion

The linkage between economic development and income distribution is frequently discussed in the economics literature. Especially in developing countries, the question of how income distribution is affected as the level of economic development rises frequently comes to the fore. Some of the studies have argued that economic development has a positive effect on income distribution, while others have concluded that it has a negative effect.

When the literature is examined, it is seen that there are many studies on the Kuznets hypothesis and most of these studies measure economic development with gross domestic product. In this study, economic development is measured by Gross Domestic Product per capita and economic development is also measured by HDI.

In the study, MIST countries were taken as samples in order to analyze the relationship between economic development and income distribution. The common features of these four countries are that they have a large population, have a GDP equivalent to more than 1% of the global economy, and are members of the G-20. Utilizing the MIST countries during the period 1990-2022 and the ARDL panel approach, this study explores the nonlinear relationship between economic development and income inequality. Also, IVA and URB are included in the model as control variables. Since industrial development is also an important determinant of income inequality, the IND variable is also included in the model as a control variable. In this context, the aim of the study is to provide a comprehensive analysis of the relationship between economic development and income inequality.

The study reveals first that economic development reduces income inequality. Second, the increase in industrialization, which is an indicator of technological development, increases income inequality. The findings of the study offer important implications for policy formulation.

Increasing the level of economic development in MIST countries can help reduce income inequality. Considering that economic development has three pillars, it is important to increase education, health, and economic growth efforts to reduce income inequality. On the other hand, industrialization should reassess its claim in the context of income inequality. Thus, policymakers can stimulate renewables while compensating for losses. In addition, governments can offer subsidies for non-renewables to prevent a dual economy. Finally, measures can be taken to increase the qualifications of the unskilled workforce in order to prevent the dual structure created by industrialization. Policymakers can limit the negative effects of technology on unskilled workers through processes such as vocational qualification training and orientation programs.

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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EXPLORING THE IMPACT OF ECONOMIC GROWTH AND ENERGY CONSUMPTION ON ENVIRONMENTAL POLLUTION IN THE TR90 REGION: AN INSIGHT FROM THE MMQR APPROACH

TR90 Bölgesinde Ekonomik Büyüme ve Enerji Tüketiminin Çevre Kirliliğine Etkisinin Araştırılması: MMQR Yaklaşımından Bir Bakış

Vildan YAVUZ AKINCI[*], Korkmaz YILDIRIM[**] & Tunahan HACİİMAMOĞLU[***]

Keywords:
Sustainable Development, Environmental Pollution, Energy Consumption, Environmental Kuznets Curve, TR90 Region.

JEL Codes:
O44, Q00, O13.

Abstract

Governments primarily face the basic conundrums that arise from balancing environmental concerns with economic growth. In this content, since most research focuses on the cases of countries or groups of countries, a significant gap exists in how economic growth and energy consumption influence environmental pollution processes at the regional or provincial level. This study is the first to investigate the effects of energy consumption and economic growth on environmental pollution in the TR90 region of Türkiye (including the provinces of Artvin, Giresun, Gümüşhane, Ordu, Rize, and Trabzon) for the years 2007–2021 in the framework of the Environmental Kuznets Curve (EKC) hypothesis. This study utilizes the innovative Method of Moments Quantile Regression (MMQR) approach to investigate these effects. The MMQR results support the EKC hypothesis, which contends that environmental pollution rises in the early stages of economic growth but then declines as growth levels reach a turning point. Furthermore, the results demonstrate that increasing energy consumption exacerbates environmental pollution in the TR90 region.

Anahtar Kelimeler:
Sürdürülebilir Kalkınma, Çevre Kirliliği, Enerji Tüketimi, Çevresel Kuznets Eğrisi, TR90 Bölgesi.

JEL Kodları:
O44, Q00, O13.

Öz

Hükümetler öncelikli olarak çevresel kaygıları ekonomik büyümeyle dengelemekten kaynaklanan temel açmazlarla karşı karşıyadır. Bu konuda çoğu araştırma ülke veya ülke grupları vakalarına odaklandığından, ekonomik büyümenin ve enerji tüketiminin bölgesel veya il düzeyinde çevre kirliliği süreçlerini nasıl etkilediği konusunda önemli bir bilimsel boşluk vardır. Bu çalışma, 2007-2021 yılları arasında Türkiye'nin TR90 bölgesinde (Artvin, Giresun, Gümüşhane, Ordu, Rize ve Trabzon illerini kapsayan) enerji tüketimi ve ekonomik büyümenin çevre kirliliği üzerindeki etkilerini Çevresel Kuznets Eğrisi (EKC) hipotezi çerçevesinde araştıran ilk çalışmadır. Bu çalışma, bu minvalde yeni Momentler Kantil Regresyonu Yöntemi (MMQR) yaklaşımı kullanmaktadır. MMQR sonuçları, çevre kirliliğinin ekonomik büyümenin erken evrelerinde arttığını ancak büyüme seviyeleri bir dönüm noktasına ulaştığında azalmaya başladığını ileri süren EKC hipotezini desteklemektedir. Ayrıca, sonuçlar artan enerji tüketiminin TR90 bölgesinde çevre kirliliğini olumsuz şekilde etkilediğini göstermektedir.

[*] Asst. Prof. Dr. Recep Tayyip Erdogan University, Faculty of Economics and Administrative Science, The Department of Economics, Türkiye, vildan.yavuz@erdogan.edu.tr
[**] Assoc. Prof. Dr. Recep Tayyip Erdogan University, Faculty of Economics and Administrative Science, The Department of Political Science and Public Administration, Türkiye, korkmaz.yildirim@erdogan.edu.tr, (Corresponding author)
[***] Assoc. Prof. Dr. Recep Tayyip Erdogan University, Faculty of Economics and Administrative Science, The Department of Economics, Türkiye, tunahan.haciimamoglu@erdogan.edu.tr

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1. Introduction

In the 21st century, the impacts of human activities on nature have reached a point where they pose serious threats to all living organisms (IPCC, 2021). However, even today, some believe that global environmental concerns are excessively exaggerated and that some of them such as the climate change crisis are utilized as an instrument to impose political, economic, and social changes for the benefit of certain groups. They also argue that data on changes to the global environmental regime are limited to worst-case scientific possibilities. However, as the Global Resource Outlook report's succinct and unambiguous message makes clear, "It should have already been understood that the issue is not whether a transformation towards sustainable resource consumption and production on a global scale is necessary, but how this can be achieved urgently." (UNEP, 2024). Further, the main point to comprehend is that the main forces straining biocapacity are population growth and, particularly, economic growth (EGr). To determine the extent of this pressure, changes in global environmental and economic conditions throughout the last 50 years are enough to be observed (see UN Environment, 2019). The scientific evidence on the severity and urgency of global environmental issues also necessitates rapid actions towards building a sustainable future. Therefore, the pressures created by EGr and population increases require the immediate implementation of sustainable resource management and environmental protection strategies.

EGr, energy consumption (ECon), and population increase are considered key catalysts in the transformation of the global environmental regime (UN Environment, 2019: 6). For instance, as stated in the United Nations reports, the world population, which was 2.5 billion in 1950, reached 8 billion in 2022 and is estimated to be 8.5 billion in 2030, 9.7 billion in 2050, and approximately 10.4 billion in 2100 (UNDESA–PD, 2022). Similarly, EGr is a fundamental dilemma that leads to higher levels of use of natural resources and damage to ecological systems. Indeed, considering global EGr, the fact that GDP per capita worldwide increased by 2.4 times from 1970 to 2024, surpassing $11,600, which indicates that significant inequalities continue at the regional and national level (see UNEP, 2024: 22). In this context, household consumption is responsible for approximately 60% of the overall environmental effect, and about 30% of total carbon dioxide (CO_2) emissions are attributed to the production of globally traded goods (UNEP, 2010). All these findings reveal the extent of the adverse changes that EGr has caused in the global environmental regime. At this point, governments and other actors are trying to overcome the "paradoxical" situation between EGr and ecological constraints with a "sustainability" prescription.

Similarly, among the factors influencing environmental pollution (EPol) and EGr, patterns of energy production and consumption are particularly noteworthy. Energy is the cornerstone of EGr, and electricity consumption emerges as a critical infrastructure element for socioeconomic development (Ghosh, 2002: 125). Electricity, which is a secondary and most commonly used energy source, is seen as a solution for countries to cope with economic and social challenges and is regarded as a necessity for development (Wolde–Rufael, 2006: 1106). With industrialization processes, electricity has become a fundamental factor in production through technological advancements. EGr has caused production to change over time in favor of the service industry, and therefore, electrical energy has become a necessary consumption good for both direct and indirect production as well as for maintaining service quality.

Regarding all of these matters, in 2015, the 193 UN member countries unanimously accepted the 2030 Agenda for Sustainable Development, which mandates collaborative efforts to protect existing natural resources, prevent EPol, and secure that the needs of both current and future generations are met (UN, 2015). The "United Nations Sustainable Development Goals" (SDGs) include a set of objectives that are closely linked to both EGr and environmental sustainability, such as 1. (no poverty), 2. (no hunger), 7. (affordable and clean energy), 11. (sustainable cities and communities), 12. (Responsible consumption and production), and 13. (climate action). In this context, governments, businesses, civil society organizations, individuals, and all other stakeholders must cooperate to deal with poverty and hunger effectively, promote economic development, reduce inequalities, address EPol and climate change issues, and ensure peace and justice in all their initiatives (Sánchez Gassen et al., 2018: 8). At the same time, as with this regulation and other global initiatives formally adopted by national governments, an adaptation or localization process is necessary for the implementation (see Valencia et al., 2019). So, SDGs can be successfully achieved through the capacity of regional and local actors to adapt the established targets to their specific conditions (Bardal et al., 2021).

The main motivation of this research can be explained as follows: When examining the relationship between variables in the studies, it is assumed that conclusions valid at the national level will also be valid for each region. However, the assumption that "what is good for the whole must be good for each part" often may not hold true (Žiković et al., 2020: 1). Each region has unique geographical and climatic conditions, agricultural characteristics, natural resources, and economic structures. Therefore, the effect of ECon and EGr on EPol may vary from region to region, depending on local dynamics. For instance, one region may be rich in energy resources, while another may be scarce. For this reason, rather than generalizing, it is more realistic to consider the specific dynamics of each region in the environment–economy–energy relationship. However, previous studies generally examined the effect of economic factors and ECon on EPol through policies, strategies, and plans at the national level or for specific country groups. However, research on actions at the regional and local scales is still insufficiently developed, whereas how global goals will be implemented at the local level is an important question. In this context, in Türkiye, over the past 20 years, it has been observed that EGr and ECon have increased along with EPol, and regional disparities have become more significant and visible. Therefore, investigating the connection between EGr, ECon, and EPol in the TR90 region is also expected to help determine appropriate environmental and energy policies, as well as economic strategies specific to this region.

Türkiye is divided into 12 sub-regions at Level–1, 26 sub-regions at Level–2, and 81 provinces at Level–3 based on the Turkish Statistical Institute's (TURKSTAT) Nomenclature of Territorial Units for Statistics (NUTS) classification system. TR90 region is one of 26 Level-2 subregions and involves the provinces of Trabzon, Ordu, Giresun, Rize, Artvin, and Gümüşhane. In the Socio-Economic Development Ranking Surveys (SEGE) (2017), the socio-economic development ranking of the TR90 region provinces is as follows: Trabzon is ranked 26th with an index value of 0.389, Rize is ranked 36th with an index value of 0.174, Artvin is ranked 49th with an index value of –0.235, Giresun is ranked 53rd with an index value of –0.323, Ordu is ranked 60th with an index value of –0.486, and Gümüşhane is ranked 64th with an index value of –0.623 (Ministry of Industry and Technology, 2017).

In light of the Environmental Kuznets Curve (EKC) hypothesis, the study investigates the effect of ECon and EGr on EPol in the TR90 region. In this regard, the reasons for choosing the

TR90 region as the sample for the present study can be explained as follows: The TR90 region, due to its ecological richness with diverse flora and fauna, has recently seen a rapid increase in investments, particularly in hydroelectric power plants (HPPs). The region is rich in ecological diversity and abundant water resources. This region, known for its rivers and streams, contributes to regional and national clean energy supply through the construction of dams and HPPs. However, Planning and inspection deficiencies have caused significant challenges for environmental sustainability in the region. Among the primary causes of environmental issues in rural regions are irregular building and conventional solid waste management. Another important concern in the region is the absence of adequate infrastructure facilities (DOKA, 2014; Yıldırım and Ayna, 2016). Furthermore, given the region's hydroelectric potential, the Eastern Black Sea Basin harnesses almost 20% of Turkey's energy potential (see Kankal and Akçay, 2019: 896). Nonetheless, the region garners attention for its ecological significance, including land composition, water resources, soil quality, and biodiversity of forests and flora, alongside the ecological issues arising from the proposed hydropower plant in the basin and increasing the local communities concerns (Atabey and Gürdoğan, 2015: 58–59). Moreover, the TR90 region possesses significant ecotourism potential owing to its diverse flora and fauna, topographical features, and cultural values (Kaya and Yıldırım, 2020). We must also consider the potential future ramifications of this circumstance. The region attracts attention due to changes in climatic factors such as temperature and precipitation. As the area with the highest annual precipitation rate in the country, it frequently experiences disasters like erosion and flooding (Yılmaz et al., 2021). All of these findings highlight how critical it is to implement the required measures for the medium– and long–term EGr of the TR90 region. Examining how EGr and energy use have affected EPol over the past 15 years is anticipated to yield important policy recommendations in this regard.

This study makes substantial theoretical and practical contributions to the literature. First, regarding the EKC, this study is the first to consider how EGr and ECon affect EPol in the TR90 region. Second, it was discovered that national or group of countries' assessments of the links between EGr, ECon, and EPol were made in general, whereas regional or provincial–level analyses are inadequate. Yet, regarding resource consumption, environmental effects, and economic structure, subnational regions may differ greatly from one another. For instance, some of the regional economies are heavily reliant on industry, whereas those of others are centered on services or agriculture in Türkiye. Third, this study adopts the novel Method of Moments Quantile Regression (MMQR) approach as a modern and robust method addressing issues of heteroscedasticity, endogeneity, and conditional distribution rather than traditional estimation methods. On the other hand, traditional test techniques may lead to untrustworthy and biased inferences.

The study's subsequent sections have the following structure: Section 2 reviews the literature in the context of the conceptual and theoretical effects of electricity consumption and EGr on environmental degradation. Section 3 presents the data and methodology, while Section 4 addresses the findings and discussions. Section 5 also presents the conclusion and policy recommendations.

2. Literature Review

The nexus between EGr, Econ, and EPol has become a critical area of research due to the growing of environmental concerns and the commitment to SDGs. These linkages are explored from a variety of theoretical and empirical perspectives, characteristically under the following headings.

2.1. Theoretical and Conceptual Basis of the Study

The political and administrative initiatives or strategies taken to promote quicker EGr are the main reason for changes in the global environmental regime in the 21st century. In fact, there has been a notable and concerning increase in population and EGr in recent years, which has raised demand for global resources and intensified environmental strain (Nasrollahi et al., 2020: 1105). The rapid continuation of EGr on a global scale has exacerbated environmental problems. Thus, it is crucial to coordinate EGr with environmental quality, as this is a pressing strategic problem (Rao and Yan, 2020: 39442).

Previous studies addressing the relationship between ECon and environmental degradation address energy use as a factor that increases EPol. Indeed, the level of ECon is almost considered an indicator of the level of EPol (see Ibekilo et al., 2023; Sumaira and Siddique, 2023). Furthermore, previous studies generally agree that EPol originates from human activities (Fatima et al., 2021). Activities such as energy production and consumption are particularly prominent examples of anthropogenic effects on nature. While energy is considered the fundamental driving force of societal and economic development, the types of energy used, especially in terms of carbon emissions, can be primary determinants of environmental degradation (Armeanu et al., 2019). In this regard, governments are diligently implementing a range of innovative initiatives and practices to lessen environmental damage such as using renewable energy sources (Xiong and Xu, 2021).

Alongside steady economic growth, the global energy supply and consumption have lately increased. Rising ECon has also been influenced by emerging economies' attempts at EGr. The world's ECon has been rising noticeably due to rapid population growth, urbanization, and increased economic activity. On the other hand, this increase, particularly with the widespread use of non–renewable energy sources such as coal, natural gas, and oil, has had serious negative impacts on the environment. Even though economic and social development are desired by governments to be sustainable, a large-scale ecological disaster threat has emerged in many countries (Zhang et al., 2017: 365). However, to prevent any negative impacts on industrial production due to the scarcity of electricity, it is very important for policymakers to ensure the security of electricity supply and to plan sufficient production capacity to meet industrial electricity demand, which necessitates more investment in the energy sector (Shiu and Lam, 2004: 47). Energy efficiency may boost economic gains and the economy's overall competitiveness in addition to new investments. In general, the pattern of EGr is depended on a nation's energy structure, which in a sense might represent the degree of economic development of that nation. Thus, without a shift in the energy system, there will be no incentive for sustained transformation in the social and economic spheres, and the foundation for development would no longer be viable. In sum, today's world, constrained by resources and the environment, is engaged in a tough struggle to transition from high–carbon to low–carbon ECon (Zhang et al., 2017: 354).

In light of these elucidations, the theoretical framework of this study is based on the EKC hypothesis developed by Grossman and Krueger (1991, 1995). This hypothesis follows a similar analogy to the Kuznets curve, which assumes an inverted U–shaped relationship between income and income inequality, as proposed by Kuznets (1955) (Andreoni and Levinson, 2001: 269; Dinda, 2004: 431; Sulemana et al., 2017: 134). In this regard, studies examining the environmental effects of energy use and EGr at global and national levels generally rely on the EKC hypothesis. It assumes an inverted U–shaped relationship between income and EPol. A theoretical overview of this study is also seen in Figure 1, which denotes the relationship between EPol, ECon, and EGr.

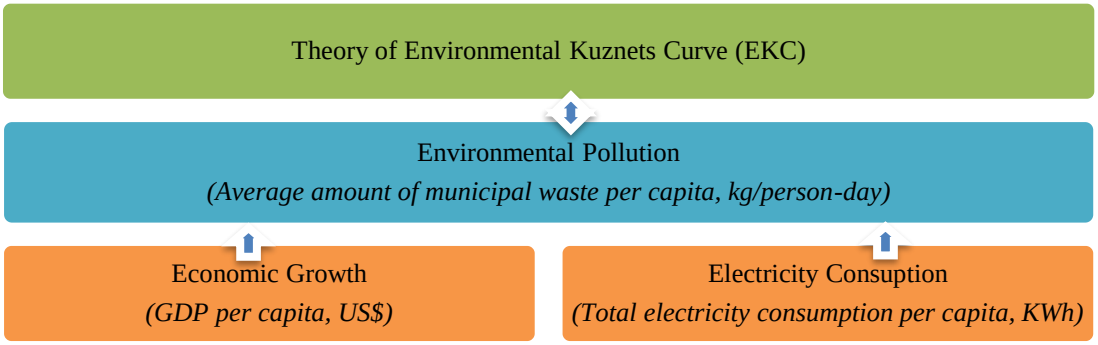

Figure 1. Theoretical Summary

The relationship between environmental deterioration, economic conditions, and economic growth is a significant study focus for several scholars and policymakers. So, analyzing the environment–economy–energy nexus accurately is essential for the research fields of sustainable development pathway.

2.2. Economic Growth and Environmental Pollution Nexus

Studies examining the impact of EGr on environmental quality were carried out using various country samples, datasets, and analytical methods. A simple search using the keywords "EGr" and "EPol" in the Web of Science database reveals that 210 academic publications have addressed this topic. Notably, 75% of these studies were published between 2014 and 2024, indicating a growing concern over the environmental constraints associated with economic developments in recent years. 80% of those of which are research articles, with 57% categorized under "environmental science or environmental studies" and 27% under "economics". This trend reflects increasing global and academic concerns about the risks and threats posed by changes in environmental systems, especially those related to climate change.

Previous research has analyzed and evaluated various groups of countries such as New Industrialized Countries (NICs), Group of Seven (G7), BRICS (Brazil, Russia, India, China, South Africa), and OECD (The Organization for Economic Co-operation and Development). Considering that these divisions are usually predicated on political and economic standards, it is ignored that there are notable variations across the nations that comprise each group. Due to the varying methods of defining and reporting environmental variables, concerns about the reliability and validity of the findings have emerged, particularly in developing countries where data

collection and methodological issues can lead to inconsistent results. However, this study uses the term "region" to refer to sub–regions that share similar geographic and economic conditions in a single country, rather than a generalized definition referring to groups of countries. This approach allows for the analysis of comparable data collected under similar political and administrative structures, which is crucial for getting reliable and consistently results.

Studies inquiring at how EGr affects ecological constraints frequently employ a variety of datasets and methodologies in their empirical evaluations at the national level. In this regard, Nasir et al. (2019) reported a direct correlation between EGr, financial development, foreign direct investment (FDI), and environmental degradation among ASEAN–5 countries (Association of Southeast Asian Nations). Similarly, Bakirtas and Cetin (2017) used a panel vector autoregressive (PVAR) model to investigate the validity of the EKC hypothesis in MIKTA countries (Mexico, Indonesia, South Korea, Türkiye, and Australia) between the years 1982 and 2011. Their empirical results, however, did not support the EKC hypothesis. Ali et al. (2023) also addressed the connection between EGr, globalization, renewable energy, and non–renewable energy in South American countries between 1995 and 2020. Given their results, while EGr increases EPol, using renewable energy reduces EPol in both the short and long run. Ali et al. (2020) also studied the relationship between environmental degradation, EGr, and energy innovation in 33 European countries for the period between 1996 and 2017. These authors also reported a significant inverse U–shaped relationship between GDP and environmental degradation, supporting the EKC hypothesis. Alike Yilanci and Ozgur (2019) analyzed the relationship between income and pollution in G7 countries (Canada, France, Germany, Italy, Japan, the UK, and the USA) using data for the years between 1970 and 2014. Their results also support the EKC hypothesis in Japan and the USA but do not indicate a U–shaped relationship between ecological footprint and GDP in other countries. Sulemana et al. (2017) tested the validity of the EKC hypothesis for CO_2 and particulate matter (PM10) emissions in African countries and high–income OECD countries as well. The results supported the EKC hypothesis for both CO_2 and PM10 emissions in these regions.

On the other hand, national–level studies generally align with the results reported by country–group studies regarding the impacts of EGr on environmental quality. For example, Cai et al. (2020) explored the relationship between China's water pollution discharges, including wastewater, chemical oxygen demand, and ammonia nitrogen, and GDP per capita from the aspect of the EKC hypothesis. Their results demonstrate that the EKC types may be distinguished from one another based on characteristics or distinct tipping points. However, it is noticed that studies on the relationship between EPol and EGr often yield different results depending on the type of analysis and model used. For instance, Giovanis (2013) aimed to provide empirical evidence of a correlation between air pollution and income by analyzing social data from the "British Household Panel Survey" covering the years 1991 to 2009. While the results achieved from the Arellano–Bond GMM and logit models, which include fixed effects and all types of family income, strongly support the EKC hypothesis for the air pollutants, the fixed effects results of the research do not support the EKC hypothesis.

Studies exploring the associations between environmental degradation and EGr at the regional and urban levels have also increased recently, much like those conducted on a global and national scale. For instance, Song et al. (2008) examined the relationship between EPol and EGr by making use of city-scale data from China between 1985 and 2005. The results revealed that all three pollutants, contaminated water, gas, and solid waste, exhibited an inverted U–shape with

respect to per capita income levels. Similarly, Liu et al. (2019) investigated the impact of EGr and foreign direct investments on CO_2 emissions using provincial-scale data from China spanning from 1996 to 2015, integrating these factors into a unified framework. The results indicate a curvilinear relationship characterized by an inverted U–shape between EGr and CO_2 emissions. Moreover, Zhang et al. (2020) analyzed the association between EGr, energy usage, and the spatial distribution of environmental pollutants in 31 cities in China from 2008 to 2018 within the context of the EKC hypothesis. Their results similarly indicated a spatial relationship in China between industrial pollution, energy structure, and EGr, and that this relationship is distributed over several agglomeration regions. Stern and Zha (2016) also scrutinized the effects of income, convergence, and time–related factors on recent fluctuations in PM2.5 and PM10 particulate pollution levels in 50 Chinese cities. Their results reveal that EGr, convergence, and time collectively contribute to reducing pollution.

All in all, it is observed that at the regional level, the effects of EGr on EPol are determined by the complex interactions of various factors which may vary depending on the characteristics of the regional economic structure, industrial activities, and environmental regulations. The initial hypothesis of the research has been formulated based on these evaluations as follows:

H1: For the case of the TR90, the EKC hypothesis is valid.

2.3. Energy Consumption and Environmental Pollution Nexus

Many studies empirically examined the relationship between ECon and EPol. Particularly, the study carried out by Bekun et al. (2019) analyzed the relationship between consumption of renewable and non–renewable energy sources, carbon emissions, and EGr over the period from 1996 to 2014 for a specific group of EU–16 countries. Their study clearly demonstrated that using renewable energy helps lower CO_2 emissions, while EGr and using non–renewable energy increase carbon emissions. Analyzing the usage of renewable and non–renewable energy sources, Anwar et al. (2021) also scrutinized the relationship between ECon, income, and the environment in ASEAN countries. Their findings clearly support the EKC hypothesis, which states that rising non–renewable ECon causes rising CO_2 emissions, whereas rising renewable ECon causes falling CO_2 emissions in ASEAN countries. In addition, as for the political recommendations of the studies, Sarkodie and Adams (2018) emphasized the need for fossil fuel-rich countries to diversify their energy portfolios by incorporating renewable energy sources to reduce sensitivity to price fluctuations, promote environmental sustainability, and improve air quality. Similarly, Destek and Aslan (2020) highlighted the effectiveness of hydroelectric, biomass, and wind ECon in reducing carbon emissions in G7 countries by focusing on different types of renewable energy sources.

Governments and all other public and non–public actors aim to improve environmental quality by utilizing regulatory environmental policy tools. For instance, Yuan (2024) investigated the restrictive influence of EPol taxes on the level of energy usage, suggesting that technological advancements, optimization of industrial structure, and tax collection further enhance the restrictive impact of EPol taxes on ECon. Similarly, improvements in environmental regulations lead to positive outcomes in clean ECon and a long–term reduction in environmental degradation, such as CO_2 emissions (Zhang et al., 2022). Furthermore, Jiatong et al. (2023) used new econometric techniques to scrutinize the impacts of geopolitical risk, economic uncertainty, and

renewable source usage on the ecological footprint from 2000 to 2021, finding that only renewable energy use positively affects environmental quality.

Research on how ECon affects environmental deterioration has produced some notable results, particularly for developing and low–income countries. For instance, increased usage of fossil fuels like coal in these countries' ECon portfolios results in increased industrial carbon emissions (Chen et al., 2024). Some studies similarly showed that an increase in the proportional use of renewable energy in total energy sources expectedly results in a reduction in EPol (see Wang, 2019; Azam et al., 2021; Wang et al., 2022). Likely, Assi et al. (2021) examined the effects of five primary factors on renewable ECon in ASEAN+3 (Indonesia, Malaysia, Philippines, Singapore, Thailand, Vietnam + China, Japan, and Korea) economies between 1998 and 2018. These factors included financial development, EPol, innovation, economic freedom, and GDP per capita. They found that while environmental degradation and economic freedom have a negative relationship with the use of renewable energy, financial progress has no discernible impact on renewable ECon. Additionally, Nawaz et al. (2021) addressed the role of ECon in environmental degradation for South Asian economies as part of their political advice, arguing that these countries should concentrate on luring clean foreign investment and that the production of renewable energy is essential to halting climate change. So, based on the latest literature, the following research hypothesis was developed.

H2: Energy consumption increases environmental pollution and hampers the environmental quality in the case of the TR90 region.

There are still many remarkable gaps in the literature regarding the analysis of the relationships between environmental degradation, ECon, and EGr, in particular at the regional level. Within this scope, it is observed that the results vary depending on factors such as the period analyzed, the selected country or regional groups, and the preferred methodology. Furthermore, studies that commonly use traditional tests often tend to produce weak or biased results. To the best of our knowledge, no empirical study examining how ECon and EGr relate to EPol in any region of Türkiye by making use of the EKC hypothesis could be found. This study aims to bridge the gaps in the literature on regional studies by analyzing the relationships between EGr, ECon, and EPol in the TR90 region of Türkiye between 2007 and 2021 within the context of the EKC hypothesis, which is the inaugural research on that point.

3. Data and Methodology

3.1. Data and Model Specification

This study examines the effects of energy consumption and economic growth on environmental pollution in the TR90 region from 2007 to 2021 in the framework of the EKC. In this direct, environmental pollution (POL) is represented by the average amount of municipal waste per capita. The gross domestic product per capita represents economic growth (GDP), and the total electricity consumption per capita indicates energy consumption (ELC). GDPSQ refers to the square of GDP. Data for POL, GDP, GDPSQ, and ELC are obtained from the Turkish Statistical Institute (TURKSTAT, 2024). The logarithmic transformations of all the variables are computed in the analysis. Table 1 presents the definitions and essential information about the variables.

Table 1. Descriptions of the Variables

Variable	Acronym	Definition (Units)	Source
Environmental pollution	POL	Average amount of municipal waste per capita (kg/person-day)	TURKSTAT
Economic growth	GDP	GDP per capita (constant 2009 US$)	TURKSTAT
Squared economic growth	GDPSQ	The square of GDP per capita (constant 2009 US$)	TURKSTAT
Energy consumption	ELC	Total electricity consumption per capita (KWh)	TURKSTAT

Following the study carried out by Lean and Smyth (2010), the basic model of this study is specified as:

$$POL = f(GDP, GDPSQ, ELC) \quad (1)$$

Econometrically,

$$POL_{it} = \beta_0 + \beta_1 GDP_{it} + \beta_2 GDPSQ_{it} + \beta_3 ELC_{it} + \varepsilon_{it} \quad (2)$$

where, *i* and *t* refer to cross sections and time, respectively, while ε_{it} denotes error terms. Since economic activities trigger environmental damage, the efforts made to achieve a faster EGr cause an increase in EPol (Beckerman, 1995). Therefore, the GDP coefficient is expected to be positive $\left(\beta_1 = \frac{\partial POL}{\partial GDP} > 0\right)$. On the other hand, GDPSQ coefficient is expected to be negative $\left(\beta_2 = \frac{\partial POL}{\partial GDPSQ} < 0\right)$. In this context, the fact that β_1 coefficient is positive and significant, and β_2 coefficient was negative and significant confirms the validity of the EKC hypothesis (Dinda, 2004; Panayotou, 1997). In accordance with the aforementioned research, ECon is essential for sustainable development and environmental quality. However, fossil fuels account for approximately 82% of global ECon (British Petroleum, 2024). Therefore, electricity consumption relies mainly on fossil fuels on a global scale. This ECon pattern causes EPol to increase and threatens environmental sustainability (He et al., 2021). In this context, the ELC coefficient is expected to be positive $\left(\beta_3 = \frac{\partial POL}{\partial ELC} > 0\right)$.

3.2. Econometric Methodology

In panel data analysis, firstly, cross-sectional dependence (CSD) and slope heterogeneity (SH) should be addressed because, in panel data samples, the likelihood of countries/regions being significantly correlated or dependent might be high due to common shocks, unknown factors, and geographical interaction. For this purpose, ignoring CSD and SH tests could lead to biased and unreliable results, and it may cause ineffective and invalid inferences regarding the subject being analyzed. For these reasons, in the study, the CSD is tested using Pesaran's (2015) CD test, and the presence of SH is verified using Pesaran and Yamagata's (2008) Delta ($\tilde{\Delta}$ test) and Adjusted Delta ($\tilde{\Delta}_{adj.}$) tests.

Traditional unit root tests, such as IPS, LLC, and Hadri unit root tests, fail to address the issues of CSD and SH. Therefore, this study uses a second–generation unit root test capable of considering CSD and SH issues to determine the stationarity of the variables. In this context, this study utilizes the cross-sectionally augmented IPS (CIPS) unit root test proposed by Pesaran

(2007). The CIPS test also regards CSD and SH and performs robustly under both T (time dimension)>N (cross–unit) and N>T conditions. The CIPS test statistic assumes the null hypothesis (H_0) that the panel has a unit root, whereas the alternative hypothesis (H_A) states that the panel is stationary.

After checking the stationarity of the variables, the study conducted two different cointegration tests, considering CSD and SH. The first was the Durbin–Hausman (DH) cointegration test advanced by Westerlund (2008), and the second was the Lagrange multiplier (LM) cointegration test proposed by Westerlund and Edgerton (2007). As second–generation cointegration tests, both DH and LM address CSD issues using the bootstrap approach. The DH cointegration test provides the DH_{group} test statistic, which permits panel heterogeneity, and the DH_{panel} test statistic, which aligns with panel homogeneity. Similarly, the LM cointegration test provides a bootstrap test statistic that allows for CSD and an asymptotic test statistic that applies in the absence of CSD. The LM test examines the null hypothesis (H_0) that cointegration exists for all units against the alternative hypothesis (H_A) that cointegration exists for some units. In the DH test, DH_{group}, and DH_{panel} test statistics test the null hypothesis of no cointegration in all units, while DH_{group} test statistic's alternative hypothesis suggests cointegration for some units, and DH_{panel} test statistic's alternative hypothesis suggests cointegration for all units.

Traditional linear estimation methods such as OLS, FMOLS, and DOLS provide limited information as they focus on average relationships. In contrast, the quantile regression models developed by Koenker and Bassett (1978), and Koenker (2004) yield different estimation results for each quantile rather than average–based estimates. Among quantile-based approaches, the MMQR with fixed–effect method, newly established by Machado and Silva (2019), comes to the forefront as a modern and robust alternative. This study uses the MMQR approach to estimate long-run coefficients. MMQR offers advantages including addressing endogeneity issues, producing robust estimates, allowing for individual effects, and considering outliers. Moreover, MMQR is capable of providing efficient and consistent estimates in explaining nonlinear and asymmetric relationships. This approach accounts for covariance effects in conditional heterogeneity and measures multiple parameters at different quantiles.

We preferred the MMQR approach in this study due to its advantages and some of its main features. As a non–parametric method, MMQR effectively captures the impact of economic growth and energy consumption on distribution tails of environmental pollution at the regional level while also alleviating the issue of misspecification bias. Moreover, previous environment–growth–energy studies have widely used this approach, which is particularly suited to the significant macroeconomic and socio-economic structural changes in recent years and provide a more detailed insight than traditional methods.

In the study, the MMQR equation is formed as follows:

$$Q_Y(\tau/X_{it}) = \left(\alpha_i + \delta_i q(\tau)\right) + X'_{it}\beta + Z'_{it}\gamma q(\tau) \quad (3)$$

In Equation (3), X_{it} is the vector of GDP, GDPSQ, and ELC, which are explanatory variables, while $Q_Y(\tau/X_{it})$ show the quantile distribution (Y_{it}) of the dependent variable of POL.

This study's small sample size necessitates the use of alternative and reliable methods, in addition to MMQR, to enhance the reliability of the analysis results. For this reason, the study employs fixed effects with Driscoll–Kraay standard errors (FE–DKSE) and the Augmented Mean Group (AMG) estimators to gauge the robustness of the MMQR results. FE–DKSE is a very

reliable method against heteroskedasticity, autocorrelation, and CSD, while AMG is a powerful technique against SH and CSD.

4. Findings and Discussion

This study first estimated descriptive statistics that provide a priori information about the variables in order to scrutinize the association between EPol and explanatory variables for the TR90 region. So, Table 2 displays the results of descriptive statistics. GDP (GDPSQ) data has the highest maximum value, whereas data with the lowest minimum value is POL. The POL data also has the lowest standard deviation value. Chen–Shapiro (1995) normality test statistics demonstrate that all variables, except for POL, do have a non–normal distribution. The non–normal distribution of the data renders the utilization of quantile-based techniques a superior and more efficacious methodology for the analysis process.

Table 2. Results of Descriptive Statistics

Variables	Mean	Median	Max.	Min.	Std. Dev.	Chen–Shapiro Normality Test
POL	–0.068	–0.072	0.418	–0.462	0.175	–0.073
GDP	8.893	8.886	9.351	8.450	0.223	0.993**
GDPSQ	79.152	78.964	87.458	71.405	3.976	0.994**
ELC	7.403	7.419	7.882	6.480	0.284	0.995**

Note: ** represents statistical significance at 5% level.

Subsequently, in the study, slope coefficients were scrutinized by means of Delta ($\tilde{\Delta}$ test) and Adjusted Delta ($\tilde{\Delta}_{adj.}$) tests. Table 3 shows the results of the slope heterogeneity test. Given the $\tilde{\Delta}$ and $\tilde{\Delta}_{adj.}$ test results, H_0 assuming the homogeneity of the panel was rejected. Accordingly, it is observed that the panel was determined to be heterogeneous.

Table 3. Results of the Heterogeneity Test

Test	Test Statistic	p–value
$\tilde{\Delta}$ test	3.977***	0.000
$\tilde{\Delta}_{adj.}$ test	4.871***	0.000

Note: *** represents statistical significance at the 1% level.

CSD and unit root test results are presented in Table 4. Considering the CSD test outcomes, the H_0 assuming no–CSD is rejected, and it suggests the presence of CSD in all variables. This finding reveals that disturbances or shocks occurring in any city in the TR90 region spread and affect other cities. The study used the CIPS unit root test to ascertain the degrees of integration of the variables. Considering the CIPS test results, the H_0 assuming that the panel has a unit root at the level cannot be rejected, which suggests that all variables have a unit root at the level. However, it was found that all variables become stationary at their first difference.

Table 4. Results of Cross-Section Dependence Test and Unit Root Test

Variables	CD Test	p–value	CIPS Test	
			Level	1st difference
POL	2.263**	0.024	–1.609	–2.263*
GDP	14.999***	0.000	–1.387	–3.584***
GDPSQ	14.997***	0.000	–1.393	–3.579***
ELC	14.995***	0.000	–1.897	–3.625***

Note: ***, **, and * represent statistical significance at 1%, 5%, and 10% levels, respectively.

After determining the integration degrees of the variables, the study analyzed whether the variables are cointegrated in the long–run. The cointegration relationship was estimated using LM and DH tests. The bootstrap p-value should be considered for the LM test when there is the existence of CSD, whereas the DH_{group} test statistic should be regarded for the DH test when there is the presence of slope heterogeneity. Table 5 presents the results of the panel cointegration test. Given the bootstrap p-value in the LM test, the H_0 indicating the validity of cointegration cannot be rejected for the constant and, constant and trend models, indicating the presence of cointegration. Similarly, considering the DH_{group} test statistic, the H_0 assuming no cointegration is rejected, proving the existence of cointegration for the constant and, constant and trend models. Thus, both cointegration tests confirm the long–run cointegration relationship among variables.

Table 5. Results of The Cointegration Test

LM Test	Test Statistic	Asymptotic p–value	Bootstrap p–value
Constant	4.061	0.000	0.962
Constant and trend	13.317	0.000	0.539
DH Test	**DH_{group} Test Statistic**		**DH_{panel} Test Statistic**
Constant	–2.006**		–1.660**
Constant and trend	–1.822**		–1.413*

Note: ** and * represent statistical significance at 5% and 10% levels, respectively.

In order to check the robustness of the MMQR results, this study utilizes various estimators such as AMG and FE–DKSE. Table 6 displays the AMG and FE–DKSE estimation findings. AMG and FE–DKSE results indicate that GDP has a positive and significant impact on EPol, while the GDPSQ coefficient is negative and significant. These findings confirm the validity of the EKC hypothesis. However, the AMG result shows that the impact of ELC on EPol is insignificant, whereas the FE–DKSE result demonstrates that the impact of the ELC on EPol is positive and significant.

Table 6. Results of AMG and FE–DKSE Estimation

	AMG			FE–DKSE		
Variables	Coeff.	Std. Err.	t–stats.	Coeff.	Std. Err.	t–stats.
GDP	7.579*	3.915	1.94	18.895***	6.150	3.07
GDPSQ	–0.430*	0.221	–1.94	–1.065***	0.344	–3.09
ELC	0.222	0.171	1.29	0.166***	0.052	3.16

Note: *** and * represent statistical significance at 1% and 10% levels, respectively.

The coefficient estimation was conducted after confirming the long–run cointegration relationship. Table 7 reports the MMQR results. Based on the MMQR findings, the GDP coefficient was found to be positive and significant for the POL across all quantiles, but the GDPSQ coefficient is negative and significant at all quantiles. These findings verify the validity of the EKC hypothesis in the TR90 region. Additionally, for all quantiles, the findings show that

the ELC coefficient is positive and significant for EPol, which shows that the increase in ECon in the TR90 region increases EPol.

Table 7. Results of Quantile Regression Estimation (MMQR)

Variables	Location	Scale	Quantiles			
			$Q_{(0.25)}$	$Q_{(0.50)}$	$Q_{(0.75)}$	$Q_{(0.90)}$
GDP	5.956	7.246*	18.441**	18.977***	19.563***	19.993**
GDPSQ	–0.335	–0.407*	–1.038**	–1.070***	–1.106***	–1.132**
ELC	0.137*	0.123***	0.158*	0.167***	0.178**	0.185*

Note: ***, **, and * represent statistical significance at 1%, 5%, and 10% levels, respectively.

The findings achieved in the present study support the validity of the EKC hypothesis, which states that EPol increases initially, but following a turning point, starts to decrease with increasing in income in the TR90 region. These results align with those of sub–national research including Song et al. (2008), Andreoni and Levinson (2001), and Dinda (2004). More specifically, an inverted U–shaped relationship is observed between per capita income and EPol for the six cities in the study, while environmental pressure rises to a particular income level and then falls. Thus, the first hypothesis of the study, "*H_1: For the case of the TR90, the EKC hypothesis is valid,"* is accepted.

However, the results achieved in the present study do not align with those reported by Bakirtas and Cetin (2017) and Kijima et al. (2010), who did not support the validity of the EKC. This discrepancy highlights that evaluations of the EKC may yield different results when conducted at a subnational scale. The literature is anticipated to be greatly enhanced by regional and local–scale evaluations for various nations and country groupings such as this study. In this sense, comparing TR90 with Level-1 and Level-2 sub-regions offers valuable insights.

Moreover, this study clearly reveals a positive link between electricity use and EPol at the regional level. It indicates that increased ECon in the TR90 region contributes to higher EPol. The findings align with regional–scale studies confirming that higher ECon levels lead to increased EPol. These results are also consistent with the general findings of Sumaira and Siddique (2023) and Ibekilo et al. (2023). In other words, ECon in the TR90 region is identified as a factor that exacerbates EPol. Therefore, the second hypothesis of the study, "*H_2: Energy consumption increases the amount of municipal waste and hampers the environment in the case of the TR90 region,*" is acknowledged. However, recent development initiatives in the region are expected to yield positive outcomes for maintaining and improving environmental quality in the future. These results are consistent with the studies carried out by Armeanu et al. (2019) and Anwar et al. (2021). Nonetheless, due to limited urban data, it was not possible to evaluate the types of energy used in this study. Furthermore, examining factors influencing ECon levels on a subnational scale could contribute to regional sustainable development.

5. Conclusion and Policy Recommendations

This study addressed the effects of EGr and ECon on EPol in Türkiye's TR90 region for the period 2007–2021 within the framework of the EKC hypothesis using the MMQR approach. The results achieved in this study clearly confirmed the EKC hypothesis for the TR90 region. That is, improvements in environmental quality can be achieved in the later stages of EGr once income exceeds a certain threshold, even though EPol increases during the early stages of economic development when income is low. Moreover, the results of the study indicate that ECon

also exacerbates EPol at the regional level. From this aspect, this study suggests that in the context of regional development, Türkiye should pursue policies tailored to the varying levels of regional development rather than applying a uniform policy across all regions, as this can lead to erroneous outcomes. Therefore, specific policy implementations based on the level of regional development should be enacted in Türkiye.

So, it would not be an accurate approach to restrict economic activities to control EPol in the TR90 region. Instead, focus should be placed on measures that enhance environmental quality, including improving production efficiency, promoting sustainable production and consumption patterns, afforestation activities, encouraging energy innovation, and adopting other eco–friendly production. Moreover, active policies to increase environmental awareness and implement stricter environmental regulations should be put into effect to achieve environmental sustainability in the region.

This study also highlighted that the increase in ECon in the TR90 region has led to EPol issues. Consequently, the growing energy demand poses threats to human health, nature, and biodiversity. Ensuring a sustainable environment in the TR90 region requires the adoption of clean energy sources, eco–friendly technology, and production methods. In this context, particularly in the region, the promotion of a variety of renewable energy sources such as hydropower plants, solar, and wind energy can play an important role in achieving a sustainable future. Thus, the consumption of renewable energy in this region will help mitigate environmental adversities and ensure energy security to the extent that it reduces dependency on fossil fuels. It underscores the necessity of policymakers developing region-specific policies regarding energy R&D and energy substitution to reduce EPol in the region.

However, the study has some restrictions. First, the study period is restricted to the years 2007–2021, owing to data limitations. Therefore, the small sample size of the study highlights the importance of caution in generalizing the results of the analysis. Second, this study only investigates the effects of EGr and ECon on EPol in the TR90 region, excluding other regions of Türkiye. Third, due to data limitations, no distinction could be made between renewable and non–renewable energy usage. As economic and ecological disparities between regions in Türkiye become increasingly apparent, it would be important to study the spatial–temporal characteristics of the growth–energy–pollution relationships more comprehensively. Finally, future studies could explore the effects of various factors such as EGr, ECon, education, exports, technology, and population on EPol for different regions of Türkiye. Despite the existing data and methodological limitations, this study can be considered a pioneering step in understanding the linkages between regional environment, energy, and economy. In this context, the study might inspire future research that can be supported by expanded datasets and comprehensive regional comparative analyses.

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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RELATIVE FINANCIAL DEPRIVATION AND FINANCIAL SATISFACTION AMONG MINIMUM WAGE EARNERS IN TÜRKİYE: A SERIAL MEDIATION ANALYSIS

Türkiye'deki Asgari Ücretlilerde Göreli Finansal Yoksunluk ve Finansal Memnuniyet İlişkisi: Bir Seri Aracılık Analizi

Göknur ERSARI TAŞKESEN* **& Korhan KARACAOĞLU****

Abstract

The research is a behavioral finance-based study that examines the financial difficulties experienced by minimum wage earners in Turkey from a psychological perspective. In this context, the study explains the financial difficulties experienced by minimum wage earners based on the theory of relative deprivation. The aim of the study is to determine the financial difficulties experienced by minimum wage earners and the psychological effects of this situation. To achieve this goal, the study examines the serial mediator role of financial self-efficacy and financial anxiety in the relationship between relative financial deprivation and financial satisfaction. In this context, a survey was conducted among 633 minimum wage earners in Turkey. The findings of the study indicate that minimum wage earners in Turkey experience relative financial deprivation, which in turn reduces their financial satisfaction. Furthermore, the study revealed that financial self-efficacy and financial anxiety act as mediators in the relationship between relative financial deprivation and financial satisfaction, with each acting independently. However, the study also demonstrated that financial self-efficacy and financial anxiety do not act in a serial mediation role in the relationship between financial deprivation and financial satisfaction.

Keywords:
Relative Financial Deprivation, Financial Self-Efficacy, Financial Anxiety, Financial Satisfaction, Minimum Wage Workers.

JEL Codes:
M48, M54, P34.

Öz

Araştırmamız Türkiye'deki asgari ücretlilerin yaşadığı finansal sıkıntıları psikolojik açıdan inceleyen davranışsal finans temelli bir araştırmadır. Bu kapsamda çalışmamız asgari ücretlilerin yaşadığı finansal sıkıntıları göreli yoksunluk teorisine dayandırarak açıklamaktadır. Çalışmanın amacı asgari ücretlilerin yaşadığı finansal sıkıntıların ve bu durumun yarattığı psikolojik etkilerin neler olduğunu belirlemektir. Bu amaca ulaşmak için çalışmada göreli finansal yoksunluk ve finansal memnuniyet arasındaki ilişkide finansal öz yeterlilik ve finansal kaygının seri aracı rolü incelenmektedir. Bu bağlamda Türkiye'de asgari ücretle çalışan 633 kişiye anket yapılmıştır. Araştırmanın sunucunda Türkiye'de çalışan asgari ücretlilerin göreli finansal yoksunluk yaşadığı ve göreli finansal yoksunluğun finansal memnuniyeti azalttığı tespit edilmiştir. Ayrıca göreli finansal yoksunluk ve finansal memnuniyet arasındaki ilişkiye finansal öz yeterliliğin ve finansal kaygının ayrı ayrı modellerde aracı rol üstlendiği görülmüştür. Ancak araştırmada, finansal yoksunluk ve finansal memnuniyet arasındaki ilişkide finansal öz yeterlilik ile birlikte finansal kaygının seri aracılık etkisinin bulunmadığı da ulaşılan bir başka sonuçtur.

Anahtar Kelimeler:
Göreli Finansal Yoksunluk, Finansal Öz Yeterlilik, Finansal Kaygı, Finansal Memnuniyet, Asgari Ücretliler.

JEL Kodları:
M48, M54, P34.

* Assist. Prof. Dr., Nevşehir Haci Bektas Veli University, Faculty of Economics and Administrative Sciences, Department of Business Administration, Türkiye, gersari@nevsehir.edu.tr

** Prof. Dr., Nevşehir Haci Bektas Veli University, Faculty of Economics and Administrative Sciences, Department of Business Administration, Türkiye, kkaracaoglu@nevsehir.edu.tr

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1. Introduction

Minimum wage earners represent the lowest-paid labor force in Turkey. This group constitutes approximately 50 percent of the working population (Cımrın et al., 2023). In Turkey, a country that has experienced high inflation in recent years, the government has adopted a policy of not allowing wage earners to be unduly affected by inflation. However, it is considered that wages in general and minimum wage in particular are not satisfactory by employees. As with many wage earners in general, minimum wage workers tend to compare their financial situation with others. This situation may result in financial anxiety (FA) and financial dissatisfaction. In this study, it is evaluated that minimum wage earners in Turkey may face the problem of relative financial deprivation (RFD), financial dissatisfaction, and financial anxiety even if they have financial self-efficiency.

Financial satisfaction (FS) is defined as the subjective evaluation of the satisfaction or dissatisfaction of financial resources (Hira and Mugenda, 1998). Financial satisfaction is an important phenomenon for minimum wage earners as well as for all employees. In the relevant literature, it is suggested that there are many factors that affect financial satisfaction (Asebedo and Payne, 2019). One of these factors is financial deprivation. Financial deprivation is an emotionally distressing state of mind that arises from the perception that one's financial circumstances are unfavorable in comparison to one's past financial situation or that of others (Sharma and Alter, 2012). Indeed, the impact of relative financial deprivation on financial satisfaction has been the subject of investigation in a number of studies in the literature. In these studies, it has been observed that relative financial deprivation negatively affects financial satisfaction (Hastings, 2019; Mahmoud et al., 2022). Conversely, another variable that affects financial satisfaction is financial anxiety, which is defined as an emotional state in which a person feels depressed or worried about their financial situation (Zhang et al., 2023). There is a body of literature that indicates that financial anxiety has a negative effect on financial satisfaction (Archuleta, 2020). Similarly, another concept that is claimed to have an effect on financial satisfaction is financial self-efficacy. In the relevant literature, it has been suggested that there is a positive relationship between financial self-efficacy and financial satisfaction (Payne and Asebedo, 2017).

The study starts from the premise that minimum wage earners in Turkey are dissatisfied with their financial situation compared to other wage earners, likely due to recent issues with purchasing power. It was thought that this dissatisfaction may be linked to relative financial deprivation, financial anxiety, and financial self-efficacy (FSE). Thus, it was decided to prepare this study to scientifically demonstrate the psychological consequences caused by financial difficulties.

In light of the economic challenges faced by minimum wage earners during the global and Turkish economic crisis, it is important to understand how they cope with financial deprivation and anxiety. International literature has examined the connections between financial self-efficacy and financial anxiety (Kim et al., 2020), as well as the association between relative financial deprivation, financial anxiety, and financial satisfaction (Mahmoud et al., 2022). However, no study has yet examined the relationship between these four variables in the context of the psychological effects of the financial situation of minimum wage earners in Turkey. Therefore, this study is significant in revealing the psychological consequences of the financial difficulties experienced by minimum wage earners. This study hypothesizes that the financial

satisfaction of minimum wage earners in Turkey will be reduced due to relative financial deprivation and financial anxiety. Additionally, financial self-efficacy is expected to play a significant role in this relationship. However, this study is also significant in highlighting the adverse psychological impact of financial hardship on minimum wage earners in Turkey. The study's findings can inform policymakers in developing solutions to address this issue.

Based on the conceptual relationships emphasized above and the importance of the subject, the aim of this study is to examine the effect of relative financial deprivation on the financial satisfaction of minimum wage earners in Turkey and the serial mediating role of financial anxiety and financial self-efficacy in this effect. For this purpose, firstly a literature review was conducted in the study, and concepts were introduced and conceptual relationships were written. Then, the data obtained from minimum wage workers were analyzed with Amos 22, SPSS 26, and Process Macro 2.16 programs and the hypotheses were tested.

2. Literature Review

The current research is informed by the theoretical framework of Relative Deprivation Theory. In accordance with the theory developed by Runciman (1966) and Crosby (1976), the individual subjectively assesses their disadvantaged circumstances by comparing them with those of others. This situation gives rise to a cognitive awareness of the disadvantaged position of the individual. Crosby (1976) identified five distinct preconditions that contribute to the emergence of relative deprivation. These are (I) the individual's awareness that others possess the desired outcome, (II) the individual's desire to possess the desired outcome, and (III) the individual's belief that they are entitled to possess the desired outcome. (IV) the individual's perception that he/she can attain the desired outcome, and (V) the individual's belief that the reason for not attaining the desired outcome is not due to the individual but to other people or the existing system. As can be discerned from the five prerequisites, relative deprivation encompasses cognitive and justice-based emotional dimensions shaped by perceptual processes and subjective evaluations. It has been frequently observed that perceived deprivation reduces people's satisfaction with their life circumstances and causes depressive feelings (Lyubomirsky, 2001). A decline in satisfaction with life circumstances may lead to a decline in financial satisfaction by taking the form of relative financial deprivation arising from financial situations.

Relative financial deprivation is related to how individuals perceive their financial situation compared to others (Mahmoud et al., 2022). According to Sharma and Alter (2012), relative financial deprivation is a state of feeling psychologically unwell due to the belief that one's financial situation is bad by comparing one's financial situation with one's past financial situation or with others. On the other hand, financial satisfaction is a subjective measure of financial well-being (Xiao and Porto, 2017) and involves subjective assessments of whether financial resources are sufficient or insufficient, or whether they satisfy or dissatisfy the individual (Hira and Mugenda, 1998). Individuals experiencing relative financial deprivation perceive their financial resources as relatively insufficient and believe that they are financially deprived. In this study, it is predicted that minimum wage earners in Turkey will tend to compare themselves to people with higher incomes and this will negatively affect their financial satisfaction. Previous empirical studies support that relative financial deprivation negatively affects financial satisfaction. For example, Mahmoud et al. (2022) found that the relationship between financial deprivation and financial satisfaction is negatively significant. Hastings

(2019) also found that an increase in income inequality significantly reduces financial satisfaction due to feelings of relative deprivation. Hira and Mugenda (1998) confirmed that financial satisfaction decreases as relative deprivation increases for both retirees and non-retirees. In addition, an individual's sense of having fewer financial resources than others and experiencing relative financial deprivation may have a negative impact on their financial self-efficacy. The individual's inability to achieve his/her financial goals will lead to feelings of financial inadequacy. Because having fewer financial resources affects the individual negatively, this situation may also lead to a decrease in financial self-efficacy. Consequently, it is anticipated that relative financial deprivation will have a detrimental effect on financial self-efficacy.

As evidenced by the studies referenced above, relative financial deprivation is associated with diminished financial satisfaction and self-efficacy. Furthermore, relative financial deprivation is a significant predictor of financial anxiety. According to Marx (1902), a house can be small or big. What matters here is the size of the neighbor's house. If the neighbor's house is like a palace, the small house is perceived as a hut (Hastings, 2019). Duesenberry (1949) posited that income is inherently unstable, whereas consumption is relatively stable. Put differently, even if a family's income declines, they will not choose to live a life below their established standard of living. Consequently, individuals experiencing financial deprivation will strive to maintain a standard of living that aligns with their aspirations and may resort to borrowing if necessary. This can give rise to feelings of financial anxiety. These ideas suggest that individuals will experience relative financial deprivation by comparing themselves with others. Consequently, as financial deprivation increases, financial anxiety will also increase.

Financial anxiety is a concept that essence of financial stress (Adinda et al., 2023). Research suggests that financial stress and financial anxiety have an impact on financial satisfaction. Joo and Grable (2004) found an adverse correlation between financial stress and financial satisfaction. In their study of university students Archuleta et al. (2013) found a negative correlation between financial anxiety and financial satisfaction. However, Mahmoud et al. (2022) did not reveal a meaningful relationship between financial anxiety and financial satisfaction in their research. Based on the literature, it is expected that a negative correlation exists between financial anxiety and financial satisfaction.

Another variable of the study is financial self-efficacy, which refers to an individual's confidence in their ability and knowledge of financial management (Farrell et al., 2016; Ismail et al., 2017). Individuals who possess financial self-efficacy are better equipped to handle stress and anxiety caused by negative financial events (Asebedo and Payne, 2019). For instance, Kim et al. (2020) discovered a significant negative correlation between financial self-efficacy and financial anxiety in their study of African refugees. Similarly, Lee et al. (2023) also observed a negative correlation between financial self-efficacy and financial anxiety. Therefore, based on this study, we expect a significant negative correlation between financial self-efficacy and financial anxiety.

Individuals who possess high levels of financial self-efficacy tend to demonstrate superior financial performance, as they exhibit greater confidence in attaining their financial objectives (Farrell et al., 2016). Consequently, this circumstance enhances the financial satisfaction of individuals. Individuals with high financial self-efficacy demonstrate enhanced resilience in the face of stress and depression, along with greater job satisfaction (Mubarik et al., 2020). Prior

empirical research has also indicated that financial self-efficacy exerts an influence on financial satisfaction (Lee and Dustin, 2021; Kumar et al., 2023). Asebedo and Payne (2019) posited that there is a positive correlation between financial self-efficacy and financial satisfaction. Consequently, it is anticipated that an increase in financial self-efficacy will result in an enhancement of financial satisfaction.

The present study posits that relative financial deprivation will have a negative impact on financial satisfaction. In addition, firstly, it is hypothesized that financial self-efficacy will mediate the relationship between relative financial deprivation and financial satisfaction. Secondly, it is hypothesized that financial anxiety will mediate the relationship between financial deprivation and financial satisfaction. Finally, it is claimed that financial self-efficacy and financial anxiety will have a serial mediation effect on the effect of relative financial deprivation on financial satisfaction. Based on this information, the following hypotheses were developed.

Hypothesis 1 (H1): Financial self-efficacy mediates the relationship between relative financial deprivation and financial satisfaction (mediation model 1). Specifically, relative financial deprivation is negatively related to financial self-efficacy (H1a), while financial self-efficacy is positively related to financial satisfaction (H1b). Additionally, there is a negative correlation between relative financial deprivation and financial satisfaction (H1c).

Hypothesis 2 (H2): Financial anxiety mediates the relationship between relative financial deprivation and financial satisfaction (mediation model 2). Specifically, relative financial deprivation is positively related to financial anxiety (H2a), while financial anxiety is negatively related to financial satisfaction (H2b). Additionally, there is a negative correlation between relative financial deprivation and financial satisfaction (H2c).

Hypothesis 3 (H3): Financial self-efficacy and financial anxiety will serially mediate the relationship between relative financial deprivation and financial satisfaction (serial mediation model 3). Financial anxiety will have a negative relationship with financial self-efficacy (H3a).

3. Methods

3.1. Research Sample and Data Collection

This cross-sectional study examines the psychological aspects of financial difficulties faced by minimum wage earners in Turkey. The study collected data from 633 participants through a questionnaire to gain insight into the views of a large segment of employees over a certain period of time. Approval was acquired from the ethics committee commission authorized by the institution before collecting the data for this study. Participants were selected using the snowball sampling method. The study includes individuals who are 18 years of age or older and work for minimum wage in any workplace. As of July 2023, the minimum wage in Turkey was 11,402,32 TL net, which is approximately 423 USD.

The study found that 57.8% of the participants were male and 42.2% were female. In terms of marital status, 44.4% of the respondents were married and 55.6% were single. The age distribution of the respondents was as follows: 35.4% were under the age of 25, 29.9% were between the ages of 26-35, 23.5% were between the ages of 36-45, 8.1% were between the ages of 46-55, and 3.2% were aged 56 and over. With regard to education level, 31.6% of the

employees were high school graduates and 30.8% were bachelor's degree graduates. Additionally, 50.7% of the employees have less than 5 years of experience in the sector.

The surveys underwent a series of stages prior to administration to the participants. Initially, data collectors were instructed on the survey questions and the data collection procedure. Furthermore, a conceptual understanding of each question was ensured to ensure consistency and equivalence between different language versions of the survey. The original English scales were translated into Turkish with the assistance of experts in the field. Finally, before answering the questions, participants were informed about the concepts included in the survey. It was ensured that the questions included in the survey were understood by the respondents.

3.2. Measures

The study employed generalized scales that have been used in numerous previous studies across various groups. To ensure accuracy and validity, the scales underwent rigorous testing for both reliability and validity. The research scale is comprised of five distinct sections. The initial section comprises five inquiries pertaining to demographic characteristics, including gender, educational attainment, age, marital status, and occupational hours. In the second part of the scale, six items were employed to assess financial satisfaction, which serves as the dependent variable in the research (1. Regular monetary savings. 2. Current debt level, etc.) (Hira and Mugenda, 1998). The financial satisfaction scale was subjected to two distinct analytical techniques: exploratory factor analysis and confirmatory factor analysis. The results of the analysis indicated that the factor loadings of all items were above 0.60. The fit indexes of the scale were found to be within acceptable limits, with values for CMIN/DF (3.771), GFI (0.985), CFI (0.987), RMSEA (0.066), and SRMR (0.023) falling within the recommended range. In the third section, the financial self-efficacy scale, which is the first mediator variable of the research, is included. The financial self-efficacy scale comprises a total of five items (1. I am fully capable of making personal financial decisions, 2. I am confident in my ability to make personal financial decisions, etc.) (Dare et al., 2023). The factor analysis conducted on the financial self-efficiency scale revealed that the factor loading of the third item (FSE3) was below 0.50. Consequently, item FSE3 was removed from the scale. Analyses for financial self-efficiency continued with four items. The fit indexes of the scale (CMIN/DF= 4.147; GFI= 0.997; CFI= 0.997; RMSEA= 0.071; SRMR= 0.009) are within acceptable limits. The fourth section of the study comprises the financial anxiety scale, which represents the second mediator variable. The financial anxiety levels of minimum wage earners were gauged through responses to seven items (1. I feel anxious about my financial situation. 2. I have difficulty sleeping because of my financial situation, etc.) (Archuleta et al., 2013). The results of the analyses indicated that the fit indexes of the scale (CMIN/DF= 3.964; GFI= 0.979; CFI= 0.990; RMSEA= 0.068; SRMR= 0.016) were within the acceptable limits.

3.3. Scale Validity and Reliability Analysis Results

As one of the prerequisites for determining the statistical analyses to be used, it is important to know whether or not the data are normally distributed. In this sense, in order to apply parametric analysis techniques, the data must be normally distributed or have a

distribution close to normal (Geisser and Johnson, 2006). In this sense, missing data that disrupt the general order of the scales used in the research were first checked, and then the kurtosis and skewness scores were used to assess whether the data set met the normal distribution condition. For exploratory and confirmatory factor analyses, skewness and kurtosis values between -3 and +3 are considered acceptable for normal distribution (Shao, 2002). On the other hand, the fact that the absolute value of the skewness is below 3 and the absolute value of the kurtosis is below 10 reveals that there is a distribution close to the normal distribution (Kline, 2016). The financial anxiety scale has a skewness value of (0.50) and a kurtosis value of (0.67), while the financial satisfaction scale has a skewness value of (0.37) and a kurtosis value of (0.44). The financial self-efficacy scale has a skewness value of (0.33) and a kurtosis value of (0.163). The relative financial deprivation scale has a skewness value of (0.09) and a kurtosis value of (0.44). The data met the normal distribution condition as the kurtosis and skewness values of the scales were within the specified ranges. Therefore, the appropriate conditions for parametric analyses were met.

Table 1. Scale Validity and Reliability Analysis Results

Variables	α	CR	AVE	MSV	ASV	√AVE
Relative financial deprivation	0.81	0.87	0.56	0.35	0.20	0.75
Financial self-efficacy	0.84	0.90	0.64	0.17	0.18	0.80
Financial anxiety	0.94	0.95	0.74	0.35	0.22	0.86
Financial satisfaction	0.87	0.90	0.61	0.30	0.24	0.78

The reliability of the financial anxiety, financial satisfaction, financial self-efficacy, and relative financial deprivation scales was analyzed using Cronbach's alpha and CR values. Alpha values and CR values are required to be above 0.70. When the alpha and CR values of the scales related to the variables are examined, it is seen that all values are above 0.70. Therefore, looking at the results in Table 1, we can say that the scales are reliable. To determine convergent and discriminant validity, the AVE, MSV, and ASV values of the variables were calculated. To maintain discriminant validity, MSV and ASV should be smaller than AVE, and the inter-factor correlation should be less than the square root of AVE. In order to demonstrate convergent validity, the AVE must be greater than 0.50, while the CR must be greater than 0.70 and the CR must be greater than the AVE. In order to demonstrate discriminant validity, the MSV must be less than the AVE, the ASV must be less than the AVE, and the √AVE must be less than the correlation between factors (Hair et al., 2021). When we look at Table 1, it is seen that the AVE values are lower than the CR values and the AVE values are above 0.50. According to these results, the variables have convergent validity. On the other hand, the fact that the AVE values of the variables are higher than the MSV and ASV values shows that the variables also have discriminant validity. In addition, the fact that the √AVE scores of the variables are higher than the correlations between the factors is another indicator that the scales have discriminant validity.

3.4. Data Analysis

This study examined whether there is a serial mediation effect of financial self-efficacy and financial anxiety on the effect of relative financial deprivation experienced by minimum wage earners on financial satisfaction. The independent variable of the study is relative financial

deprivation (X), the dependent variable is financial satisfaction (Y), and the mediator variables are financial self-efficacy (M1) and financial anxiety (M2). Amos 22, SPSS 26 and Process Macro 2.16 programs were used in the analysis of the data. Descriptive statistics, correlation and multivariate relationships related to the study were evaluated using SPSS 26 (IBM Corp. Released, 2016). Amos 22 program was used to ensure the reliability and validity of the scales. The mediation effects of the variables in the model were analyzed using Process Macro 2.16, created by Hayes (2013). This tool is particularly beneficial for mediation analysis as it allows for a single-test approach to assess the significance of mediation effects (Hayes, 2013). Specifically, Process Macro evaluates the direct impact of X (relative financial deprivation) on Y (financial satisfaction) and the indirect impact of X on Y through M (financial anxiety or financial self-efficacy). To estimate the mediating effects of financial anxiety and financial self-efficacy on the link between relative financial deprivation and financial satisfaction, 5,000 bootstrap samples were utilized, and 95% confidence intervals (CI) were calculated.

In the study, firstly, the mediating effect of financial self-efficacy on the effect of relative financial deprivation on financial satisfaction (Model 1) was examined. Then, the mediating effect of financial anxiety on the effect of relative financial deprivation on financial satisfaction (Model 2) was examined. Finally, the serial mediating effect of financial self-efficacy and financial anxiety on the effect of relative financial deprivation on financial satisfaction (Serial Mediation Model 3) was analyzed.

4. Findings of the Research

4.1. Correlation Results

Table 2 presents the means (M), standard deviations (SD), and correlation r-values for the variables. Upon analysis of the mean values presented in Table 2, it becomes evident that the financial anxiety of minimum wage earners (3.46) is above the average. This outcome is consistent with expectations, indicating that minimum wage earners experience financial anxiety due to their low income. The average of financial satisfaction, another variable presented in Table 2, is (2.42). This value demonstrates that the financial satisfaction of minimum wage employees is below the average. In other words, this result indicates that employees are not financially satisfied. When the means of both financial self-efficacy (3.09) and relative financial deprivation (3.25) were examined, it was understood that both were at a moderate level. This suggests that the financial self-efficacy level of minimum wage employees is not as low as anticipated, and they experience relative financial deprivation to a limited extent.

Table 2. Descriptive Statistics and Correlations

Variables	M	SD	1	2	3	4
Relative financial deprivation	3.25	0.91	-			
Financial self-efficacy	3.09	0.91	-0.15**	-		
Financial anxiety	3.46	1.09	0.59**	-0.07	-	
Financial satisfaction	2.42	0.93	-0.48**	0.42**	-0.55**	-

Note: N= 633, *p<.05, **p<.01.

When the correlation relations for the variables of the study were examined, it was determined that relative financial deprivation had a moderate negative significant relationship with financial satisfaction ($r = -0.48$, $p<.01$) and a weak negative significant relationship with financial self-efficacy ($r = -0.15$, $p<.01$). However, it was observed that there was a moderate positive significant relationship between relative financial deprivation and financial anxiety ($r = 0.59$, $p<.01$). In other words, as expected, while the financial anxiety of those experiencing relative financial deprivation increased, their financial self-efficacy and financial satisfaction decreased. In addition, while there was a moderate positive significant relationship between financial self-efficacy and financial satisfaction ($r = 0.42$, $p<.01$), there was a moderate negative significant relationship between financial anxiety and financial satisfaction ($r = -0.55$, $p<.01$). In other words, while financial self-efficacy positively affected financial satisfaction, financial anxiety negatively affected financial satisfaction.

4.2. Testing Research Hypotheses

4.2.1. Model 1 Results (RFD→FSE→FS)

In Model 1, it was examined whether there was a mediating effect of financial self-efficacy on the effect of relative financial deprivation and financial satisfaction. Process Macro Model 4 was used to test the mediation relationship shown in Figure 1. As a result of the analyses, it was found that financial self-efficacy had a mediating effect on the relationship between relative financial deprivation and financial satisfaction.

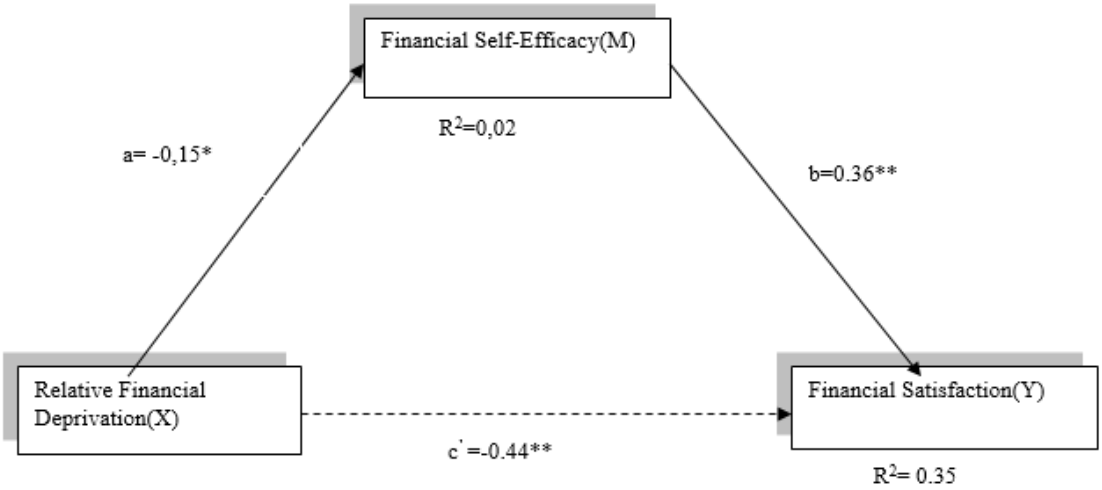

Figure 1. The Relationship Between Relative Financial Deprivation with Financial Satisfaction, and the Mediating Role of Financial Self-Efficacy (Model 1)

Figure 1 shows that (c') the direct effect of relative financial deprivation on financial satisfaction is negative and significant ($\beta = -0.44$, $p<.001$). Secondly, the (a) path was examined and it was found that the direct effect of relative financial deprivation on financial self-efficacy was negative and significant ($\beta = -0.15$, $p<.001$). Then, the (b) path was examined and it was understood that the direct effect of financial self-efficacy on financial satisfaction was also positive and significant ($\beta = 0.36$, $p<.001$). After the significant results obtained, regression

analysis was conducted with the Bootstrapping method to understand whether there was a mediation effect. The results obtained from the bootstrapping analysis (Table 3) showed that the indirect effect of relative financial deprivation on financial satisfaction was significant since the 95% confidence intervals (CI) did not include zero (0) (β = -0.054, 95% CI [-0.09, - 0.02]). According to this result, the relationship between relative financial deprivation and financial satisfaction is mediated by financial self-efficacy. Accordingly, the hypothesis (H1) that financial self-efficacy will mediate the relationship between relative financial deprivation and financial satisfaction (Model 1) was accepted. In addition, the hypotheses (H1a) relative financial deprivation will be negatively related to financial self-efficacy; (H1b) financial self-efficacy will be positively related to financial satisfaction; and (H1c) relative financial deprivation will be negatively related to financial satisfaction were also accepted.

4.2.2. Model 2 Results (RFD→FA→FS)

Model 2 aimed to test whether financial anxiety mediates the effect of relative financial deprivation on financial satisfaction. As shown in Figure 2, financial anxiety has a significant mediating effect on the relationship between relative financial deprivation and financial satisfaction.

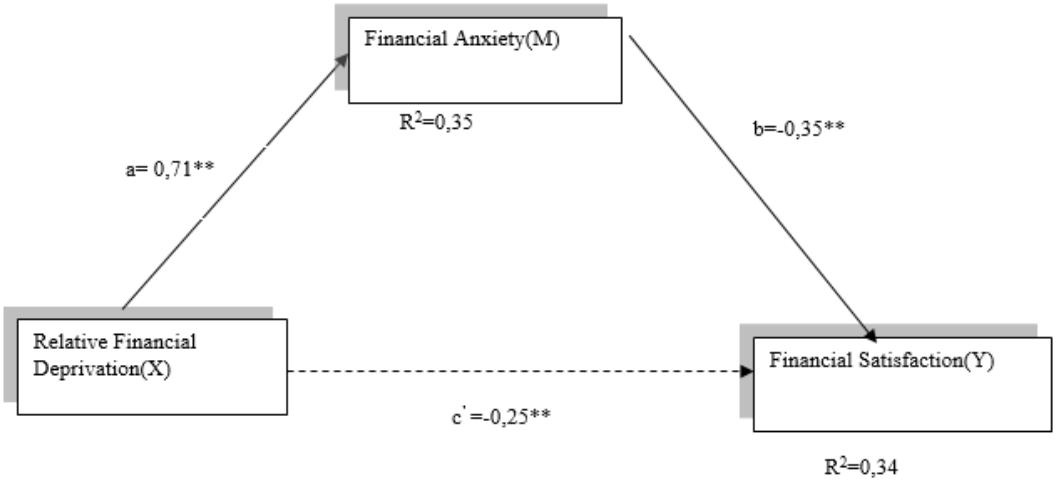

Figure 2. The Relationship Between Relative Financial Deprivation with Financial Satisfaction, and the Mediation Role of Financial Anxiety (Model 2)

When the relationship between the variables is examined in detail, it is seen that (c') the direct effect of relative financial deprivation on financial satisfaction is significant (β = -0.25, p<0.001). However, it is found that (a) the direct effect of relative financial deprivation on financial anxiety is positive (β = 0.71, p<0.001) and (b) the direct effect of financial anxiety on financial satisfaction is negative (β = -0.35, p<0.001). After these results are obtained, the mediation test is performed by selecting 5000 resample options and Model 4 with the Bootstrap technique. Since the results obtained from the bootstrapping analysis (Table 3) do not include zero (0) in the 95% confidence interval (CI), it was understood that the indirect effect of relative financial deprivation on financial satisfaction was also significant (β = -0.25, 95% CI [-0.30, -0.19]). Based on these results, it can be said that financial anxiety mediates the relationship

between relative financial deprivation and financial satisfaction. Accordingly, hypothesis H2: financial anxiety will mediate the relationship between relative financial deprivation and financial satisfaction (Model 2) was accepted. However, the hypotheses (H2a) relative financial deprivation will be positively related to financial anxiety; (H2b) financial anxiety will be negatively related to financial satisfaction; and (H2c) relative financial deprivation will be negatively related to financial satisfaction; were also accepted.

4.2.3. Model 3 Results (RFD→FSE→FA→FS)

Model 3 tests whether financial self-efficacy and financial anxiety have a serial mediating role in the relationship between relative financial deprivation and financial satisfaction.

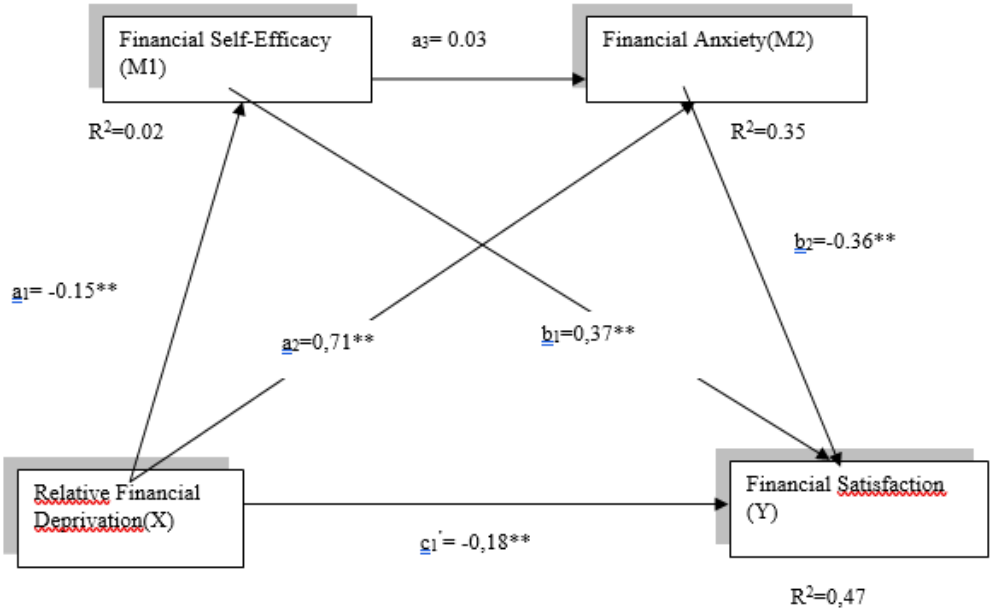

Figure 3. The Serial Mediating Role of Financial Self-Efficacy and Financial Anxiety in the Connection Between Relative Financial Deprivation with Financial Satisfaction (Model 3)

Process Macro Model 6 was used to test whether there is a serial mediation effect of financial self-efficacy and financial anxiety in the relationship between relative financial deprivation and financial satisfaction shown in Figure 3. The results of the serial mediation effect analysis indicated that the path estimates provided partial support for our hypotheses. As seen in Figure 3, the direct effect of (c_1) relative financial deprivation on financial satisfaction (β = -0.18, p<.001), (a_1) relative financial deprivation on financial self-efficacy (β = -0.15, p<.001) and (a_2) relative financial deprivation on financial anxiety (β = 0.71, p<.001) is significant. However, (b_1) financial self-efficacy on financial satisfaction (β = 0.37, p<.001); and (b_2) the direct effect of financial anxiety on financial satisfaction (β = -0.36, p<.001) was found to be significant. However, (a_3) the direct effect of financial self-efficacy on financial anxiety (β = 0.03, p>.05) was not significant. In addition, the results obtained from the Bootstrapping analysis (Table 3) showed that the indirect effect of relative financial deprivation on financial

satisfaction was not significant because the 95% confidence intervals (CI) included zero (0) (β = -0.01, 95% CI [-0.01, 0.01]). According to this result, (H3): both financial self-efficacy and financial anxiety will serially mediate the relationship between relative financial deprivation and financial satisfaction (Model 3) was rejected. In addition, (H3a) was rejected because the relationship between financial self-efficacy and financial anxiety was not significant.

Table 3. Direct and Indirect Effects of X on Y

	Effect	**SE**	**T**	**LLCI**	**ULCI**
Direct Effect of X on Y					
(Model 1) RFD → FS	-0.44	0.03	-13.22	-0.51	-0.38
(Model 2) RFD → FS	-0.24	0.04	-5.94	-0.33	-0.16
(Model 3) RFD → FS	-0.18	0.04	-4.88	-0.26	-0.11
	Effect	**BootSE**		**BootLLCI**	**BootULCI**
Indirect Effect of X on Y					
(Model 1) RFD → FSE → FS	-0.05	0.02		-0.09	0.01
(Model 2) RFD → FA → FS	-0.25	0.03		-0.30	-0.20
(Model 3) RFD → FSE→ FS	-0.06	0.02		-0.09	0.02
(Model 3) RFD → FA → FS	-0.26	0.03		-0.31	-0.21
(Model 3) RFD → FSE → FA → FS	-0.01	0.01		-0.01	0.01

Note: RFD: Relative financial deprivation, FS: Financial satisfaction, FSE: Financial self-efficacy, FA: Financial anxiety.

5. Discussion and Implications

This study explains the issue within the framework of relative deprivation theory by selecting variables proposed by previous research (Mathur and Kasper, 2019; Kim, 2020; Mahmoud et al., 2022). The present study aims to explain the financial behavior of minimum wage earners within the relative deprivation theory. To demonstrate the application of the relative deprivation theory, a limited number of variables were derived from each component of the conceptual model. Based on the model, hypotheses related to relative financial deprivation, financial anxiety, financial satisfaction, and financial self-efficacy were developed and tested using data obtained from minimum wage earners working in Turkey.

The aim of this article is to enhance the existing literature by examining the impact of relative financial deprivation on financial anxiety, financial self-efficacy, and financial satisfaction among minimum-wage workers in Turkey. The study analyzed the direct relationships between relative financial deprivation, financial satisfaction, financial anxiety, and financial self-efficacy. The study tested separately the mediating effects of financial anxiety and financial self-efficacy on the relationship between relative financial deprivation and financial satisfaction. Additionally, the serial mediation effect of financial self-efficacy and financial anxiety on the relationship between relative financial deprivation and financial satisfaction was analyzed.

In general, the analysis of the research findings suggests that minimum wage earners in Turkey experience relative financial deprivation. This is expected in countries with high-income inequality. Additionally, minimum wage earners in Turkey report low financial satisfaction and experience financial anxiety. However, contrary to expectations, the research concludes that their financial self-efficacy is not low. The results of our research partly confirmed our hypotheses. We found that relative financial deprivation has a significant negative impact on

financial satisfaction and financial self-efficacy, but a significant positive impact on financial anxiety. However, the relationship between financial self-efficacy and financial anxiety is statistically insignificant.

When the mediation relationships are examined, the mediation effect of financial self-efficacy in the relationship between relative financial deprivation and financial satisfaction is found to be significant. Although theories and general expectations show that the financial self-efficacy of minimum wage earners will be low, statistical results show that minimum wage earners in Turkey have financial self-efficacy despite everything. This situation has affected the mediation role of financial self-efficacy in the relationship between relative financial deprivation and financial satisfaction. This finding is one of the most striking results of the study. Because minimum wage earners feel financially self-efficacy despite everything. The fact that some of the minimum wage earners have a high level of education has been effective in the emergence of this result. Because a large number of university graduates in Turkey have started working for minimum wage. Another reason why minimum wage earners have financial self-efficacy is that they do not have to live only on minimum wage and may have other side incomes.

The study found that financial anxiety mediates the relationship between relative financial deprivation and financial satisfaction. This suggests that relative financial deprivation decreases financial satisfaction while increasing financial anxiety. Therefore, these findings demonstrate that the financial satisfaction of minimum wage earners in Turkey is reduced due to relative financial deprivation, which in turn increases financial anxiety and negatively impacts their mental health. These results are particularly noteworthy given that approximately 50% of the working population in Turkey are minimum wage earners. The continuous and high rate of price increases may contribute to the emergence of financial anxiety. The recent high inflation rate and the resulting decrease in purchasing power may contribute to financial anxiety among minimum wage earners.

Finally, the study found that the serial mediating role of financial self-efficacy and financial anxiety in the relationship between relative financial deprivation and financial satisfaction was insignificant. These results suggest that while relative financial deprivation negatively affects financial satisfaction, the introduction of financial anxiety as another negative factor further reduces financial satisfaction. Financial satisfaction is negatively affected by relative financial deprivation. However, high levels of financial self-efficacy also reduce financial satisfaction, and therefore the expected mediation effect does not emerge.

The findings of this study are consistent with the findings of previous research. Mahmoud et al. (2022), Hastings (2019), and Hira and Mugenda (1998) reported a negative correlation between relative financial deprivation and financial satisfaction. Kumar et al. (2023) and Asebedo and Payne (2019) found that self-efficacy has an impact on financial satisfaction. Kim et al. (2020) and Lee et al. (2023) found a negative relationship between financial self-efficacy and financial anxiety. Additionally, Joo and Grable (2004) demonstrated that financial stress can reduce financial satisfaction.

Our study makes several contributions to the literature. This article has drawn attention to the psychological effects of income inequality by focusing on feelings of relative financial deprivation and financial satisfaction. Thus, the results of this study have brought to light the psychological consequences of the economic hardship experienced by minimum wage earners

in Turkey, such as financial anxiety. The existing literature has often implied that income inequality, experienced by minimum wage earners who experience a feeling of relative financial deprivation, may also cause various social problems. In addition, this study has enabled the modeling of complex relationships that have not been modeled in the literature before, with the advanced statistical methods used.

In conclusion, financial deprivation has a negative impact on financial satisfaction and self-efficacy, while increasing financial anxiety. It is evident that minimum wage earners in Turkey experience financial deprivation, which in turn decreases their financial satisfaction and increases their financial anxiety. The current situation indicates that there are economic and psychological challenges being faced. Urgent action is required to address this issue. The government should first increase the salaries of minimum wage earners at the rate of inflation. Secondly, the state can provide social assistance to minimum wage earners, including heating, shelter, clothing, and food aid. Additionally, free financial education opportunities can be offered to minimum-wage earners. Providing credit and debt management training to minimum wage earners can alleviate their financial distress. The Minimum Wage Determination Commission has recently been considering implementing different minimum wage practices based on provinces such as Istanbul, Ankara, and Izmir in Turkey. This is thought to help employees overcome psychological difficulties they may experience due to the minimum wage. However, it is important to ensure that any such practices are objective and free from bias.

The study has limitations as it did not include a clear question about the income level of minimum wage earners in the sample, nor did it inquire about the income status of other family members in questions directed to employees. It is important to note that the self-efficacy perception of a married family member with one or both spouses earning minimum wage may differ from that of a single minimum wage earner. Future studies should take into account the household income of the minimum wage earner and whether they have additional sources of income when collecting data. Different methodological approaches, such as qualitative methodology, can be used to collect and interpret data. Longitudinal studies can be conducted over a period of years to examine whether the results obtained at different minimum wage levels are consistent with each other. These approaches can contribute to the depth and richness of the relevant literature.

Declaration of Research and Publication Ethics
This study complied with research and publication ethics. Ethic permission for the study was obtained from the Scientific Research and Publication Ethics Committee of Nevşehir Hacı Bektaş Veli University with the decision dated 26.12.2022, 13 meeting and numbered 2022.13.415.

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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THRESHOLD EFFECT OF INFLATION ON THE RELATIONSHIP BETWEEN STOCK MARKET INDEX AND INTEREST RATE*

Borsa Endeksi ile Faiz Oranı Arasındaki İlişkide Enflasyonun Eşik Etkisi

Kenan İLARSLAN**

Keywords:
Stock Market Index,
Inflation,
Interest Rate,
Threshold Regression.

JEL Codes:
G10, E31, E43, C32.

Abstract

This research examines how the deposit interest rate impacts Turkey's stock market index and the inflation rate from January 2003 to June 2024. The empirical findings derived from the analyses conducted under the threshold regression model indicate that the inflation rate has a single threshold impact on the connection among the stock market index and the interest rate. Thus, when inflation rates are at 2.67% or lower, rising bank deposit interest rates negatively impact the stock market index. Nevertheless, when inflation rates exceed 2.67%, the rise in bank deposit interest rates positively influences the stock market index. As a result, empirical evidence indicates that deposit interest rates have a nonlinear effect on the stock market index in Turkey, which is influenced by the level of inflation. These findings suggest policy implications for investors concerning the impact of the inflation rate on the connection among stock market indices and deposit rates.

Anahtar Kelimeler:
Borsa Endeksi,
Enflasyon,
Faiz Oranları,
Eşik Regresyon.

JEL Kodları:
G10, E31, E43, C32.

Öz

Bu çalışma, Türkiye bağlamında Ocak 2003- Haziran 2024 döneminde enflasyon düzeyine bağlı olarak mevduat faiz oranının borsa endeksi üzerindeki etkisine odaklanmıştır. Eşik regresyon modeli çerçevesinde yapılan analizlerden elde edilen ampirik sonuçlar enflasyon oranının, borsa endeksi ile faiz oranı arasındaki ilişkide tek bir eşik etkisine sahip olduğunu göstermektedir. Buna göre %2,67 ve altındaki enflasyon oranları döneminde banka mevduat faiz oranındaki artış borsa endeksini negatif yönde etkilemektedir. Ancak %2,67 üstündeki enflasyon oranı dönemlerinde ise banka mevduat faiz oranındaki artış borsa endeksi üzerinde pozitif yönlü etkiye neden olmaktadır. Bu nedenle, enflasyon düzeyine bağlı olarak mevduat faiz oranlarının Türkiye'deki borsa endeksi üzerinde doğrusal olmayan bir etkiye sahip olduğuna dair ampirik kanıtlara ulaşılmıştır. Elde edilen bu sonuçların yatırımcılar için borsa endeksi ile mevduat faizleri arasındaki ilişkide enflasyon oranının rolüne ilişkin politika çıkarımları sağladığı söylenebilir.

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** Assoc. Prof. Dr., Afyon Kocatepe University, Bolvadin Faculty of Applied Sciences, Department of Accounting and Financial Management, Türkiye, ilarslan@aku.edu.tr

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1. Introduction

Stock exchanges are regarded as a significant measure since they represent the overall state of a nation's economy. The stock market index (*smi*) is a fluctuating environment that provides individual and institutional investors with positive or negative signals regarding stock prices and market returns. Chikwira and Mohammed (2023), Omar et al. (2022), and Ali (2021) contend that fluctuations in stock prices and, consequently, price movements in the stock market are influenced by the robust and sound framework of the nation's economy, with macroeconomic indicators and their uncertainties acting as the main catalysts of stock market volatility. Adjasi (2009) asserts that the critical significance of uncertainty in macroeconomic data lies in the essential role stock markets have in comprehending the consequences of risk management. Additionally, insights into macroeconomic indicators can assist market participants and analysts in managing their portfolios more effectively. It also creates an environment for policymakers to formulate suitable policies that will enhance the stock market more effectively and efficiently by managing the macroeconomic variables influencing the stock market.

Inflation (*inf_rt*) and interest rates (*int_rt*) are crucial macroeconomic factors that significantly influence the economy and, more specifically, the stock market. When an economy faces elevated *inf_rt*, the actual value of money declines, resulting in diminished purchasing power, reduced profitability, and lower actual returns on investments. In other words, rising *inf_rt* prompts an increase in the nominal *int_rt* to maintain a positive real *int_rt*, rendering the stock market less appealing than other investment options. Additionally, this significant rise can lead to numerous challenges in corporate performance, diminish future dividend yields, and eventually lower stock prices (Bui and Nguyen, 2023). When *int_rt* rise, it leads to increased costs and lower profitability, signaling to investors that bonds provide better returns compared to stocks, which causes a drop in stock prices (Verma and Kumar, 2015; Eldomiaty et al., 2020). In theory, there is a negative link among *int_rt* and *smi*. This occurs because an increase in *int_rt* reduces the present value of future dividend earnings, which in turn lowers stock prices. On the other hand, reduced *int_rt* lead to decreased opportunity costs associated with borrowing. Reduced *int_rt* promotes investment and economic activity, increasing prices (Hamrita and Trifi, 2011). *Int_rt* is a crucial instrument for central banks in regulating monetary policy. Monetary policy can influence financial markets, such as bond and stock markets, through changes in the money supply and *int_rt*. Monetary policy can influence fluctuations in stock prices and bond yields. When a central bank reduces *int_rt*, borrowing is less expensive, which motivates businesses and consumers to obtain loans and invest in the economy. This can boost economic growth, enhance employment, and elevate stock prices.

On the other hand, when a central bank increases *int_rt*, the borrowing cost rises, discouraging both borrowing and investment, potentially hindering economic growth, controlling *inf_rt*, and decreasing stock prices Schrank (2024). In these situations, when the *int_rt* banks offer depositors rises, individuals move their capital from the stock market to the bank. This leads to reduced stock demand and a decline in stock prices. The contrary is also correct. To put it differently, theoretically, there exists an inverse correlation between stock price and *int_rt* (Alam and Uddin, 2009). Investors have other choices like the stock market and savings accounts. The attractiveness of investing in bank deposits depends on the connection between the nominal *int_rt* and the *inf_rt*. Nevertheless, putting money into bank deposits could encounter the risk of value loss because of negative real *int_rt* and the suppression of nominal

int_rt caused by high *inf_rt*. In reality, depositors effectively incur an *inf_rt* tax by considering the elevated *inf_rt* and the absence of a relationship between the nominal *int_rt* and the *inf_rt* of their bank deposits. As a result, investors select financial markets based on their risk assessment and potential for profit. Consequently, the rise or at least maintenance of various assets' value over time leads investors to opt for the stock market, bank savings, or other financial markets (Sadeghi et al., 2023).

Various scholars have applied different theoretical frameworks in the studies carried out to link macroeconomic variables broadly and *int_rt* specifically to the *smi*. Among these theories is the semi-strong efficient market hypothesis created by Fama (1970) and the Arbitrage Pricing Model (APM) introduced by Ross (1976). According to Fama, an efficient market is characterized by prices consistently reflecting all available information. Nonetheless, various kinds of information influence market operations. The semi-strong market efficiency hypothesis examines the negative or positive connection among stock market returns and macroeconomic variables, as it posits that macroeconomic factors are entirely incorporated into stock market prices. In other studies, Fama (1981, 1990) posits that there is an inverse connection between *int_rt* and stock prices over the long term, which is directly influenced by the impact of long-term *int_rt* on the discount rate. The negative connection is also founded on the idea that a rise in *int_rt* will result in increased borrowing costs, reduced future profits, and a higher discount rate for stock investors, and consequently, stock prices will decline.

Consequently, *int_rt* rises indirectly impact stock prices (Al-Naif, 2017; Bahloul et al., 2017; Hashmi and Chang, 2023; Belhoula et al., 2024). APM represents an alternative method for determining asset prices, as proposed by Ross, who advocates for a multi-factor approach to describe asset pricing via APM. The theory suggests that an asset is influenced by market risk and a range of unanticipated elements. These elements are systematic risks that cannot be eliminated through diversification. Once arbitrage opportunities in the market environment have been removed, the returns on financial assets are influenced by two main groups of factors. The first group comprises macroeconomic factors that are systematic risk components like *int_rt* and *inf_rt*. The second group consists of factors specific to companies. These elements are defined by coefficients specific to each factor that assess the sensitivity of assets to those factors. APM offers a more realistic account of shifts in stock prices since it accommodates a broader range of factors influencing stock returns. As a result, APM has emerged as a significant theory in elucidating the influence of macroeconomic factors on stock returns (Nordin et al., 2014; Atıcı et al., 2019; Daariy et al., 2023; Ichwanudin et al., 2023).

Generally, the stock market offers long-term funding options, particularly for fixed capital investments. Consequently, assessing the performance and efficiency of the stock market is critical for investors, policymakers, and other market players who provide and request long-term financing in an economy. Globally, the stock market is viewed as a measure of the well-being and prospects of a country's economy and a gauge of the confidence exhibited by both local and international investors (Alam and Uddin, 2009). As a critical element, *inf_rt* influences financial markets by leading to variations in *int_rt*, stock prices, and exchange rates. The connection between *inf_rt* and financial market risks is especially significant during high *inf_rt*, a crucial concern in investment and policy decisions (Choi and Kim, 2023). During the assessed period, elements such as the Covid-19 pandemic, the implementation of the Currency Hedged Deposit system in December 2021, the subsequent Russian invasion of Ukraine in February 2022, the Kahramanmaraş earthquakes in February 2023, as well as national and

global supply chain disruptions, fluctuations in energy prices, and changes in the labor market, have arisen as contributors to inflationary pressure. In this context, Kim (2023) noted in his research that the *inf_rt* caused by the Covid-19 pandemic and the Russia-Ukraine conflict presented a challenge to the global economy, leading to assessments that the U.S. Federal Reserve raised *int_rt* aggressively to combat rising *inf_rt*, which resulted in the strengthening of the U.S. dollar against other currencies, prompting investors to withdraw from stock markets, particularly in developing countries.

Moreover, the implementation of both orthodox and heterodox economic and monetary policies in Turkey indicates that there could be variations in the relationships between money and capital market instruments, thereby offering a chance for contemporary analyses. In this context, a threshold effect might occur in causal relationships, given that the influences of both *int_rt* and *inf_rt* on stock prices are not consistent and could differ depending on the levels of *int_rt* and *inf_rt*. Specifically, a threshold level of *inf_rt* could influence the *smi*. This threshold effect separates two regimes linked to low and high *inf_rt* values. Consequently, the pertinent study employs the threshold regression model to examine the effect of *int_rt* on the *smi* at a specified *inf_rt*. Therefore, the objective of this study is to obtain a pragmatic argument on the impact of the deposit *int_rt* on the *smi* depending on the inflation level from January 2003 to June 2024, specifically in Turkey. The research contributes to the literature as follows: 1) providing findings related to current data on the interplay between *int_rt* and *smi* at a specific *inf_rt* threshold, 2) offering empirical evidence that the connection between *int_rt* and *smi* shows nonlinear behavior relative to a specific inflation level. As a result of the analyses conducted within the framework of threshold regression analysis in the study, the value of the threshold variable *inf_rt* was determined to be 2.67%. In the *inf_rt* periods below and above this threshold value, the monthly deposit *int_rt* has nonlinear effects on the *smi*.

There are four sections to the study. The research topic is presented in the first section, and empirical literature on the topic is summarized in the second. The data and methodology are presented along with the results of the econometric analysis in the third step, which is referred to as the application phase. The findings and suggestions are presented in the fourth and final sections.

2. Literature Review

Many scientific studies have explored the connection between global stock market performance and macroeconomic indicators. While earlier research concentrated on the uniform impact of economic variables, like *int_rt* and *inf_rt*, on the *smi*, recent studies employing advanced econometric techniques have shown that this effect can also be nonlinear. This study focuses on determining the impacts of *int_rt* on the *smi* at a certain *inf_rt* level, based on the assumption that many national and international risk factors may be reflected in the markets from January 2003 to June 2024, specific to Turkey. The findings obtained from empirical studies conducted on the subject at different times, with different methods and samples, are summarized in Table 1.

Table 1. Summary of Empirical Literature on the Topic

Study	Period	Method	Findings
Vo and Nguyen (2024)	2012-2022	VAR, NARDL models	The results of the research indicate that the market risk in the Vietnamese stock market reacts asymmetrically to variations in *int_rt*, exchange rates, trade openness, financial development, and economic growth both in the short and long term.
Belhoula et al. (2024)	1 June 2005- 1 June 2022	TV-AR, AMG estimator, Panel ARDL, Dumitrescu and Hurlin causality test	It has been determined that a significant bidirectional causality exists between stock exchange efficiency and *int_rt*, exchange rates, market volatility, and economic policy uncertainty in the G7 countries.
Nguyen et al. (2024)	2013-2022	EGARCH	According to a study specifically for Vietnam, *int_rt* have asymmetric effects on the *smi*.
Ünal (2024)	2021-2023	t-statistics	Research from the study conducted in Turkey indicates that changes in *int_rt* have a meaningful impact on companies' financial performance and stock returns. Nevertheless, it has been noted that these effects differ based on the market value of firms, sector characteristics, and economic circumstances.
Vaswani and Padmaja (2024)	January 2013-June 2021	NARDL	The research results confirm the asymmetric linkage for *int_rt* in the Indian stock markets. Accordingly, a positive change in *int_rt* worsens stock returns, while a negative change improves them.
Kim (2023)	31 May 2022-30 June 2022	CAPM	As a result of the *int_rt* hikes by the U.S. Federal Reserve, companies with less export orientation and less foreign capital have not only become more volatile but also have more negative returns.
Song and Xu (2023)	1982-2007	VAR, GARCH models	Findings from the study conducted on U.S. stock exchanges show a positive money demand shock that increases *int_rt* and decreases stock prices. It has been determined that the reactions of stock prices are symmetrical in positive and negative money supply shocks.
Wang et al. (2023)	1 January 2008-21 December 2021	Quantile regression analysis	The study's findings indicate that Brazilian, Russian, and South African stock markets react negatively to both short-term and long-term *int_rt* shocks. In comparison, the reaction of the Indian stock market to short-term *int_rt* and the Chinese stock market to long-term *int_rt* is favorable.
Kazak (2023)	2015-2022	ARCH-LM, EGARCH models	The research specifically carried out for Turkey indicates that the BIST 100 index is influenced by changes in the policy rate, with negative shocks having a greater impact on the BIST 100 than positive ones.
Alzoubi (2022)	1991-2020	ARDL	The results obtained from the study on Jordan show that the increase in *int_rt* and *inf_rt* has a decreasing effect on the *smi*.
Baykara (2021)	2015-2020	AR, CAAR, t-test	Findings from the study conducted specifically for Türkiye show a negative price response in banking and insurance companies when monetary policy *int_rt* increase.
Bhuiyan and Chowdhury (2020)	2000-2018	Johansen cointegration analysis, VAR, VECM	The findings indicate a long-term equilibrium connection among the macroeconomic variables that reflect money supply, real economic activity, and long-term *int_rt* for the U.S., the SandP 500, and all sector indices. Furthermore, there is an inverse relationship between long-term *int_rt* and stock market indices.
Eldomiaty et al. (2020)	1999-2016	Johansen cointegration test, cointegration regression analysis, VECM model	The findings indicate that the change in stock prices due to *inf_rt* is negative and significant. Conversely, the coefficient indicating the change in stock prices due to *int_rt* is positive and significant.

Table 1. Continued

Poyraz et al. (2020)	2010-2020	AR, CAR, Wilcoxon signed-rank test	The research carried out in Turkey found that the central bank's *int_rt* cut decisions had a considerable yet restricted negative impact on the BIST100 index. Interest rate hikes were seen to exert a slight negative influence, although the impact was not significant.
Maji et al. (2020)	September 2005-November 2016	ARDL-UECM model	The study carried out in India found that the link between the BSE-BM index and *int_rt* has a negative elasticity that is statistically meaningful. This outcome aligns with the established theoretical premise that there is a negative relationship between *int_rt* and stock price movements.
Gürsoy (2019)	January 2006-December 2017	Regression analysis, Marginal effects analysis	The study stated that U.S. *int_rt* negatively and significantly affect bank stocks traded in BIST.
Fahlevi (2019)	2013-2017	OLS regression analysis	Results from the research carried out in Indonesia indicate that *inf_rt* has a positive impact, while *int_rt* have a negative and meaningful effect on the *smi*.
Ahiadorme et al. (2019)	January 1995-December 2015	OLS regression analysis, Johansen cointegration test, VAR, VECM model	The study results show a positive and significant long-term connection among *int_rt* and stock market returns for the Ghanaian stock market.
Bahloul et al. (2017)	2002-2014	Linear regression model, Markov regime regression, MS-VAR model, Granger causality analysis	*Int_rt* adversely affect the Islamic *smi* in both developed and developing nations. The results further indicate that the returns on traditional stock indexes and the money supply in both low and high-volatility environments influence Islamic *smi* in both developed and developing countries.
Otieno et al. (2017)	January 1993-December 2015	ARFIMA method, Granger causality analysis	The findings from the study conducted in Kenya indicate a negative Granger causality relationship between *int_rt* and stock market returns over the long term.
Al-Mukit (2013)	1991-2012	Johansen cointegration analysis, VECM model, Granger causality analysis	The research carried out in Bangladesh shows a consistent and important long-term connection among the variables. It has been noted that a rise in *int_rt* leads to a decline in the *smi* over the long term. Moreover, a unidirectional causality exists between the *int_rt* and the market index.
Tripathi and Seth (2014)	July 1997-June 2011	ARCH model, Granger causality, and Johansen cointegration test	The research demonstrates a negative connection among *int_rt* and the Sensex stock market.
Nordin et al. (2014)	December 1997-September 2012	ARDL	The study shows an inverse correlation between the Malaysian stock market and *int_rt* over both the short and long term.
Alam and Uddin (2009)	January 1988-March 2003	Panel data method, OLS regression analysis	The results obtained from the analysis of data from 15 developed and developing countries show that *int_rt* have a meaningful negative link with stock prices for all countries.
Panda (2008)	April 1996-June 2006	Johansen cointegration analysis, VECM model	The study's results show a long-term link among *int_rt* and stock prices and that *int_rt* affect stocks negatively and positively in the short term.

3. Methodology

The econometric approach taken in the research is as follows. Initially, fundamental statistical tests and correlation analysis concerning the data were reviewed under the Descriptive Statistical Tests. In the subsequent stage, the overall framework of the model was established by conducting analyses for linearity, structural breaks, and stationary of the data. In the subsequent phase, threshold value regression analysis was applied to the application.

3.1. Data

The study utilizes monthly data that spans from January 2003 to June 2024. The dependent variable, the *smi* variable, signifies data for the BIST100 index. The *inf_rt* variable is also a threshold variable and consists of monthly consumer inflation data. The other independent variable, *int_rt*, is the monthly average foreign currency bank deposit *int_rt*. As of the period under review, the average monthly deposit *int_rt* for TL is 1.28%; the average monthly deposit *int_rt* for Euro is 1.60%; and the average monthly deposit *int_rt* for Dollar is 2.18%. Therefore, since it offers higher earning opportunities to investors, the average of Euro and Dollar deposit *int_rt* was taken and defined as the monthly deposit *int_rt* of the foreign currency in the study. All variables used in the analysis based on their nominal values were obtained from the official website of the Central Bank of the Republic of Türkiye. Stata 18 and Eviews were utilized in the analysis stage using nominal values.

3.2. Method

Threshold regression analysis, introduced by Hansen (2000), is an econometric method used to study the nonlinear connection between two or more variables. Using threshold regression provides the benefit of dividing a sample into groups and customizing the threshold variable to assess if countries are below or above the threshold parameter. Therefore, this model can be applied to real-world conditions and produce further realistic results (Raouf, 2022). This method allows us to obtain differences in slope coefficients. Such models are convenient for investigating different effects (e.g., differences in sign, magnitude, and statistical significance) on the connection between dependent and independent variables. The threshold model shows the connection between variables in different data regimes of a defined threshold variable (Siddiki and Bala-Keffi, 2024). The threshold regression model aims to incorporate a particular threshold variable as an unknown variable within the regression model, create a piecewise function, and experimentally evaluate and estimate the relevant threshold value and its impact (Wang and Wang, 2021).

A threshold regression model may have one or more threshold values. The sample is divided into one more regime than the equal number of values. For example, the sample is divided into two regimes if there is a threshold value. In the threshold model, it is evident that observations are categorized into two regimes, which are differentiated by their distinct regression slopes based on whether each observation is above or below the threshold value (Lin and Fu, 2024). As Thanh (2019) stated in his study, the threshold regression model has two categories of explanatory variables. The threshold variable is one, serving as the primary variable to measure the threshold effect on the dependent variable. Once the threshold variable surpasses the threshold value (γ), the sample set can be split into two groups, represented by

distinct slope coefficients β_1 and β_2. The explanatory variable is a variable that indicates its impact on the dependent variable. In the threshold regression model, the effects of the explanatory variables are variable and depend on the threshold value of the threshold variable. After these explanations, the mathematical representation of the single threshold regression model can be made as follows (Huang et al., 2019).

$$y_t = \begin{cases} \alpha_1 + \beta_1' x_t + \epsilon_1, \; q_t \leq \gamma \\ \alpha_2 + \beta_2' x_t + \epsilon_2, \; q_t > \gamma \end{cases} \quad (1)$$

Here, *y* represents the explained variable, *x* represents the explanatory variable, *q* represents the threshold variable, γ represents the threshold value, *α* represents the constant term, and *ε* represents the error term. Considering the variables used in the study, the single threshold regression model can be shown as follows.

$$smi = \begin{cases} \alpha_1 + \beta_1 int\_rt + \epsilon_t, \inf\_rt \leq \gamma \\ \alpha_2 + \beta_2 int\_rt + \epsilon_t, \inf\_rt > \gamma \end{cases} \quad (2)$$

inf, the threshold variable in the study, is included as an exogenous variable.

3.3. Empirical Analysis and Findings

The results of the tests and analyses conducted to examine the general structure and summary of the data and the connection among the variables in terms of the study design are presented in Table 2. If the mean and median values are equal or very close to each other, then the distribution is symmetric (normal). However, the mean and median values of the variables were not close. In addition, none of the variables provide the assumption of normality according to the Jarque-Bera statistics and probability values at the 1% significance level. The skewness and kurtosis values are far from the values of 0 and 3 supports this finding (Lins et al., 2023; Alomari et al., 2024). According to the correlation analysis findings, there is a positive connection among the *smi* and the *inf_rt* and a negative connection with the *int_rt* variable.

Table 2. Descriptive Statistical Tests

	Basic Statistical Tests								Correlation Analysis		
	Mean	**Median**	**Max.**	**Min.**	**St.Dev.**	**Skew.**	**Kurt.**	**J.B.**			
smi	1264.48	741.73	10647.91	95.34	1897.69	3.24	13.22	1577.22***	1		
int_rt	0.01	0.01	0.04	0.00	0.00	0.52	3.02	11.961***	-0.219	1	
inf_rt	0.01	0.00	0.13	-0.01	0.01	3.25	18.02	2872.73***	0.521	-0.237	1

Note: Significance level; ***%1

As Yılancı and Tıraşoğlu (2016) stated in their research, before conducting empirical studies, it is essential to examine the structures of the financial and economic time series variables and to conduct analyses using processes and tests appropriate to these structures. In this respect, analyzing the linear or nonlinear structures of the series is a critical issue to consider for the analyses' validity and reliability. Thus, the model's functional form must be established initially in the analysis process. The aim of conducting a linearity test is to determine if the variables intended for statistical analysis exhibit a linear relationship (Nafisah et al., 2023). This study conducted analyses using the Wald test and L.R. test to evaluate the functional structure of the model and to determine if the variables demonstrate a linear or

nonlinear relationship during the examined period, with the results presented in Table 3. According to the results of both tests, the null hypothesis that the model is linear is rejected at the 1% and 10% significance levels. These results show a nonlinear connection among the *smi*, *int_rt* and *inf_rt*.

Table 3. Linearity Test Results

	Test Statistics	p-value
Wald test	49.88	[0.000]***
L.R. test	3.41	[0.064]*

Note: Significance level; ***%1, *%10

Once it is established that the model has a nonlinear structure, it becomes essential to identify the regime number resulting from the structural break in the second stage. Breaks may be either single or multiple. The Bai-Perron multiple structural break test was employed to assess this and the findings are presented in Table 4. The results of the Bai-Perron test conducted with the maximum five break options indicated that the ideal number of breaks was found to be one. The F and Scaled F statistics computed for a break number exceed the critical value. Furthermore, the break date was set as May 2021.

Table 4. Bai-Perron Multiple Structural Break Test Results

Break	F-Statistics	Scaled F-Statistic	Critical Value *	Estimated Break Dates
0-1**	265.351	796.054	13.98	2021-05
1-2	3.406	10.220	15.72	2010-03 2021-05
2-3	1.513	4.541	16.83	2009-07 2017-04 2021-05
3-4	0.239	0.718	17.61	2008-01 2011-03 2017-04 2021-05
4-5	0.000	0.000	18.14	2008-01 2011-03 2015-01 2018-03 2021-05

Note: Significance level; **5%, *Bai-Perron critical values

Once it is confirmed that there exists a nonlinear link among the variables and a structural break during the examined period, the data will undergo a stationarity test. Wahab et al. (2023) state that stationarity is a characteristic in which the statistical properties of a time series do not change over time. Having stationary data is crucial for precise modeling and credible analysis. Traditional unit root tests such as ADF, P-P, KPSS, DF-GLS, and Ng-Perron tests can yield varying results in the presence of structural breaks (Yıldırım et al., 2015; Diler, 2018). Applying unit root testing in a structural break offers two possible advantages. Firstly, it prevents biasing test outcomes towards non-rejection. This method will also offer valuable insights to ascertain if a structural break in a specific variable is connected to government policy, financial crises, regime shifts, or other factors, as it can identify when a structural break is expected to happen (Ike et al., 2024). Thus, to assess the stationarity of the data, unit root tests that consider the structural break were conducted; the Zivot-Andrews test, which is a test for a single internal break, along with ADF tests with Structural Breaks were utilized, and the findings are presented in Table 5. The null hypothesis for the Zivot-Andrews test is that the variables examined have a unit root, whereas the alternative does not have a unit root. Accordingly, the null hypothesis is rejected for the *smi* and *inf_rt* variables in different models but cannot be rejected for the *int_rt* variable. On the other hand, the null hypothesis of a unit root in the ADF test with structural

break was rejected for all variables in the fixed and trended models, and the series were stationary at their levels.

Table 5. Unit Root Test Results with Structural Breaks

Test	**Zivot-Andrews Test**			**ADF Test with Structural Break**	
Model	**Constant**	**Trend**	**Costant+Trend**	**Constant**	**Constant+Trend**
smi	5.209** [2021-03]	-2.418 [2021-03]	-3.738 [2021-03]	-0.770 [2023-01]	-4.637* [2024-04]
inf_rt	-6.729*** [2021-03]	-6.190*** [2019-07]	-6.507*** [2021-03]	-10.789*** [2021-06]	-11.126*** [2021-11]
int_rt	-3.554 [2008-12]	-2.847 [2021-03]	-4.802 [2008-12]	-4.548** [2008-11]	-5.097* [2008-11]

Note: Significance level; ***%1, **%5, *%10, Breaking dates are given in parentheses

The results of the threshold regression analysis, which is the basic analysis method, are presented in Table 6. The threshold regression analysis results indicate a break, leading to two regimes, with the threshold variable valued at 2.67%. Thus, when monthly consumer *inf_rt* is 2.67% or lower, the rise in monthly bank deposit *int_rt* has a statistically meaningful reducing impact on the *smi*. This situation is consistent with theoretical expectations and can be interpreted as investors preferring favor bank deposit *int_rt* over stock investments during periods of low *inf_rt*. As emphasized by Amata et al. (2016), there is a positive connection among *inf_rt* and stock market volatility in the short and long term. Accordingly, it may not be possible to make big profits in stock markets due to low stock market volatility in low inflation periods. In this respect, the stagnation seen in stock markets may lead investors to want to evaluate their investments in increasing bank deposit *int_rt*. This result, which is consistent with theoretical expectations, is also similar to the findings obtained from the studies of Hashmi and Chang (2023), Kazak (2023), Gu et al. (2022), Baykara (2021), Münyas (2019), Bissoon et al. (2016), Al-Mukit (2013), Alam and Uddin (2009). In the model, May 2021 is the date of the structural break. In periods of *inf_rt* above the threshold value of 2.67%, an increase in monthly bank deposits has a statistically meaningful and increasing effect on the *smi*. The following arguments can be put forward, considering that this situation occurs during periods of high *inf_rt* and needs explanation.

Table 6. Threshold Regression Analysis Results

	Regime 1: Low inflation period inf_rt ≤ %2.67			**Regime 2**: High inflation period inf_rt > %2.67%		
Variables	**Coefficient**	**95% Confidence Interval**		**Coefficient**	**95% Confidence Interval**	
int_rt	-32557.71 [0.001]***	[-51162.45	-13952.96]	187718.3 [0.002]***	[114207.3	261229.4]
c	1439.273 [0.000]***	[1043.085	1835.462]	2560.423 [0.000]***	[1421.05	3699.797]

Note: Significance level; *** %1

In Turkey, annual *inf_rt* in 2020, 2021, 2022, and 2023 was 14.60%, 36.08%, 64.27%, and 64.77%, respectively. 2021, there was a significant increase in *inf_rt*, especially in the last quarter. For example, *inf_rt* in December 2021 was very high at 13.58%. Ünüvar and Aktaş (2022) argued that the main reason for the increase in *inf_rt* during the last period of 2021 was

the exchange rate increase. In addition, the increase in international food prices, agricultural drought, and supply problems have increased *inf_rt*. It has been stated that there is an indirect connection between this increase in *inf_rt* and the COVID-19 outbreak. However, the Central Bank data shows that policy *int_rt* have been below high *inf_rt*. For example, the policy *int_rt* of 17% in December 2020 was 14% in December 2021 and 9% in November 2022. Alongside the policy *int_rt*, the *int_rt* on bank deposits has been observed to be lower than *inf_rt*. According to Graph 1(d) and Graph 1(e) in the Appendix, from January 2003 to May 2021, monthly bank deposit *int_rt* were typically higher than the monthly consumer *inf_rt*, with only minor negative differences observed in certain months.

Conversely, following May 2021, identified as the structural break date, an opposite trend was observed where monthly bank deposit *int_rt* fell below *inf_rt*. As a result, because the Central Bank's low *int_rt* policy was set below *inf_rt*, investors sought refuge in the stock market to safeguard against inflation. Due to high inflation and, conversely, low *int_rt*, negative real *int_rt* does not present an appealing opportunity for investors. As a result, investors have focused on stock markets to safeguard themselves from inflation. These findings indicate that the connection among deposit *int_rt* and the *smi* does not follow a linear pattern during periods of low and high *inf_rt*.

4. Conclusion and Recommendations

This research investigates the impact of deposit interest rates on Turkey's stock market index at a specific inflation rate. The research spans from January 2003 to June 2024. The occurrence of numerous domestic and international political, economic, financial, and epidemic risk factors indicates that the impact of interest rate and inflation rate on stock prices is not consistent and may differ based on the levels of these rates, suggesting a possible threshold effect in the connection among the variables. As a result, Threshold Regression Analysis was utilized as the primary analysis method in the research. Moreover, descriptive statistical tests and several econometric methods, including linearity, structural break, and stationarity analysis, were employed to generate trustworthy results and to uncover the connection between stock market price fluctuations and factors like inflation rate and interest rate.

The study has three important results, which aim to reach empirical evidence on how the deposit interest rates affect the stock market index depending on the inflation level. First, the value of the threshold variable inflation rate was found to be 2.67%. At this and below inflation rates, the increase in interest rates has a decreasing effect on the stock market index, which is in line with theoretical expectations. Second, in monthly inflation rates above the threshold value, the increase in interest rate has an increasing effect on the stock market index. As a potential reason for this, due to the low interest rates policy implemented in the country, interest rates are below inflation rates, and investors may have turned to the stock market to protect themselves from inflation. Third, it was observed that there was a nonlinear connection between the interest rates and the stock market index in the country during the analysis period.

The subsequent recommendations can be proposed for decision-makers, given that the outcomes achieved carry practical significance. First, based on these findings, individual and institutional stock market investors should be attuned to fluctuations in macroeconomic variables like inflation rate and interest rates, as these variables have demonstrated considerable

impacts on the stock market. Second, because of the nonlinear connection between interest rates and the stock market index, portfolio management should follow dynamic strategies. Third, these findings can form a basis for investors' decision-making mechanisms regarding how interest rates affect the stock market at a particular inflation rate level.

Data regarding the variables used in the study prior to 2003 could not be obtained. This can be expressed as a limitation of the study. In addition, in future studies, the reflections of the interest rate decisions taken by the U.S. Federal Reserve on Borsa Istanbul can be suggested as another research topic.

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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 are no potential conflicts of interest in this study.

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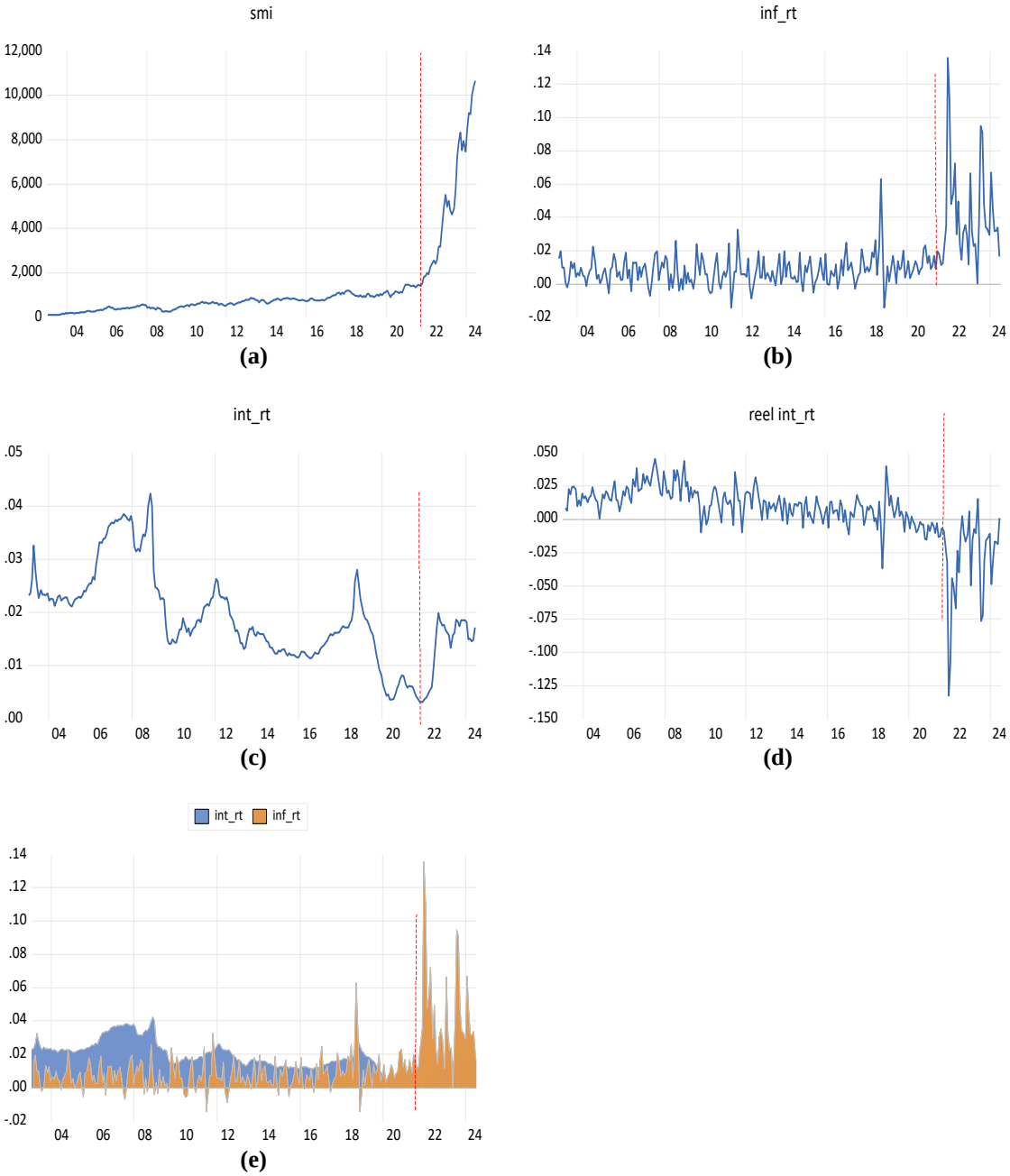
APPENDIX-I



Graph 1. Time Path Graphs of Variables

Note: The red dashed line on the graphs indicates the break date, May 2021.

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THE NEXUS BETWEEN CDS PREMIUMS AND EXCHANGE RATES: EVIDENCE FROM BRICS COUNTRIES AND TÜRKİYE*

CDS Primleri ile Döviz Kurları Arasındaki Bağlantı: BRICS Ülkeleri ve Türkiye'den Kanıtlar

Yüksel İLTAŞ** **Fatih GÜZEL*****

Keywords:
BRICS-T, Exchange Rate, CDS Premiums, RALS-LM Unit Root Test, RALS-EG Cointegration Test

JEL Kodları:
C22, C58, F31, G17, G19.

Abstract

This study investigates the long-term relationship between Credit Default Swap (CDS) premiums and exchange rates among the BRICS-T countries (Brazil, Russia, India, China, South Africa, and Turkey) known for their significant impacts on both regional and global dynamics, advanced industrialization, rapid economic growth, and considerable profit potential. Utilizing the RALS-LM unit root test and the RALS-EG cointegration test, and Hacker and Hatemi-J bootstrap causality test, this research circumvents the limitations commonly associated with traditional econometric approaches. A comprehensive and up-to-date dataset, reflecting intensive global and regional movements, was employed, consisting of daily data from January 2020 to June 2024. The findings indicate a long-term relationship between CDS premiums and exchange rates in all countries except Turkey. As the relationship is positive, it can be interpreted that an increase in the exchange rate will increase the CDS premium of countries. In terms of causality, strong evidence that the CDS premium is the cause of the exchange rate is only valid for Turkey. For Brazil, Russia, China and South Africa, we find that the exchange rate is the cause of the CDS premium. As a result, it is concluded that exchange rate movements may affect CDS premiums in these countries.

Anahtar Kelimeler:
BRICS-T, Döviz Kuru, CDS Primleri, RALS-LM Birim Kök Testi, RALS-EG Eşbütünleşme Testi

JEL Codes:
C22, C58, F31, G17, G19.

Öz

Bu çalışmada bölgesel ve küresel çaptaki dinamiklerde önemli etkilere sahip, sanayileşme yolunda ilerlemiş, hızlı büyüyen ve yüksek kazanç imkânı sunan gelişmekte olan ülkelerden oluşan BRICS-T (Brezilya, Rusya, Hindistan, Çin, Güney Afrika ve Türkiye) grubu ülkelerinin CDS primleri ile döviz kuru arasındaki uzun dönem ilişkisi analiz edilmektedir. Analizler, geleneksel ekonometrik testlerin kısıtlamalarını barındırmayan RALS-LM birim kök testi, RALS-EG eşbütünleşme ve Hacker ve Hatemi-J (2012) bootstrap nedensellik testi ile gerçekleştirilmiştir. Küresel ve bölgesel hareketlerin yoğun olarak yaşandığı geniş ve güncel bir veri seti kullanılmıştır. Veri seti Ocak 2020 – Haziran 2024 dönemini kapsayan günlük frekanslı verilerden oluşmaktadır. Elde edilen bulgular Türkiye hariç diğer ülkelerde (Brezilya, Rusya, Çin ve Güney Afrika) CDS pirimi ile döviz kuru arasında uzun dönemli bir ilişki olduğunu göstermektedir. İlişkinin pozitif olması neticesinde, döviz kurundaki bir artışın ülkelerin CDS primini yükselteceği yorumu yapılabilir. Nedensellik ilişkisi açısından, CDS priminin döviz kurunun nedeni olduğuna yönelik güçlü kanıtlar sadece Türkiye için geçerlidir. Brezilya, Rusya, Çin ve Güney Afrika içim döviz kurunun CDS priminin nedeni olduğu bulgusuna ulaşılmıştır.

* This study was presented at the 27th Finance Symposium, revised, expanded, and reprepared.

** Assoc. Prof. Dr., Kırşehir Ahi Evran University, Faculty of Economic and Administrative Sciences, Kırşehir, Türkiye, yiltas@ahievran.edu.tr

*** Assoc. Prof. Dr., Kırşehir Ahi Evran University, Faculty of Economic and Administrative Sciences, Kırşehir, Türkiye, fatih_guzel1990@yahoo.com

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1. Introduction

Derivatives function as hedging instruments aimed at mitigating counterparty risks and various other risks. Credit derivatives are employed to provide protection and insurance against the risk of default by borrowers. Among these, Credit Default Swaps (CDS) are the most commonly traded instruments worldwide (Hull and White, 2000). CDS instruments, first designed by Blythe Masters, a former executive at JP Morgan, in 1994, were developed to transfer the risk of the borrower failing to meet their payment obligations (Corte et al., 2021; Saparca and Yenipazarlı, 2023). CDS premiums serve as a measure of the likelihood of default by the borrowing party, enabling risk assessment.

CDS premiums serve as a measure of the likelihood of default by the borrowing party, enabling risk assessment. Similarly, exchange rates reflect the strength of a national currency and the economic-political stability of a country. Fluctuations in exchange rates occur in response to distortions in economic indicators and changes in risk perception. Notably, the depreciation of a country's national currency is often associated with increased country risk, which can prompt investors to withdraw from the market (Hui and Chung, 2011). Therefore, understanding the relationship between CDS premiums and exchange rates is crucial for assessing economic stability and managing risks in financial markets.

CDS premiums can vary according to market conditions and are updated on a daily basis. A high premium indicates a higher level of counterparty risk (Çonkar and Vergili, 2017). Following the 2008 global financial crisis, these derivative instruments were suggested as alternatives to credit rating agency assessments (Financial Stability Board, 2010). This is attributed to the ability of CDS premiums to reflect the instantaneous response of credit risk to rapidly changing market conditions, whereas credit ratings are updated more slowly and less frequently.

Foreign currency liabilities are frequently regarded as a financial fragility in emerging markets. It is widely acknowledged that these liabilities intensified the Mexican Debt crisis (1994), the Russian Ruble Crisis (1998), and the East Asian crisis of the late 1990s (Eichengreen and Hausmann, 1999). The management of these debts is critically dependent on exchange rate policies (Bordo et al., 2010). Furthermore, fluctuations in exchange rates also represent a market-based measure of a country's default risk. The risk of default is determined by the country's asset and debt levels. Exchange rates are directly related to the ability to service debts. An increase in the exchange rate indicates a depreciation of the national currency against foreign currencies, which results in a higher burden of foreign-denominated debts. This, in turn, raises the likelihood of default and the associated country risk. Additionally, a rising exchange rate signals a deterioration in the country's financial system and can trigger capital flight, further increasing default probabilities (Wang et al., 2022). In this context, an increase in the exchange rate is expected to elevate CDS premiums. Overall, understanding the relationship between exchange rates and CDS premiums is a significant step in evaluating the value of a national currency and its impact on economic stability. This relationship can aid investors in developing risk management strategies and mitigating uncertainties in financial markets.

This study analyzes the long-term relationship between CDS premiums and exchange rates within the BRICS-T group (Brazil, Russia, India, China, South Africa, and Turkey), comprised of emerging economies with significant impacts on regional and global dynamics, advanced industrialization, rapid growth, and substantial profit potential. The general acceptance of the

countries concerned as investment factors, the lack of consensus among previous studies on the relationship between the relevant parameters, the unprecedented processes both regionally and globally in the countries concerned, the introduction of new methods that can analyze the relevant process or time and overcome the limitations of traditional empirical methods to a large extent constitute the motivation for the current study and the reason for the analyses. The analyses are conducted using the RALS-LM Unit Root Test and the RALS-EG Cointegration Test, which do not carry the limitations of traditional econometric tests, through a comprehensive and current dataset reflecting extensive global and regional movements. The study includes a literature review summarizing previous research, a methodology section detailing the dataset and tests employed, empirical findings reporting the test results, and a conclusion section providing a general evaluation of the study and its findings.

2. Literature Review

Multiple studies in the literature investigate the relationship between CDS premiums and various variables. Table 1 below includes studies that are directly related to this topic. It is apparent that interest in this issue has risen, particularly in recent years. The incorporation of many variables and approaches in the analytical process aims to evaluate the subject from diverse viewpoints.

Table 1. Literature Summary

Author (Year)	Country	Variable	Method	Period	Findings
Longstaff et al., 2011	26 Countries	CDS, Stock Market Index, Exchange Rate, etc.	Clustering and Regression Analysis	10.2000-01.2010	In emerging markets, CDS and exchange rates mutually affect each other.
Silva and Paulo, 2015	Brazil	CDS, Stock Market Index, VIX, National Currency FX Volatility, etc.	Linear Regression	05.2009-05.2014	There is a linear relationship between CDS and National Currency FX Volatility
Başarır and Keten, 2016	12 Developing Countries	CDS, Exchange Rate (USD), Stock Market Index	Granger Causality, Kao, Pedroni Panel Cointegration	01.2020-01.2016	CDS → Exchange Rate
Çonkar and Vergili, 2017	Turkey	CDS Exchange Rate (Currency Basket)	Johansen Cointegration, Granger Causality	01.2010-08.2015	Exchange Rate (USD) → CDS
Aksoylu and Görmüş, 2018	9 Developing Countries	CDS, Exchange Rate (USD), Interest Rate, VIX Index	Granger Causality, Hatemi J Causality	06.2005-07.2015	CDS ↮ Exchange Rate
Özpınar et al., 2018	Turkey	CDS, Exchange Rate (USD), Interest Rate	Granger Causality, Johansen Cointegration	09.2005-02.2017	Exchange Rate → CDS, There is a positive cointegration between exchange rate and CDS.
Şengül, 2020	Turkey	CDS, Exchange Rate (USD)	Hatemi J - Roca Causality	05.2013-10.2020	CDS → Exchange Rate, $ER^- \rightarrow CDS^-$, $CDS^+ \rightarrow ER^+$
Uzunoğlu et al., 2020	Turkey	CDS Exchange Rate (Currency Basket), Foreign Political Actors	Granger Causality, GARCH	01.2007-3.2020	CDS ↔ Exchange Rate
Bayhan et al., 2021	Turkey	CDS, Exchange Rate (USD)	Frequency Domain Causality	03.2020-04.2021	Long Term: Exchange Rate → CDS

Table 1. Continued

Calice and Zeng, 2021	29 Countries	CDS, Exchange Rate (USD), Stock Market Index, etc.	Fama-MacBeth Regression	12.2007-06.2017	In general, country CDSs affect the exchange rate in emerging markets and can be used to forecast the exchange rate.
Corte et al., 2021	8 Developed and 12 Developing Countries	CDS, Exchange Rate	Linear Regression	01.2003-11.2003	There is a strong bidirectional relationship between CDS and exchange rate. Moreover, an increase in the CDS spread decreases the value of the local currency.
Çetin, 2022	Turkey	CDS, Exchange Rate (USD), Stock Market Index, Interest rate	VAR Granger Causality	04.2010-01.2021	CDS → Exchange Rate
Wang et al., 2022	Latin American Countries	CDS, Exchange Rate (USD), Interest rate, VIX, etc	Granger Causality	01.2004-09.2010	CDS ↔ Exchange Rate
Buz and Küçükkocaoğlu, 2023	Turkey	CDS, Exchange Rate (USD), Stock Index, Inflation, Interest Rate, Current Account Balance, GDP	Toda-Yamamoto Causality	01.2005-11.2020	CDS ↮ Exchange Rate
Saparca and Yenipazarlı, 2023	Turkey	CDS, Exchange Rate (USD), Stock Market Index	Toda-Yamamoto Causality	01.2009-03.2023	CDS ↔ Exchange Rate
Sarı, 2024	Turkey	CDS, Exchange Rate (USD), Stock Market Index, Inflation, Current Account Balance, Industrial Production Index	RALS Regression, Granger Causality	01.2008-08.2023	CDS ↮ Exchange Rate

Upon reviewing Table 1, which summarizes the literature, it is noteworthy that there is a lack of consensus regarding the findings of the studies. From a causality perspective, some studies report that CDS premiums are the cause of the exchange rate (Başarır and Keten, 2016; Şengül, 2020; Çetin, 2022), while others attribute the causality to the exchange rate itself (Çonkar and Vergili, 2017; Özpınar et al., 2018; Bayhan et al., 2021). Additionally, some research reports the existence of a bidirectional relationship (Uzunoğlu et al., 2020; Wang et al., 2022; Saparca and Yenipazarlı, 2023), In contrast, other research suggests that there is no causal relationship between the two variables (Aksoylu and Görmüş, 2018; Sarı, 2024). The presence of differing perspectives and findings in the literature underscores the need for novel tests that transcend the limitations of traditional econometric methods. Given the recent experiences of unprecedented regional and global impacts, coupled with the significance of the topic, it has become essential to contribute original evaluations to the literature. This study has been prepared with these factors in mind.

3. Econometric Methodology

This section summarizes the econometric methodology of the study. Financial time series are created by arranging sequentially observed data from financial markets according to their

chronological order. Prior to performing the econometric analysis of a financial time series, it is crucial to assess the stationarity levels of the series (Tatoğlu, 2013: 199). Unit root tests, utilized to assess the stationarity of time series, generally presuppose that the error terms follow a normal distribution. Im et al. (2014) observed in their study that, although the asymptotic distribution of test statistics in unit root tests is unchanged, the non-normal distribution of error terms must not be overlooked.

This paper assessed the stationarity levels of financial time series utilizing the RALS-LM unit root test, as formulated by Meng et al. (2014), which yields more robust outcomes in the presence of violations of the normality assumption for error terms. Following the determination of the stationarity levels of the variables, the presence of long-term cointegration relationships among them was examined utilizing the RALS-EG cointegration test established by Lee et al. (2015). Based on the results of the RALS-EG cointegration test, long-term coefficient estimation was conducted to determine the direction and magnitude of the relationships among the series that were found to move together in the long run. The Dynamic Ordinary Least Squares (DOLS) and Fully Modified Ordinary Least Squares (FMOLS) techniques were utilized to estimate the long-term coefficients. In the concluding phase of the empirical analysis, Hacker and Hatemi-J (2012) bootstrap causality test was used to identify the causal relationships between the variables.

3.1. Data Set

This study examines the relationship between exchange rates and CDS premiums for BRICS-T nations utilizing daily frequency data from January 2020 to June 2024. The need for foreign resources, particularly foreign exchange, due to their status as developing economies, along with the regional and even global scope of their influence, are critical factors in determining the sample. The analysis period, spanning from January 2020 to June 2024, was determined by practical factors such as data availability, the adequacy of historical records, and the consistency of data publication. Table 2 presents the abbreviations, definitions, data periods, and data sources for the variables utilized in the analysis.

Table 2. Variables Information

Variable	Description	Country	Data Source	Freq.	Period
CDSTR	Turkiye Credit Default Swap	Türkiye	Investing	Daily	2020:01-2024:06
USDTL	USD/Turkish Lira Exchange Rate	Türkiye	Investing	Daily	2020:01-2024:06
CDSBRG	Brazil Credit Default Swap	Brazil	Investing	Daily	2020:01-2024:06
USDBRL	USD/Brazilian Real Exchange Rate	Brazil	Investing	Daily	2020:01-2024:06
CDSRUG	Russia Credit Default Swap	Russia	Investing	Daily	2020:01-2022:05
USDRUB	USD/Russian Ruble Exchange Rate	Russia	Investing	Daily	2020:01-2022:05
CDSCNG	China Credit Default Swap	China	Investing	Daily	2020:01-2024:06
USDCNY	USD/Chinese Yuan Exchange Rate	China	Investing	Daily	2020:01-2024:06
CDSZAG	South Africa Credit Default Swap	S. Africa	Investing	Daily	2020:01-2024:06
USDZAR	USD/South African Rand Exc. Rate	S. Africa	Investing	Daily	2020:01-2024:06

The study focuses on the relationship between exchange rates and CDS spreads within the context of the BRICS-T countries. Data for CDS spreads and exchange rate variables for Brazil, China, South Africa, and Turkey is available for the period from January 2020 to June 2024. For Russia, data is available for the period from January 2020 to May 2022. However, data for India

has been excluded from the dataset due to irregularities in data publication and supply, resulting in significant data losses. This study employed the logarithmic transformation of the data in econometric analyses to achieve more consistent and efficient empirical results, while also ensuring a more stable representation of the series.

3.2. RALS-LM Unit Root Test

Financial time series refers to sequences of consecutive data observed in financial markets, arranged in the order of their occurrence. Stock prices, stock market indices, interest rates, and exchange rates exemplify financial time series. The time series structure and dynamics of financial variables are of great importance for understanding and analyzing the data generation processes of these data (Çil, 2018: 5). Unit root tests used in econometric time series analysis assume that the error terms of the test regressions conform to a normal distribution. In their study, Im, Lee, and Tieslau (2014) emphasized that, although the asymptotic distributions of test statistics in unit root tests remain unaffected, the normality assumption should not be disregarded (Hepsağ, 2022: 203).

The RALS-LM test, proposed by Meng, Im, Lee, and Tieslau (2014), is an adaptation of the Residual Augmented Least Squares (RALS) method developed by Im and Schmidt (2008) for use in the LM-type unit root test. The RALS-LM unit root test, which does not account for structural breaks, follows a two-step estimation procedure. In the first step, the conventional LM test regression, as developed by Schmidt and Phillips (1992), is estimated using the least squares method, and the residual series from this regression is obtained (Hepsağ, 2022: 211). The LM unit root test statistic is typically derived from the following regression, in accordance with the LM (score) principle (Meng vd., 2014: 346-348):

$$\Delta y_t = \delta' \Delta z_t + \phi \tilde{y}_{t-1} + \varepsilon_t \tag{1}$$

where $\tilde{y}_t = y_t - \tilde{\psi} - z_t\tilde{\delta},\ t = 2, \dots, T$; $\tilde{\delta}$ is the vector of coefficients in the regression of Δy_t on Δz_t, To address autocorrelated error terms, it is possible to include the terms $\Delta\tilde{y}_{t-1}$ in equation (1), where j=1,…,p, and the testing regression is expressed as follows:

$$\Delta y_t = \delta' \Delta z_t + \phi \tilde{y}_{t-1} + \sum_{j=1}^{P} c_j \Delta \tilde{y}_{t-j} + e_t \tag{2}$$

The term $Z_t = [1, k]$ in Equation (2) represents the deterministic component, which includes the constant term and the trend function. Equation (3) illustrates the calculation of the second and third moments of the residual series:

$$m_2 = \frac{\sum_{t=1}^{T} \tilde{\varepsilon}_t^2}{T},\quad m_3 = \frac{\sum_{t=1}^{T} \tilde{\varepsilon}_t^3}{T} \tag{3}$$

In Equation (3), T represents the number of observations, m2, and m3 are the second and third moments of the residuals, respectively. While $\hat{\varepsilon}_t^2$ represents the squared residuals obtained in the first stage of the test, $\hat{\varepsilon}_t^3$denotes the cubed residuals. After the second and third moments of the residual series are calculated, the variables $(\widehat{w}_{2t})$ and $(\widehat{w}_{3t})$ referred to as residual-augmented variables, are computed as shown below.

$$\widehat{w}_t = [\hat{e}_t^2 - m_2, \hat{e}_t^3 - m_3 - 3m_2\widehat{e_t}]' \tag{4}$$

In the second step of the test, the residual-augmented variables $(\widehat{w}_{2t})$ and $(\widehat{w}_{3t})$ are included into the standard LM test regression defined in Equation (2), resulting in the RALS-LM test regression, which does not account for structural breaks:

$$\Delta y_t = \delta' \Delta z_t + \phi \tilde{y}_{t-1} + \sum_{j=1}^{p} g_j \Delta \tilde{y}_{t-1} + \widehat{w}'_t \gamma + e_t \quad (5)$$

The RALS-LM statistic is derived from the conventional least squares estimation method applied to Equation (5). The test statistic used to assess the presence of a unit root in the series is calculated as follows:

$$\tau_{RLM} \rightarrow \rho \tau_{LM} + \sqrt{1-\rho^2}\, N\,(0,1) \quad (6)$$

In the equation (5), τ_{RLM} represents the test statistic calculated for the case without structural breaks, while τ_{LM} denotes the conventional LM test statistic. The parameter estimated as $\rho^2, \hat{p}^2 = \hat{\sigma}_u^2 \Big/ \hat{\sigma}_\varepsilon^2$ is calculated as the ratio of the variance estimate of the error term in the RALS-LM equation to the variance estimate of the error term in the conventional LM equation, and it determines the distribution of the τ_{RLM} test statistic.

In the RALS-LM unit root test, the null hypothesis indicating the presence of a unit root $(\emptyset = 0)$ is tested against the alternative hypothesis that the series is stationary $(\emptyset < 0)$. If the calculated τ_{RLM} test statistic is less in absolute terms than the critical value determined based on ρ^2, the null hypothesis cannot be rejected, and it is concluded that the time series follows a unit root process. Conversely, if the τ_{RLM} test statistic exceeds the critical value established by ρ^2 in absolute terms, the null hypothesis is rejected, and it is concluded that the time series follows a stationary process.

3.3. Lee, Lee and Im (2015) RALS Cointegration Test

The cointegration test introduced by Engle and Granger (1987) (EG) is a method used to investigate whether two or more series exhibit a common movement trend in the long term. It is assumed that the error terms of regression tests used in cointegration analysis, which investigates the long-term relationship between variables, follow a normal distribution. When the error terms of regression tests used in cointegration analysis do not follow a normal distribution, the asymptotic distributions of the test estimators remain unaffected. Therefore, cointegration tests can be applied even if the normality assumption is not met. In the study by Lee et al. (2015), it is stated that although the asymptotic distribution of test statistics in cointegration analysis remains unchanged, incorporating non-normality information into the analysis process can yield more efficient estimators and enhance the robustness of cointegration tests (Hepsağ, 2022: 235).

Lee et al. (2015) enhanced the power of the EG approach by developing RALS-based cointegration tests through the adaptation of the RALS method. The four test regressions and their names considered in the RALS cointegration tests developed by Lee et al. (2015) are as follows (Lee et al., 2015: 5):

$$ECM: \Delta y_{it} = d_{it} + \delta_1 z_{t-1} + \emptyset' \Delta y_{2t} + \widehat{w}'_t \gamma + v_t \quad (7)$$

$$ADL: \Delta y_{1t} = d_{1t} + \delta_1 y_{1,t-1} + \gamma' y_{2,t-1} + \emptyset' \Delta y_{2t} + \widehat{w}'_t \gamma + v_t \quad (8)$$

$$EG: \Delta\hat{u}_t = d_{1t} + \delta_1\hat{u}_{t-1} + \hat{w}'_t\gamma + v_t \quad (9)$$

$$EG2: \Delta\hat{u}_t = d_{1t} + \delta_1\hat{u}_{t-1} + \emptyset'\Delta y_{2t} + \hat{w}'_t\gamma + v_t \quad (10)$$

In the first stage of the RALS cointegration test, the test regressions in equations (7), (8), (9), and (10) are estimated. Thereafter, the second and third moments of the residual series are calculated to address non-normality. The second and third moments of the residual series are computed as follows:

$$m_2 = \frac{\sum_{t=1}^{T}\hat{\varepsilon}_t^2}{T} \quad (11)$$

$$m_3 = \frac{\sum_{t=1}^{T}\hat{\varepsilon}_t^3}{T} \quad (12)$$

In equations (11) and (12), m2 and m3 denote the second and third moments of the residuals, respectively. Once the second and third moments are calculated, $(\widehat{w}_{2t})$ and $(\widehat{w}_{3t})$, referred to as residual-augmented variables, are computed as follows:

$$\widehat{w}_{2t} = \hat{\varepsilon}_t^2 - m_2 \quad (13)$$

$$\widehat{w}_{3t} = \hat{\varepsilon}_t^3 - m_3 - 3m_2\hat{\varepsilon}_t \quad (14)$$

In the second stage of the RALS cointegration tests, the residual-augmented variables $(\widehat{w}_{2t})$ and $(\widehat{w}_{3t})$ are incorporated into the conventional test regressions presented in equations (7), (8), (9), and (10). Lee, Lee, and Im (2015) derived the distributions and critical values for the residual-augmented versions of all four conventional tests presented above. However, they found that the RALS-EC and RALS-EG cointegration tests exhibit size distortion and possess very low power. Consequently, they recommend the use of the RALS-ADL and RALS-EG2 cointegration tests in their study (Hepsağ, 2022: 237):

$$RALS-ADL: \Delta y_t = d_t + \delta y_{t-1} + \emptyset\Delta x_t + \sum_{i=1}^{k} a_i\Delta y_{t-i} + \gamma_2\widehat{w}_{2t} + \gamma_3\widehat{w}_{3t} + u_t \quad (15)$$

$$RALS-EG2: \Delta\hat{u}_t = d_t + \delta\hat{u}_{t-1} + \emptyset\Delta x_t + \sum_{i=1}^{k} a_i\Delta u_{t-i} + \gamma_2\widehat{w}_{2t} + \gamma_3\widehat{w}_{3t} + u_t \quad (16)$$

After estimating the test regressions in equations (15) and (16) using ordinary least squares, the test statistics for testing the presence of a unit root are calculated as follows:

$$\tau_{RALS-ADL} = \rho\tau_{ADL} + \sqrt{1-\rho^2}Z \quad (17)$$

$$\tau_{RALS-EG2} = \rho\tau_{EG2} + \sqrt{1-\rho^2}Z \quad (18)$$

In equations (17) and (18), ρ^2 represents the square of the long-term correlation coefficient, estimated as $\hat{\rho}^2 = \hat{\sigma}_{u\varepsilon}^2 \Big/ \hat{\sigma}_u^2\hat{\sigma}_\varepsilon^2$.

In the RALS-ADL and RALS-EG2 cointegration tests, the null hypothesis, which indicates the absence of cointegration (δ = 0), is tested against the alternative hypothesis, which suggests the presence of cointegration (δ <0). If the calculated $\tau_{RALS-ADL}$ and $\tau_{RALS-EG2}$ test statistics are smaller than the critical value determined by the ρ^2 value, the null hypothesis cannot be rejected, leading to the conclusion that no cointegrated relationship exists. Conversely, if the $\tau_{RALS-ADL}$

and $\tau_{RALS-EG2}$ test statistics exceed the critical value determined based on ρ^2, The null hypothesis is dismissed, signifying the existence of a cointegrated relationship.

3.4. Hacker and Hatemi-J (2012) Causality Test

The causality test is a method employed to ascertain the direction and impact of the relationship among two or more variables. One of the most commonly used and earliest methods in this field is the Granger causality test, introduced to the literature by Granger (1969) (Kutlar, 2019: 20). In Granger causality analysis, the stationary versions of the series are employed to ascertain the direction of the relationship between two variables. The Toda and Yamamoto (1995) causality test, founded on the Vector Autoregressive (VAR) model framework established in the empirical literature, accommodates series with varying integration orders. The bootstrap causality test proposed by Hacker and Hatemi-J (2006) follows the Toda-Yamamoto causality test protocol, with critical values obtained by bootstrap Monte Carlo simulation. However, the lag length of the VAR model used in the Hacker and Hatemi-J (2006) bootstrap causality test is determined exogenously. To address this limitation, the authors improved the test in 2012 by introducing the Hacker and Hatemi-J (2012) test, which allows for the endogenous determination of lag length.

Hacker and Hatemi-J (2012) employ the following Vector Autoregressive (VAR) model to test for Granger causality (Hacker and Hatemi-J, 2012: 146):

$$y_t = B_0 + B_1 y_{t-1} + \cdots + B_k y_{t-k} + u_t \tag{19}$$

Here, y_t, B_0 and u_t represent, respectively, the n x 1 vector, the n x n coefficient matrix for $B_i, i \geq 1$, and the error term u_t with an expected value of zero. The error vector u_t has an expected value of zero and is assumed to be independent and identically distributed with a non-singular covariance matrix $\boldsymbol{\Omega}$ that satisfies the condition $E|u_{it}|^{2+\lambda} < \infty$ for some $\lambda > 0$. Here, u_t denotes the i-th element of u_t. This assumption is necessary to ensure appropriate testing conditions. Non-Granger causality from the r-th element of y_t to the j-th element of y_t holds only if the following condition is satisfied:

$$H_0: \text{the element in } B_i\text{'s row j, column r is zero for } i = 1, \dots, k. \tag{20}$$

Hacker and Hatemi-J, in order to express a Wald test statistic that can be used to test the null hypothesis defined by Equation (20) in a compact form, assume that there are k pre-sample values available for each of the $y_{-k+1,\dots,}y_0$ variables and define the following matrixes (Hacker and Hatemi-J, 2012: 159-160):

$$Y \coloneqq \left(y_{1,\dots,}y_t\right) \ \ (n\ x\ T)\ matrix, \tag{21}$$

$$D \coloneqq \left(B_{0,}B_{1,\dots,}B_k\right) \ \ (n\ x\ (1+nk))\ matrix, \tag{22}$$

$$Z_t \coloneqq \begin{bmatrix} 1 \\ y_t \\ y_{\ t-1} \\ \vdots \\ y_{t-k+1} \end{bmatrix} \left((1+nk)x1\right) matrix, for\ t = 1, \dots, T. \tag{23}$$

$$Z \coloneqq (Z_0, \dots, Z_{T-1}) \ \ \left((1+nk)xT\right) matrix, and \tag{24}$$

$$\hat{\delta} \coloneqq (\hat{\varepsilon}_1, \dots, \hat{\varepsilon}_T) \ \ (n\ x\ T) matrix. \tag{25}$$

The null hypothesis of the Hacker and Hatemi-J (2012) test is stated as "no causality," and the Wald test statistic (W) necessary to test this hypothesis is derived using Equation (26).

$$W = \left(Q\hat{\beta}\right)' [Q((Z'2)^{-1} \otimes S_U)Q']^{-1}(Q\hat{\beta}) \quad (26)$$

Here, $\otimes$ represents the Kronecker product, which denotes the multiplication of all elements of the matrices, and Q is a matrix with dimensions k x n(1+nk). S_U; is the variance-covariance matrix of the error terms of the unrestricted VAR model and is defined as $S_U = S_U \delta S'/T - (1 + nk)$.

In the Hacker and Hatemi-J (2012) test, the suitable lag length is ascertained endogenously, and the Schwarz Bayesian Criterion (SBC) applied is defined as follows (Hacker and Hatemi-J, 2012: 147):

$$SBC = \ln\left(det\, \widehat{\Omega}_j\right) + k\left(\frac{n^2 \ln T}{T}\right) \quad (27)$$

Here, det $\widehat{\Omega}_k$ represents the determinant of the estimated variance-covariance matrix of the error term vector u_t when the VAR model is evaluated with a lag order of k. T is the quantity of observations (time periods) utilized to estimate the VAR model.

4. Empirical Findings

In this study, the conventional LM test was initially applied to determine the stationarity levels of the series, and the results are reported in Table 3. Examination of the descriptive statistics for the residual series obtained from the conventional LM test regression indicated, based on the Jarque-Bera test, that the residuals do not conform to a normal distribution. This finding suggests that the results obtained from the conventional LM test may not be reliable and are open to interpretation. Following the conventional LM test, due to the lack of normality in the residuals of the auxiliary regression models, the stationarity levels of the series were reassessed using RALS-LM tests, with the results presented in Table 3.

The τ-RALS-LM test statistic in Table 3 is compared with the critical values. If the calculated test statistic is less than the critical values, the null hypothesis indicating the presence of a unit root cannot be rejected. According to the RALS-LM unit root test results in Table 3, for all variables at their level values, the test statistics calculated at the 5% statistical significance level are, in absolute terms, smaller than the critical values based on ρ2, and thus, the null hypothesis cannot be rejected. Based on this result, it can be inferred that the series in the study follow a unit root process. The presence of a long-term cointegration relationship among the variables deemed non-stationary at level values by the RALS-LM unit root test was assessed using the RALS-EG (2015) cointegration test, and the results are reported in Table 4.

Table 3. Results of Conventional LM and RALS-LM Unit Root Tests

Country	Variable	Conventional LM Unit Root Test		RALS-LM Unit Root Test		
		τ-LM	JB	τ-RALS-LM	ρ^2	Decision
Türkiye	CDS	-2.03848	5153.94*	-1.03302	0.80	I(1)
	ΔCDS	-4,75673	1954.04*	-4.37834	0.70	I(0)
	USDTL	-1.59268	448420.96*	-1.28828	0.30	I(1)
	ΔUSDTL	-6.44397	25824.87*	-5.26209	0.30	I(0)
Russia	CDS	-1.24322	865425.27*	-0.12314	0.40	I(1)
	ΔCDS	-3,75487	24385.61*	-3.55029	0.40	I(0)
	USDRUB	-4.28477	738632.64*	-2.64064	0.40	I(1)
	ΔUSDRUB	-4.83062	31759.74*	-3.70213	0.60	I(0)
China	CDS	-2.92818	7641.95*	-3.12806	0.60	I(1)
	ΔCDS	-7.78085	4476,44*	-9.24561	0.60	I(0)
	USDCYN	-1.52421	810.99*	-0.77891	0.80	I(1)
	ΔUSDCYN	-5.45726	700.85*	-5.34966	0.80	I(0)
Brazil	CDS	-2.17485	19087.21*	-2.05003	0.60	I(1)
	ΔCDS	-4.93293	20551.42*	-5.06656	0.60	I(0)
	USDBRL	-1.27903	47.86*	-1.15126	0.90	I(1)
	ΔUSDBRL	-3.98717	48.56*	-3.75562	0.90	I(0)
S. Africa	CDS	-3.24087	6490.07*	-3.32271	0.60	I(1)
	ΔCDS	-3.67710	6660.41*	-3.60065	0.70	I(0)
	USDZAR	-1.40531	792.19*	-0.57607	0.80	I(1)
	ΔUSDZAR	-6.26974	773.01*	-6.58102	0.80	I(0)

Note: The critical values for the RALS-LM unit root test are sourced from Meng et al. (2014). For τ-RALS-LM with ρ^2=0.3, the critical values at the %1, %5 and % significance levels are: -3.205, -2.568 and -2.234 respectively. For ρ^2=0.4, the critical values at the %1, %5 and %10 % significance levels are: -3.299, -2.677 and -2.352. For ρ^2=0.6, the critical values at the %1, %5 and %10 significance levels are: -3.428, -2.836 and -2.535. ρ^2=0.7, the critical values at %1, %5 and %10 significance levels are: -3.474, -2.897 and -2.605. ρ^2=0.8, the critical values at %1, %5 and %10 significance levels are: -3.510, -2.947 and -2.667. ρ^2=0.9, the critical values at %1, %5 and % significance levels are: -3.538, -2.990 and -2.715. The difference operator (Δ) shows the difference of the variable. * It indicates that the null hypothesis of normal distribution is rejected at the 5% significance level.

According to the RALS-EG cointegration test results presented in Table 4, for Turkey, ρ2 is 0.7, and the critical value at the 5% significance level for a single independent variable is -3.535. Since the calculated τ-RALS-EG test statistic of -2.33223 is smaller in absolute terms than the critical value, the null hypothesis, which states the absence of a cointegration relationship, cannot be rejected. Based on this result, it is concluded that there is no long-term relationship between the CDS premium and the exchange rate for Türkiye.

Table 4. Results of the RALS-EG Cointegration Test

Country	Test Statistic	ρ2
$RALS\text{-}EG_{TÜRKİYE}$	-2,33223	0,70
$RALS\text{-}EG_{BRAZIL}$	-3,43401	0,50
$RALS\text{-}EG_{RUSSIA}$	-4,78972	0,60
$RALS\text{-}EG_{CHINA}$	-3,68877	0,60
$RALS\text{-}EG_{S.AFRICA}$	-3,94600	0,60

Note: The critical values are derived from the study by Lee et al. (2015). For the RALS-EG test, the critical values are as follows: for ρ^2=0.5, the critical value at the 5% significance level is-3.274; for ρ^2=0.6, the critical value at the 5% significance level is -3.428; and for ρ^2=0.7, the critical value at the 5% significance level is -3.535.

For Brazil, ρ2 is 0.5, and the critical value at the 5% significance level for a single independent variable is -3.274. As the calculated τ-RALS-EG test statistic of -3.43401 is larger in absolute terms than the critical value, the null hypothesis of no cointegration relationship is rejected. Consequently, it is inferred that a long-term relationship exists between the CDS premium and the exchange rate for Brazil.

For Russia, China, and South Africa, ρ2 is 0.6, with a critical value of -3.428 at the 5% significance level for a single independent variable. The separately calculated τ-RALS-EG test statistics for these three countries (-4.78972, -3.68877, and -3.94600, respectively) are all larger in absolute terms than the critical value, leading to the rejection of the null hypothesis of no cointegration relationship. This result indicates the presence of a long-term relationship between the CDS premium and the exchange rate for Russia, China, and South Africa.

To assess the magnitude of the detected long-term relationship, long-term coefficient estimates were obtained, and the results are presented in Table 5. Upon assessing the long-term coefficients derived from the DOLS and FMOLS methodologies presented in Table 5, it is evident that the findings are very analogous, signifying a positive impact of the exchange rate on the CDS premium for each nation. Based on this finding, it can be inferred that an increase in the exchange rate is likely to raise the CDS premium of the countries.

Table 5. Long-Term Coefficient Estimation Results

Variable	Dynamic OLS (DOLS)		Fully Modified OLS (FMOLS)	
	Coefficient	**Probability**	**Coefficient**	**Probability**
USD/BRL	2,418055*	0,000	2,417829*	0,000
USD/RUB	4,592034*	0,000	4,505400*	0,000
USD/CNY	3,918522*	0,000	3,881196*	0,000
USD/ZAR	2,045475*	0,000	2,024724*	0,000

Note: *, **, and *** denote significance levels of 1%, 5%, and 10%, respectively.

In the causality test developed by Hacker and Hatemi-J (2012), where the lag length is determined endogenously, the MWALD statistic—indicating causality from the first to the second variable—is compared against critical values obtained through the bootstrap method. If the MWALD statistic falls below these critical values, the null hypothesis (H0), which asserts the absence of a causal relationship, cannot be rejected, thus leading to the conclusion that no causality exists between the variables. In this study, the Hacker and Hatemi-J (2012) causality test was conducted, and the results are presented in Table 6.

Upon examining the results in Table 6, according to the Hacker and Hatemi-J (2012) bootstrap causality test results, Except for Türkiye, a statistically significant causality from exchange rates to CDS premiums at the 5% significance level has been observed in other countries. This finding suggests that exchange rate movements influence country risk premiums in BRICS nations, exerting a meaningful impact on CDS premiums. However, in the analysis conducted for Turkey, no significant causality from exchange rates to CDS premiums was identified, indicating that exchange rate fluctuations do not have a notable effect on CDS premiums in the Turkish context.

The Hacker and Hatemi-J (2012) bootstrap causality test results in Table 6 indicate that, at the 5% statistical significance level, there is no significant causal association from CDS premiums

to exchange rates in BRICS countries, with the exception of Turkey. This finding suggests that CDS premiums have no effect on exchange rates in BRICS countries.

Table 6. Results of the Hacker and Hatemi-J (2012) Bootstrap Causality Test[a]

Hypotheses	MWALD Test Statistic	Bootstrap Critical Values[b]			Decision
		1%	5%	10%	
USDTRY ≠> CDSTR	1.603	13.327	6.778	4.660	Fail to Reject H_0
CDSTR ≠> USDTRY	26.873*	13.582	7.072	4.741	Reject H_0
USDBRL ≠>CDSBRL	15.257*	9.287	5.905	4.536	Reject H_0
CDSBRL ≠> USDBRL	5.580***	9.367	6.042	4.652	Fail to Reject H_0
USDRUB ≠>CDSRUS	34.408*	11.243	6.392	4.690	Reject H_0
CDSRUS ≠> USDRUB	3.559	10.758	6.105	4.570	Fail to Reject H_0
USDCNY ≠> CDSCHI	7.144**	9.465	5.961	4.637	Reject H_0
CDSCHI ≠> USDCNY	1.369	9.562	6.109	4.720	Fail to Reject H_0
USDZAR ≠> CDSSAF	5.160**	6.482	3.888	2.674	Reject H_0
CDSSAF ≠> USDZAR	2.808***	6.670	3.848	2.672	Fail to Reject H_0

Note: a: The optimal lag length is found by the HJC information criterion. Bootstrap critical values are derived from 10,000 iterations. *, **, and *** denote the existence of a causal association from the first variable to the second variable at the 10%, 5%, and 1% significance levels, respectively. The notation ≠> in the table denotes the hypothesis of no causality in the specified direction between the respective variables.

5. Conclusion and Recommendations

This study examines the relationship between CDS premiums and exchange rates in BRISC-T countries from 2020:01 to 2024:06 utilizing daily frequency data. The study tests financial time series stationarity with the RALS-LM unit root test, which yields robust results even for non-normally distributed series. After confirming series stationarity, the RALS-EG (2015) cointegration test is used to determine cointegration. The long-term RALS-EG (2015) cointegration test shows that CDS premiums and exchange rates move together in Brazil, Russia, China, and South Africa except Turkey. DOLS and FMOLS approaches estimate the long-run coefficient of the exchange rate variable for each nation after determining the cointegration between CDS premiums and exchange rates. The long-run coefficients of DOLS and FMOLS are consistent, and exchange rates and CDS premiums are positively and statistically meaningfully related. The study's findings align with those of Bayhan et al. (2021), Çonkar and Vergili (2017), and Özpınar (2018). The findings for Turkey align with studies by Aksoylu and Görmüş (2018), Buz and Küçükkocaoğlu (2023), and Sarı (2024). This study uses the Hacker and Hatemi-J (2012) bootstrap causality test to examine CDS premiums and exchange rates. At the 5% statistical significance level, Hacker and Hatemi-J (2012) bootstrap causality tests reveal that exchange rates cause CDS premiums in BRICS nations except Turkey. This suggests that exchange rate swings affect country risk premiums and CDS premiums statistically. Hacker and Hatemi-J (2012) bootstrap causality test shows that CDS premiums do not affect exchange rates in BRICS countries at the statistically significant level, but they do in Turkey at the 1% level.

According to the study's empirical analysis, currency rate changes can have an impact on the adequacy of foreign exchange reserves and the payback duration for external debt. When a country's currency rapidly depreciates, the default risks of institutions with foreign currency-denominated debt rise due to increased costs, resulting in higher CDS premiums. Investors may

demand an increase in the country's CDS premiums as a result of increased risk perception caused by financial market uncertainty.

The empirical analysis of the study demonstrates that Turkey varies from BRICS countries. In August 2018, Turkey implemented restrictions on swap transactions to prevent fluctuations and speculative trades in the foreign exchange market. To avert the depreciation of the TL and maintain financial stability, foreign entities were prohibited from supplying TL liquidity in foreign currency. This occurred due to foreign investors generating speculative fluctuations in the TL by supplying foreign currency liquidity in the swap market. The imposition of this limitation on the swap market curtailed foreign investors' access to the Turkish lira and inhibited speculative activities. The limits on the swap market effectively diminished volatility in the foreign currency market in the near term; nevertheless, they also resulted in adverse consequences, including foreign investor withdrawals, liquidity problems, and a decline in domestic market dynamics.

The relationship between CDS premiums and exchange rates is essential for comprehending sovereign risk and market sentiment. Policymakers must consider the relationship between CDS premiums and the exchange rate, since it directly influences a nation's borrowing costs and investor risk perception, in their efforts to maintain economic and financial stability. Increased CDS premiums reflect heightened economic uncertainties, political risks, and financial difficulties within a country, signaling a decline in market confidence. Therefore, CDS premiums can be used as an indicator to assess the effectiveness of economic policies implemented by policymakers. The reflection of fiscal or monetary policy outcomes on CDS premiums demonstrates how such policies are perceived and assessed by financial markets. Stabilizing CDS premiums is crucial for ensuring the healthy functioning of a country's financial markets. To reduce CDS premiums and maintain stability, policymakers must implement strategies focused on controlling inflation, ensuring budget discipline, promoting economic growth, strengthening the financial system, and stabilizing financial markets. Furthermore, strategies to improve the investment climate play a critical role in achieving these objectives. Since CDS premiums are influenced not only by domestic factors but also by global economic developments and geopolitical risks, policymakers should consider external factors and global market sentiments alongside internal dynamics when formulating or adjusting economic and monetary policies. From the investors' perspective, an increase in CDS premiums signifies a heightened risk level for the country, which correlates with an elevated risk of local currency depreciation. The correlation between exchange rates and CDS premiums offers significant insights into the influence of economic and financial risks on financial markets. This opens a new subject of study for future research. Furthermore, in light of advancements in econometrics literature, subsequent research can be enhanced by employing novel econometric methodologies on an expanded dataset and diverse nation cohorts.

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.

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There is no potential conflicts of interest in this study.

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ANALYSIS OF BITCOIN VOLATILITY DURING THE COVID-19 PANDEMIC: AN EXAMINATION USING ARCH AND GARCH MODELS

Bitcoin Volatilitesinin COVID-19 Pandemisi Döneminde Analizi: ARCH ve GARCH Modelleriyle Bir İnceleme

Ulaş ÜNLÜ* **& Vildan BAYRAM****

Keywords:
Bitcoin, Volatility, Covid-19, GARCH, ARCH.

JEL Codes:
G10, G15, C22.

Abstract

The COVID-19 pandemic has had a profound effect on the global economy and financial markets, including a significant impact on the cryptocurrency markets. This study analyzes the impact of the COVID-19 process on bitcoin price movements. The study examines the daily price data of bitcoin between 01/03/2020 and 01/04/2022 and uses ARCH and GARCH models to estimate volatility. The results show that there was a significant increase in bitcoin volatility during the initial period of the pandemic. This reflects a period when the pandemic increased uncertainty in financial markets and spurred investor interest in cryptocurrencies. While the ARCH model showed limited success in analyzing the short-term dynamics of volatility, the GARCH model captured the long-term trends in volatility more effectively. However, both models were insufficient to fully predict the sudden and extreme increases in volatility observed during crisis periods such as the pandemic. In addition to analyzing the impact of the pandemic on cryptocurrency markets, the study provides important implications for investor behavior and volatility management. In this context, it highlights the importance of developing risk management and regulatory frameworks in cryptocurrency markets.

Anahtar Kelimeler:
Bitcoin, Volatilite, Covid 19, GARCH, ARCH.

JEL Kodları:
G10, G15, C22.

Öz

COVID-19 pandemi süreci küresel ekonomi ve finansal piyasalar üzerinde derin etkiler bırakmış olup bu durum kripto para piyasalarını da önemli ölçüde etkilemiştir. Bu çalışmada COVID-19 sürecinin Bitcoin fiyat hareketleri üzerindeki etkileri analiz edilmiştir. Araştırmada, Bitcoin'in 01/03/2020- 01/04/2022 tarihleri arasındaki günlük fiyat verileri incelenmiş ve ARCH ve GARCH modelleri kullanılarak volatilite tahmini yapılmıştır. Bulgular pandeminin başlangıç döneminde Bitcoin'in volatilitesinde belirgin bir artış olduğunu göstermektedir. Pandemi dönemi finansal piyasalardaki belirsizlikleri artırmakla birlikte yatırımcıların kripto paraları ilgisinin de yükseldiği bir dönemi yansıtmaktadır. Çalışmada kullanılan ARCH modeli, volatilitenin kısa vadeli dinamiklerini analiz etmede sınırlı bir başarı gösterirken, GARCH modeli sonuçları volatilitenin uzun vadeli eğilimlerini daha etkili bir şekilde yakalamıştır. Bununla birlikte her iki model de pandemi gibi kriz dönemlerinde gözlemlenen ani ve ekstrem volatilite artışlarını tam anlamıyla öngörmekte yetersiz kalmıştır. Çalışma, yalnızca pandeminin kripto para piyasalarındaki etkilerini analiz etmekle kalmayıp, yatırımcı davranışları ve volatilite yönetimi konularında da önemli çıkarımlar sağlamaktadır. Aynı zamanda kripto para piyasalarında risk yönetimi ve düzenleyici çerçevelerin geliştirilmesinin önemine işaret etmektedir.

* Doç. Dr., Akdeniz University, Faculty of Applied Sciences, Finance and Banking Department, Türkiye, ulasunlu@akdeniz.edu.tr
** Independent Researcher, Akbank, Türkiye, vildankrsln@gmail.com,

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1. Introduction

Cryptocurrencies are virtual currencies traded in technology-based financial systems. They are typically produced digitally by individuals or institutions rather than by countries. Cryptocurrencies are generally used in the market for investment purposes rather than commercial transactions. Bitcoin is considered the first digital currency. Although thousands of cryptocurrencies have been launched over time, bitcoin is still considered to have a high transaction volume. While the strengths of cryptocurrencies include ultra-secure encryption, the inability to make the desired redirects and the inability to change the amount, the difficulty of acceptance, lack of account security, inability to be taxed and money laundering risks are the weaknesses of the system (Çetinkaya, 2018: 20). In particular, hacking of digital wallets and exchanges can lead to users losing their assets. In addition, phishing attacks and malware also pose serious threats to cryptocurrency owners. The fact that governments around the world do not have a legal infrastructure for cryptocurrencies and that cryptocurrencies are not backed by a government guarantee exacerbates the problems associated with this issue. Having a decentralized payment system is an important advantage because there is no dependency problem on institutions and individuals.

The number and usage of traded crypto assets are increasing every day. Although Bitcoin was not very popular in its early years, its popularity increased with the rapid rise in its price in later years, and it is the cryptocurrency with the most transactions (Ngunyi, 2019: 591). Initially, it was only used for investment purposes, but over time it began to be used for commercial transactions, albeit to a lesser extent (Dilek, 2018: 16). Fluctuations in the price of bitcoin bring with them the risk of large gains and losses, so examining the volatility of bitcoin can provide important data for investors.

The COVID-19 pandemic has significantly affected the use and value of cryptocurrencies. As global economic uncertainties increased during the pandemic, many investors sought safe havens. For risk-averse investors, bitcoin and other cryptocurrencies have come to the forefront as alternative investment vehicles during this period. The increased demand for digital and contactless payment methods during the pandemic has increased the adoption rate of cryptocurrencies. However, the negative impact of COVID-19 on economies has increased the volatility of cryptocurrencies and caused speculative movements in the markets. The pandemic has revealed the potential of cryptocurrencies to be used not only for investment purposes but also for everyday financial transactions. This process has strengthened the position of Bitcoin and other cryptocurrencies in the financial system. At the same time, it has caused regulators and governments to reevaluate their attitudes toward these new financial instruments. In the post-pandemic period, discussions about the legal regulations and security protocols of cryptocurrencies are expected to intensify (Yermack, 2020).

With the COVID-19 pandemic affecting the entire world, there has been an increase in the number of deaths and cases. This situation has posed a major threat to economies and has caused economies and stock markets to react quickly to risk perceptions around the world. The uncertainty experienced has led to quite sharp declines in stock markets. The pandemic period, which has even affected the growth and development indices of countries, has caused quite high losses in value. It can be said that the most curious feature of cryptocurrencies, which can be bought and sold 24/7 without any trading day limit, is the price volatility (Guizani and Nafti, 2019; Saleh, 2019). The autoregressive conditional heteroskedasticity (ARCH) model is often

used in these volatility calculations. Since financial time series generally do not show a normal distribution, ARCH models and their derivatives are commonly used to solve these problems (Kahraman et al., 2019).

With the development of the ARCH model, many generalized ARCH models have emerged. The most popular are the symmetric GARCH model and the non-symmetric EARCH, PARCH, and TGARCH models. These models allow more accurate estimation of volatility and risk in financial time series. This study aims to analyze the volatility dynamics of bitcoin prices during the COVID-19 pandemic. In this context, the effects of the pandemic on the price movements of bitcoin have been comprehensively examined using the ARCH and GARCH models. A fundamental framework for examining volatility dynamics, especially in financial data, is offered by the ARCH and GARCH models. This study aims to investigate general volatility dynamics and evaluate the effects of the COVID-19 pandemic, even though EGARCH and TGARCH models are known in the literature for their better performance in modeling asymmetric effects and more accurately capturing the impact of negative shocks (Ni et al., 2022; Marisetty, 2024). Since the study's main goal is to shed light on the broader market behavior during this extraordinary global event, ARCH and GARCH models were thought to be better suited for capturing the overall volatility patterns.

The originality of the study lies in the limited number of studies examining the effects of the pandemic on volatility and investor behavior in cryptocurrency markets. In addition, a detailed examination of Bitcoin's responses to positive and negative shocks provides important insights for understanding the dynamics of these new investment instruments in the financial system. In this respect, the present study aims to contribute to the literature by providing important insights from both an academic and an investor perspective.

2. The Impact of the COVID-19 Pandemic on Financial Markets

Stock markets reflect political, cultural, social, and economic developments in prices. Information appearing on the stock exchanges receives very fast reactions. With the COVID-19 pandemic affecting the entire world, there has been an increase in the number of deaths and cases. This situation has posed a great threat to economies and has allowed economies and stock exchanges to react quickly to risk perceptions around the world. The uncertainty experienced has led to quite sharp declines in stock markets. Situations such as curfews, closures of workplaces, mandatory use of masks and health equipment, and the suspension of activities of production and service companies have increased the perception of risk and fear in global markets. Despite the declaration of a pandemic, the lack of a vaccine or medicine to treat the COVID-19 virus, the increase in deaths and severe illnesses, the rapid spread of the epidemic around the world, and the lack of information on how to take precautions against this epidemic have paved the way for sharp sell-offs on the stock markets. There have been historic declines in stock markets and cryptocurrency markets. If we look at the U.S. stock markets, the sharp declines that occurred in the second week of March reached 7%, and more daily, circuit breakers were implemented (Şenol, 2020).

Table 1 shows the declines experienced by some of the world's leading stock exchanges and Borsa Istanbul in Turkey after the global pandemic was declared by the World Health Organization on March 11, 2020. Just one day later, on March 12, 2020, it was observed that the

S&P 500 U.S. Stock Exchange lost 9.51%, the Developed Markets Index lost 9.91%, the NASDAQ lost 9.43%, the SHCOMP Stock Exchange lost 1.52%, the NIKKEI lost -4.41% and the Emerging Markets Index lost 6.71%. In addition, the BIST100 index in Turkey lost 7.25%. If we look at this table, we can see that the highest percentage loss was in the CAC40 stock exchange and the lowest decrease was in the SCHOMP stock exchange with 1.52.

Table 1. Percentage Change Between Global Pandemic and Stock Indices

Index	Index Value	Return (%)
S&P 500	2.741	-9,51
MSCI-DM	1.972	-9,51
CCO-NASDAQ	7.952	-9,43
DAX	10.439	-12,24
FTSE 100	5.877	-10,87
CAC40	4.61	-12,27
NIKKEI 225	19.416	-4,41
HANG SENG	25.232	-3,66
SHCOMP	2.969	-1,52
SENSEX	35.697	-8,18
RTSI(RUSYA)	1.086	-11,03
MSCI-EM	947	-6,71
BIST 100	1.009	-7,25

Source: Kazan (2020).

From the first day of the outbreak in Turkey, the value of the BIST100 index decreased from 1,159 to 936. If we look at these figures, there was a loss of approximately 20% (Karpuz and Koç, 2022). As can be seen in the table, the losses of approximately 30% in the world's major stock market indices during this period also increased the volatility rates in the stock markets. The return volatility levels experienced during the COVID-19 pandemic are very close to the volatility levels experienced during the 2008 global crisis. The declines experienced on some days have brought them to historical levels. For example, at the beginning of the pandemic, on March 16, 2020, the losses experienced were 11% on the U.S. stock market, 10.7% on the French stock market, 8.65% on the U.K. stock market, 11.3% on the Italian stock market, and 8.65% on the Turkish BIST 100. The losses experienced on March 12, 2020, in the table are among the historical declines in the Dow Jones Index. In addition, the 13% decline experienced on March 16, 2020, is the third-highest single-day decline in the history of the Dow Jones Index. The decline experienced during the Great Depression on October 28, 1929, is equal to the 13% decline experienced on March 16, 2020. At the same time, looking at other economic indicators, the asset with the largest decline in yield was the yield on US Treasury bonds. Immediately after that, however, the price of oil fell sharply. As the pandemic spread around the world, central banks also adopted a policy of lowering interest rates. The FED cut rates to 1.75% and then to 0%. Japan and Europe made no changes as their interest rates were negative. While the US 2-year Treasury rate was 1.5% at the beginning of the year, it fell to 0.15% in May, a total decline of 85%. The Central Bank of Turkey reduced interest rates three times during the pandemic and the last level remained at 8.25% (Şenol, 2020).

If we look at the world, there has been a decrease in the prices of materials and substances in many sectors, especially energy. The reason for this is the decrease in production and consumption levels. Historic declines have been experienced in the price of oil, one of the largest sectors. The price of a barrel of Brent oil, which was $71 on January 6, 2020, fell to $18 on April

22, 2020, a decrease of 74%. According to the International Energy Agency (IEA), oil demand in 2020 has decreased by 57% (IEA, 2020).

3. The Impact of the COVID-19 Pandemic on Cryptocurrency Markets

With many people around the world forced to stay at home, digitization has increased across all platforms, combined with the driving force of technology. In the process, consumers have experienced more digital services than ever before. In the 2020-2021 period, when the pandemic was most effective, changes in investor behavior were observed (Öztürk and Dilek, 2021). If we look at Bitcoin, which is known as the first crypto asset and still has the largest market value, it was much more affected by the Covid-19 period. As of May 11, 2024, there are 19.6 million bitcoins in circulation (Blockchain, 2024). It is estimated that the production of this encrypted coin, which is limited to a total of 21 million, will continue until 2140 (Göktaş and Aksu, 2021). Bitcoin is the crypto asset with the highest market value.

Currently, there are hundreds of active crypto assets in the market. As of July 2024, the top 10 crypto assets with the highest market value were identified as Bitcoin, 18.34% Ethereum, Tether, BNB, Solana, XRP (Ripple), USDC, Dogecoin, Toncoin, and Cardano. The total value of crypto assets, which could reach $3 trillion by 2021, has fallen to $2.5 trillion by July 2024 (https://coinmarketcap.com/charts/). The pandemic, when people were confined to their homes, combined with the impact of technology, increased activity on all digitized platforms, and consumers benefited from the service experiences they received digitally. There has also been curiosity and an increase in cryptocurrency markets and supporting platforms (Öztürk and Dilek, 2021). With the declaration of the pandemic by the World Health Organization, the prices of BTC and ETH decreased by about 50% on March 12, 2020. Later, institutional investors such as Grayscale, Square, and MicroStrategy announced large BTC purchases. Coinbase was listed on the NASDAQ under the name COIN in April 2020. According to Forbes, the global crypto ETF market grew 549% in November 2021 compared to the end of 2020. Many new business forms have emerged, namely decentralized finance (DeFi) and NFT. The DeFi market will reach $300 billion by the end of 2021.

Table 2. Bitcoin and Ethereum Returns

	Cumulative Return in 2020 (USD %)	2020 % Change (Start-to-End of Year)	Cumulative Return in 2021 (USD %)	2021 % Change (Start-to-End of Year)
BTC	170,9	315,2	77,6	44,8
ETH	226,4	479,1	219,3	254,0

Source: https://finance.yahoo.com/

In Table 2, the returns of Bitcoin and Ethereum are shown as daily and annual returns based on 2020 and 2021. Looking at 2020, Bitcoin's cumulative return was 170.9%, while the change in year-end value was 315.2%. Looking at 2021, these numbers dropped from 77.6% to 44.8%. Looking at these values for Ethereum, while the cumulative return in 2020 was 226.4%, the change in the year-end value in 2020 was 479.1%. Looking at 2021, these values appear to be 219.3%. Looking at the year-end change in 2021, we can see that the Ethereum price is 254.0%.

Looking at this, it can be said that Bitcoin and Ethereum provided very high returns during the pandemic period.

4. Literature Review

Today, with the impact of technological advances, money transfers, and commercial transactions are largely conducted over the Internet. With the increasing use of technology, interest in virtual currencies has grown rapidly. Especially during the COVID-19 pandemic, interest in cryptocurrencies has increased even more with the reduction of physical contact and the acceleration of digitalization. Discussions about the functioning, advantages, disadvantages, price movements, and system of bitcoin occupy an important place in the academic literature. The COVID-19 pandemic added a new dimension to these discussions and drew more attention to the potential role of bitcoin. During the pandemic, the loss of trust in traditional financial systems has increased people's interest in digital assets. In addition, the uncertainties experienced in traditional financial markets during the pandemic have increased demand for the value of digital assets such as bitcoin and led to significant fluctuations in their prices. The COVID-19 pandemic has accelerated the digitization of financial infrastructure and contributed to the greater acceptance of cryptocurrencies on a global scale.

The study conducted by Kristoufek (2013) analyzed the relationship between search volume and price movements of the cryptocurrency Bitcoin on Google Trends and Wikipedia. The study hypothesized that the popularity and demand of Bitcoin could affect the price of this digital asset. The results of the study show that Bitcoin experiences increased interest during periods when its prices are high, and this interest further increases its prices. Christopher (2014) examined the process of processing Bitcoin in terms of money laundering legislation in the US government, and mentioned the difficulties that Bitcoin can be used as a malicious virtual currency and the possible difficulties in combating crimes in this direction. In this analysis, it was emphasized that the anonymous and decentralized structure of Bitcoin may make it difficult to prevent its use in illegal activities such as money laundering and that existing legal regulations may be inadequate to prevent such misuse of Bitcoin.

MacDonell (2014) studied the price bubble phenomenon in Bitcoin and found that a bubble occurred in 2013. The study highlighted the reasons for this bubble, such as the lack of reliable bitcoin platforms and the intensity of black-market transactions. It also emphasized that the high price volatility in the market created an environment open to speculation. In particular, as demand for bitcoin increased, investors turned to black market transactions due to the scarcity of reliable platforms, creating uncertainty and volatility in the market. It has also been noted that the high volatility of bitcoin prices has contributed to the market being open to speculation. High price volatility can encourage investors to enter and exit the market in search of quick profits, which can lead to bubble-like conditions.

Chu et al. (2015) made a mathematical analysis of eight different exchange rates based on BTC/USD rates. When we consider the last 2 years, they determined that the BTC/USD rate has increased more than 50 times and that Bitcoin has high volatility. Georgoula et al. (2015) used time series analysis in their study to investigate the relationship between the basic financial values of Bitcoin prices, Twitter data, and values developing with technology. According to the results of the study, a positive situation was determined between the pricing made on Bitcoin in the short

term and Twitter data. Baek and Elbeck (2015), In their study, researchers used daily return data sets of Bitcoin and the American stock market index and tried to determine whether Bitcoin is open to manipulation. As a result of their analysis, they stated that the Bitcoin money market has a volatility of 26 times that of the S&P 500 and that Bitcoin has a speculative structure. These findings show that Bitcoin has a higher risk and speculative character compared to other assets in the financial markets. In his study, Dyhrberg (2016) investigated the economic viability of Bitcoin using GARCH models. In the model, Bitcoin functions as a hedge against change and risk, similar to gold and dollars, and shares several similar characteristics. In addition, it can be said that Bitcoin's volatility changes over time and is acceptable in the long term. These findings help us better understand Bitcoin's place in financial markets and the opportunities it provides for investors.

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Stavroyiannis (2017) examined Bitcoin, Ethereum, Ripple, Litecoin, and the S&P 500 index as examples of risk management in his study. He tested 10-day VaR and Expected Shortfall (ES) methodologies. The data obtained showed that cryptocurrencies are risky. This finding emphasizes that cryptocurrencies have high volatility and should be carefully considered in terms of risk management. In his study, Katsiampa (2017) investigated the most appropriate model for price volatility in the financial valuation of bitcoin. According to the results of the study, it was analyzed that the long-term variance in the bitcoin market is not constant and varies with the process. However, it was found that the most applicable model is the AR-GARCH model. These results show that the price volatility of bitcoin is not constant and can change over time. The AR-GARCH model was found to be an effective tool for estimating the volatility of bitcoin prices. The study by Yıldırım and Bekun (2023) used weekly opening prices between November 24, 2013 and March 22, 2020, and calculated log returns. The results of the analysis showed that the GARCH model was more successful in capturing the volatility of Bitcoin compared to the ARCH and EGARCH models.

Studies of the cryptocurrency market examine Bitcoin's price volatility and speculative structure from a broad perspective. Studies generally show that Bitcoin's popularity, demand, and price movements are interrelated and that it is a speculative market with high volatility. Volatility estimation models such as ARCH and GARCH have been used as an effective method to analyze

bitcoin's price movements, and these methods have contributed to understanding bitcoin's risk dynamics in financial markets. In general, it has been emphasized in the literature that bitco'n carries high risk compared to traditional financial assets and its fluctuations are higher than other assets. In addition, it has been found that macroeconomic indicators and social media data can be determinants of bitcoin price formation.

However, there is no study in the literature that specifically addresses the COVID-19 pandemic period. Examining the dynamics of cryptocurrency markets during the pandemic process is very important to fill this gap in the existing literature. This study aims to both bring a new perspective to the literature and test existing methods in the context of this extraordinary period by analyzing the impact of the pandemic on volatility and investor behavior in cryptocurrency markets. In doing so, it aims to contribute to a better understanding of the impact of extraordinary conditions such as the pandemic on markets.

5. Data and Research Methodology

5.1. Data

In the study, the volatility of bitcoin during the pandemic period was tested using ARCH and GARCH models. The dataset consists of a 763-day price/time series consisting of Bitcoin's daily closing prices, including the weekend between 03/01/2020 and 04/01/2022, and was obtained by generating historical data from the Coinmarketcap.com website. Additional macroeconomic and market factors, such as the post-pandemic recovery and regulatory reforms, would have been included in the dataset if it had been extended past April 1, 2022. This restriction is regarded as a study limitation. In the study, comparisons were made using volatility prediction models for bitcoin, a cryptocurrency.

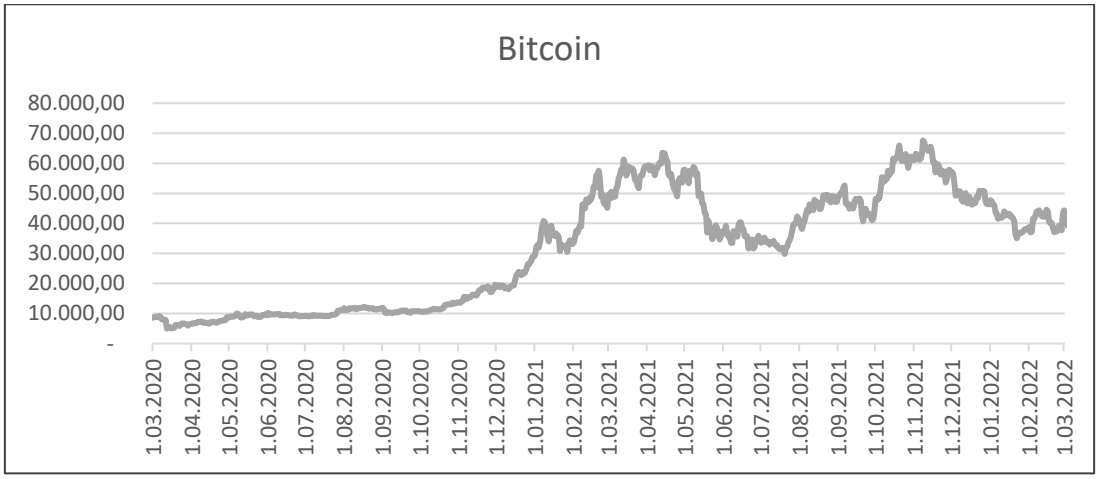

Figure 1. Bitcoin Price Change

Figure 1 shows bitcoin price movements over time. Daily bitcoin price information for the period 01.03.2020-01.04.2022 is shown based on US dollars. At the beginning of 2020, the price was below $10,000, reached $10,000 by mid-year, and increased rapidly after October, reaching

$29,000. In 2021, the increase continues and exceeds $60,000, but prices then fall and fluctuate between $30,000 and $40,000.

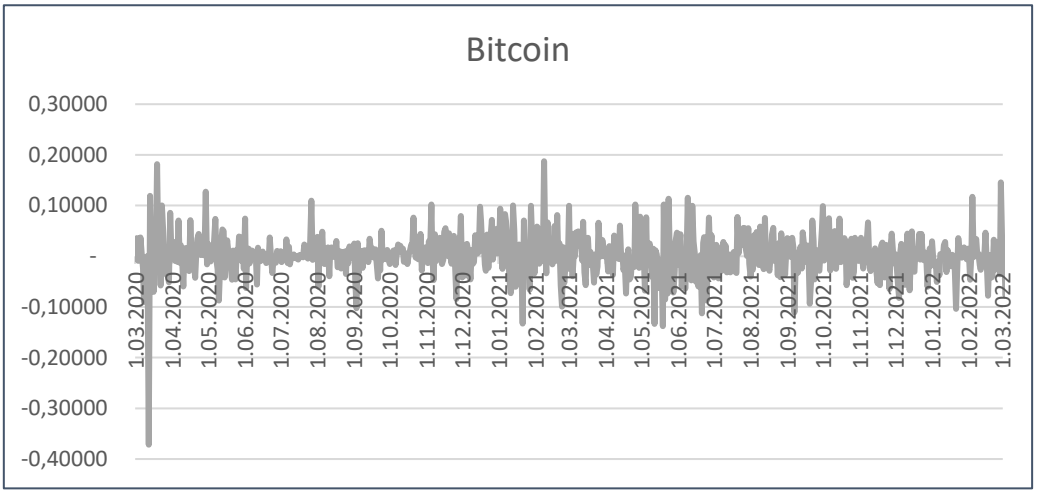

Figure 2. Bitcoin Return Rates

Figure 2 illustrates the daily return rates of Bitcoin over time. During the period from 2020 to 2022, significant fluctuations in return rates can be observed. The graph highlights periods of high volatility while showing that the return rates generally oscillate between positive and negative values.

5.2. ARCH Method

Modeling on time series generally suggests the assumption of constant variance of error terms. However, this assumption is often not valid for data observed in financial markets. The ARCH model is a type of regression model used to model the variance of variables in time series. It was first developed by Robert F. Engle in 1982 and has become well-established in the literature. The ARCH model models how the variance in a time series changes based on past values. For instance, a first-order autoregressive model (AR(1)) is expressed as $y_t = \boldsymbol{a} y_{t-1} + u_t$ (Brooks, 2008). Where y_t: Observed value at time t, $\boldsymbol{a}$: Autoregressive coefficient of the AR(1) model, y_{t-1}: Observed value at time $_{t-1}$, ut: Random error term (noise) at time t.

The parameters of the ARCH model are generally estimated using the Maximum Likelihood Estimation (MLE) method. This method is used to determine the parameter values that best fit the data set. The ARCH(p) model is typically formulated as follows (Engle, 1982).

$$h_t = a_0 \sum_{i=1}^{p} a_1 u_{t-i}^2 \quad (1)$$

Where h_t: Represents the conditional variance at time t, a_0: The constant term, a_i: Coefficients of the ARCH terms for the lagged squared residuals I=1,2,3…,p, u_{t-i}^2: The error term (residual) at time t−i.

The ARCH model aims to capture a volatility structure that changes over time by modeling the effect of the squares of past errors through these terms. Recent developments in financial econometrics suggest the use of nonlinear time series models to model risk and expected return.

Bera and Higgins (1993: 315) note that an important contribution of the ARCH literature is that it shows that changes in volatility in economic time series are predictable and that these changes may be due to certain types of nonlinear dependencies rather than to external structural changes. The assumption of constant volatility over a given period is statistically inappropriate, and it has been argued that volatility is an inconsistent concept as the series progresses over time (Engle, 1982: 987-1008). The situation observed in financial markets is that large returns are accompanied by larger returns and small returns are accompanied by smaller returns, suggesting that there is a serial relationship between returns. Homoscedasticity means that the error terms are constant when the expected value is squared (Brooks, 2003). However, ARCH and GARCH models are designed to model the heterogeneous variance observed in financial data (Bollerslev, 1986: 307-327). These models reflect the fact that the variances of the error terms are not equal and may be larger in some periods than in others. ARCH and GARCH models are widely used forecasting models in financial applications. Therefore, it was decided that the above methods were appropriate to use in the study of bitcoin price volatility during the pandemic period.

5.3. GARCH Method

The GARCH model, which is an improved and differentiated version of the ARCH model, was proposed by Bollerslev (1986) as an alternative to the problem of excessive data estimation in the ARCH model. Unlike the old model, this model has deeper past-period effects and a more flexible structure. In GARCH models, the conditional variance at time 't' does not only depend on the previous values of the error term but also has to take into account the previous values of the conditional variance. The two factors affecting the past values are the variance due to the error term and the conditional variance (Bollerslev, 1986).

$$h_t^2 = \alpha_{0+}\ \alpha_1 \square_{t-1}^2 + \alpha_2 \square_{t-2}^2 + \ldots\ldots\ldots + \alpha_q \square_{t-q}^2 + \beta q h_{t-q}^2 \quad (2)$$

Non-negativity Condition $\alpha_0 > 0$ which ensures that the conditional variance is non-negative.

$$A_i \geq 0,\ I = 1,\quad \ldots,\ p-1,\ \alpha_p > 0\ ,\ \beta_i \geq 0\ ,\ = 1\ ,\ \ldots\ ,\ q-1\ ,\ \beta_q > 0 \quad (3)$$

Using the relevant lag terms, the model can be expressed as:

$$\alpha(L) = \alpha_1 L + \ldots + \alpha PLP \quad \beta(L) = \beta_1 L + \ldots + \beta q Lq \quad (4)$$

This results in the following formulation:

$$h_t^2 = \alpha_0 + \alpha(L)\ \varepsilon^2{}_t + \beta(L)\ h^2{}_t \quad (5)$$

By following this method, it becomes evident that ε_t^2 directly follows the process. Considering these equations, the model structure and parameter constraints can be understood.

$$v_t = \square_t^2 \quad (6)$$

$$E[v_t |\ I_{t-1}] = E[\varepsilon^2{}_t - h^2{}_t \mid I_{t-1}] = 0 \quad (7)$$

Thus, the relationship with v does not exist, and it satisfies the condition of having zero mean. The white noise condition will have been fulfilled.

$$\square_t^2 = h_t^2 + v_t \quad (8)$$

$$\varepsilon^2{}_t = \alpha_0 + \alpha_1 + \alpha_2 \square_{t-2}^2 + \ldots.. + \alpha_q\ \varepsilon^2{}_{t\text{-}p} + \beta_{1(}\varepsilon^2{}_{t\text{-}1} - v_{t-1}) + \ldots + \beta_{p(}\varepsilon^2{}_{t\text{-}p} - v_{t-p)+}\ v_t \quad (9)$$

$$\varepsilon^2{}_{t} = \alpha_{0+} \sum_{i=1}^{n}(a + \beta i)\ \varepsilon^2{}_{t-I} + v_t) - \sum_{i=1}^{p} \beta i\ v_{t-I} \quad (10)$$

The key point for estimating the equation of unconditional variance and serial dependence is its similarity to the ARCH methodology (Kirchgässner and Wolters, 2007: 252–254).

$$V(\varepsilon_t) = E[\varepsilon^2{}_t] = \frac{\alpha 0}{1 - a(1) - \beta(1)} \quad (11)$$

For the existence of variance in the following method:

$$\alpha(1) + \beta(1) = \sum_{i=1}^{p} \alpha i + \sum_{i=1}^{q} \beta i < 1 \quad (12)$$

The above equality must hold.

The GARCH model, like the ARCH model, is limited in that it responds the same way to both negative and positive effects. Additionally, recent studies on high-frequency financial time series have shown that the GARCH model's distribution does not decline as rapidly as the student's t-distribution (Tsay, 2005). GARCH models include features such as the conditional variance being a stochastic variable with sequential dependency, εt^2 following an ARMA model, and errors being unconditionally leptokurtic and symmetrically distributed.

The conditional variance can be expressed as follows (Brooks, 2008):

$$h_t^2 = \alpha_0 + \alpha(L)\ \square_t^2 + \beta(L)\ h_t^2$$

When the unconditional variance of the process is given as:

$$\sigma_y^2 = \frac{\alpha 0}{1 - a(1) - \beta(1)} \quad (13)$$

By substituting α_0 with σ_y^2 (1- α(1) – β(1)) into the equation:

$$h_t = \sigma_y^2(1 - \alpha(1) - \beta(1)) + \alpha(L)\ \square_t^2 + \beta(L)\ h_t^2$$

This can be rearranged as:

$$ht - \sigma_y^2 = \alpha(L)\ \square_t^2 - \sigma_y^2\ \alpha(1) + \beta(L)\ h_t^2 - \sigma_y^2 \beta(1) \quad (14)$$

Simplified as:

$$= \alpha(L)(\ \square_t^2 - \sigma_y^2\ ) + \beta(L)(\ h_t - \sigma_y^2\ )$$

In conclusion, the unconditional distribution is symmetric and leptokurtic. GARCH models exhibit complexity in their moment structure. The equation holds only when the respective parameters are zero. Changes in high or low volatility are dependent on such variations.

6. Empirical Findings

To address stationarity issues, return rates were used instead of cryptocurrency prices. The study was conducted using the most comprehensive data available, covering the beginning and progression of the COVID-19 pandemic. The data period for Bitcoin spans from 01.03.2020 to 01.04.2022, which includes the COVID-19 pandemic. Table 3 provides information explaining Bitcoin's return rates.

Table 3. Descriptive Statistics of Cryptocurrency Return Rates

Average	0,00305
Maximum	0,18746
Minimum	-0,37170
Standard Deviation	0,04022
Skewness	-0,076301
Kurtosis	11,3570
Jarque-Bera Test (P-Value)	3944,44(0,000)*
Number of Observations	763

Note: * Statistically significant at the level of $p < 0.01$.

Bitcoin's average daily return is calculated to be 0.305%. This generally indicates a positive return rate and shows that bitcoin, on average, provides investors with a positive return over the long term. Bitcoin's yield rates fluctuate within a wide range. The maximum return rate was 18.746% on 02/08/2021, while the minimum return rate was -37.170% on 03/12/2020. This shows that there are large fluctuations in the price of bitcoin and investors should be prepared for such fluctuations. The standard deviation value of 0.04022 shows that bitcoin's return rates have high volatility. High volatility means both large profit opportunities and large losses for investors. The skewness value is -0.076301, indicating that the distribution of returns is not symmetric and has a slightly negative skew. This shows that bitcoin returns are concentrated slightly below the mean. The kurtosis value is 11.3570, indicating that the distribution has sharper peaks and thicker tails than the normal distribution. Higher kurtosis indicates that extreme return rates occur more frequently.

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The Jarque Bera test result is 4169.14 and the p-value is 0.000. This result clearly shows that bitcoin return rates do not conform to a normal distribution. This Jarque Bera test result shows that Bitcoin's return rates violate the assumption of normal distribution, and therefore the assumption of normal distribution should be used cautiously in financial models. This analysis was performed using a total of 763 days of data. This period includes the COVID-19 pandemic. The high volatility and uncertainty in the markets during the pandemic period also caused significant fluctuations in the return rates of cryptocurrencies.

Tablo 4. Unit Root Test Results for Bitcoin

ADF(p)		PP(p)	
Constant	**Constant and Trend**	**Constant**	**Constant and Trend**
-29,68*(0)	-29,69*(0)	-29,69*(1)	-29,68*(1)
[0,000]*	[0,000]*	[0,000]*	[0,000]*

Note: * Significant at the 1% level, ** Significant at the 5% level, *** Significant at the 10% level. The values in square brackets represent the p-values. The number in parentheses next to the test statistic indicates the optimal lag length, determined according to the Schwarz information criterion. The PP unit root test applies the Newey-West Bandwidth and Bartlett Kernel automatic selection method.

The study analyzed whether the model had a unit root prior to estimation. According to the results of the ADF and PP tests presented in Table 4, it was determined that the series was stationary. The fact that the probability values (p-value) of the tests were less than 0.05 indicates that the series was stationary at the level. The results of the ADF and PP unit root tests support the stationarity hypothesis. Stationarity of financial time series can be considered as an indicator that volatility is predictable. Table 5 shows the results of the ARCH model calculated for the return rates of bitcoin. This analysis explains the volatility dynamics of bitcoin returns and the parameters of the model. No heteroskedasticity problem was observed in the ARCH(1,1) model, where appropriate lag lengths were determined using the ARCH-LM test. The α coefficient of the model was found to be 0.0180 and is statistically significant. This result shows that the model in question can be used effectively in estimating the volatility of Bitcoin.

Tablo 5. ARCH Model Results

Average	0,3046
Standard Deviation	0,040256
Variance	0.001621
Constant	0,003029
Unconditional Variance (omega)	0,001585
ARCH Parameter (alpha)	0,0180
Long-run Volatility	0,040174
Log Likelihood	1368,71

Bitcoin's average daily return rate is calculated to be 0.3046%. This rate shows that Bitcoin generally provides positive returns to investors over the long term. The positive average return indicates that bitcoin can be a profitable investment for investors. However, these returns are highly variable. The standard deviation is 4.0256% and the variance is 0.001621. These values indicate that bitcoin returns are highly volatile and that investors may experience large fluctuations. High volatility means that returns can change significantly in certain periods, which indicates that the level of risk is high. The constant term (mu) in the ARCH model is calculated to be 0.3029%. This value represents the average return level of the model and shows the general trend of bitcoin returns. The unconditional variance (omega) is 0.001585 and indicates the base volatility level of the model. This base level reflects the volatility level of the market under normal conditions. The ARCH parameter (alpha) 0.0180 shows that the effect of the volatility of the previous period on the volatility of the current period is weak, which means that the market is less uncertain and more stable. This means that the market can be more predictable for investors and shows a positive sign in terms of risk management. The long-term volatility is calculated to be 4.0174%. This value shows that bitcoin returns have high volatility in the long run. This level,

where volatility levels off over time, is an important indicator for investors to consider in their long-term strategies. High long-term volatility indicates that market fluctuations are continuous and the risk level will be high in the long run. The log-likelihood value was determined to be 1368.71. This value indicates how well the ARCH model fits the data set and explains the data. A high log-likelihood value demonstrates that the model is appropriate and valid, effectively capturing the volatility of Bitcoin returns.

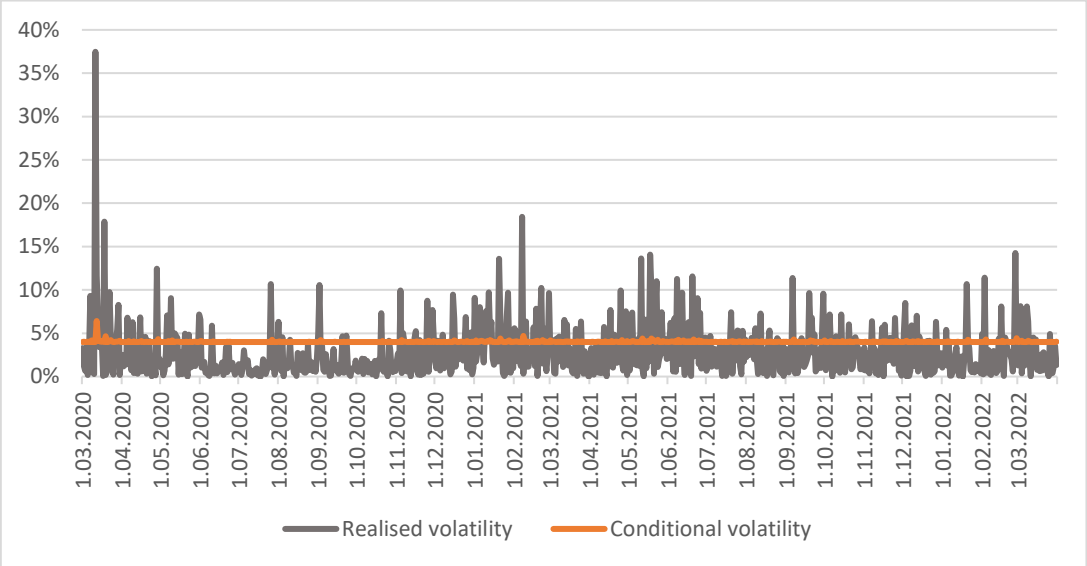

Figure 3. Realized and Conditional Volatility of Bitcoin (ARCH)

Figure 3 shows the realized volatility (gray) and conditional volatility (orange) between 01/03/2020 and 01/04/2022. The pandemic period started around March 2020 and a significant increase is observed on the graph during this period. It is observed that the realized volatility was quite high at the beginning of the COVID-19 pandemic in March 2020. During this period, there was a general atmosphere of uncertainty and panic in the financial markets, and the cryptocurrency markets experienced large fluctuations. After the initial shock of the pandemic, a general decrease in volatility was observed and the market became more stable. It can be seen that the blue line shows sudden spikes at certain intervals throughout the chart; these fluctuations may have occurred due to factors such as news, regulations, and major investment moves in the cryptocurrency market. The orange line, the conditional volatility, shows less fluctuation compared to the realized volatility and shows that the ARCH model is more stable in estimating the expected volatility of the market. In general, we can see that conditional volatility remained low and stable throughout 2020 and 2021, while realized volatility increased at certain intervals. This indicates that unexpected events occurred in the market and caused greater volatility than expected. The chart clearly shows the impact of the pandemic on market behavior and how such global events can threaten financial stability.

Table 6. GARCH Model Results

Average	0,03046
Standard Deviation	0,04023
Variance	0.001618
Constant (mu)	0,001569
Unconditional Variance (omega)	0,000271
ARCH Parameter (alpha)	0,0486
GARCH Parameter (beta)	0,7802
Alpha + Beta	0,8288
Long-run Volatility	0,03976
Average	1378,22

Table 6 shows the results of the GARCH model. Bitcoin's average daily return rate is calculated to be 0.03046%. This rate shows that Bitcoin generally provides positive returns to investors over the long term. The positive average return indicates that bitcoin can be a profitable investment for investors. However, these returns are highly variable. The standard deviation is 4.023% and the variance is 0.001618. These values indicate that bitcoin returns are highly volatile and that investors may experience large fluctuations. High volatility means that returns can change significantly in certain periods, indicating that the level of risk is high. Based on the GARCH model, the constant term (mu) in the model is calculated to be 0.001569%. This value represents the average return level of the model and shows the general trend of bitcoin returns. The unconditional variance (omega) is 0.000271 and indicates the base volatility level of the model. This base level reflects the volatility level of the market under normal conditions. The ARCH parameter (alpha) is calculated to be 0.0486. This parameter indicates that the volatility depends on the squared error (volatility) of the previous period. In other words, large fluctuations in the previous period affect the volatility of the current period, thus ensuring the continuity of volatility. This situation is important in explaining the uncertainty and volatility trend of bitcoin returns over time. The GARCH parameter (beta) was determined to be 0.7802, which represents the long-term effects of volatility. The sum of the alpha and beta parameters, 0.8288, shows that volatility is quite persistent and the effects of shocks last for a long time.

Long-term volatility was calculated as 3.976%. This value shows that Bitcoin returns have high volatility in the long term. This level, where volatility will balance over time, is an important indicator that investors should consider in their long-term strategies. High long-term volatility indicates that market fluctuations are continuous, and the risk level will be high in the long term. The log-likelihood value was determined as 1378.22. This high value shows how well the GARCH model fits the data set and how well the model explains the data. A high log-likelihood value indicates that the model is appropriate and valid and can effectively explain the volatility of Bitcoin returns.

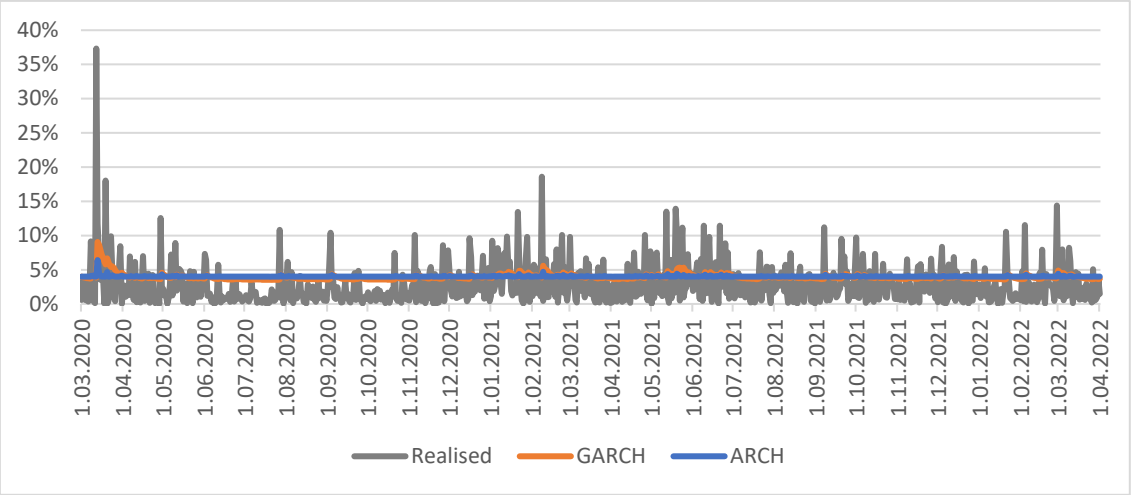

Figure 4. Realized and Conditional Volatility of Bitcoin (GARCH)

Figure 4 compares volatility estimates and realized volatility between 03/01/2020 and 04/01/2022. There are three different time series in the chart: Realized Volatility (gray), GARCH Model Estimated Volatility (orange), and ARCH Model Estimated Volatility (blue). Realized volatility shows higher volatility than the estimates of the other two models. Sharp peaks are observed especially at the beginning of the COVID-19 pandemic and in some other periods (e.g. early 2020). The GARCH line (orange) shows more volatility than the ARCH line (blue) and overlaps more with the realized volatility. The ARCH model has a flatter and more stable line. The COVID-19 pandemic has shaken global economic balances and caused severe fluctuations in financial markets. The volatility observed in the cryptocurrency markets during this period can be considered as a result of the uncertainties and sudden market reactions that occurred during the pandemic. In the presented graph, it can be observed that the volatility that occurred during the initial period of the pandemic in March 2020 increased sharply and reached 35%. This sudden increase is interpreted as an indicator of excessive volatility in the cryptocurrency markets and the panic of investors with the first effects of the pandemic. In the following months and throughout 2021, volatility fluctuations continued, but did not reach the extreme levels of March 2020; this shows that the market adapted to the uncertainties created by the pandemic and volatility became more stable over time.

7. Policy Discussion

The COVID-19 pandemic has had a significant impact on financial markets, causing volatility increases, especially in cryptocurrency markets, due to a combination of macroeconomic, psychological, and system dynamics. Policies such as monetary expansion, low interest rates, and liquidity increases in the financial system have increased both the risk appetite of investors and interest in cryptocurrencies. This process has significantly affected the price movements of digital assets with high market value such as Bitcoin and revealed the complex interaction between macroeconomic conditions and investor sentiment during periods of high uncertainty.

The response of the cryptocurrency market to regulatory news, investment decisions of large companies, and macroeconomic shocks has become even more important during the

pandemic period. Large-scale investments by funds and businesses changed the market's dynamics, either increasing speculative activity or stabilizing prices during uncertain times. Sudden jumps in volatility have usually been triggered by such external events, but the psychological aspect of the market has further strengthened the impact of these movements. The sharpening of investor sentiment during periods of uncertainty has led to an intensification of speculative behavior, dramatically directing market dynamics. This also indicates that cryptocurrencies are seen as a "safe haven" in times of uncertainty, as well as being a speculative tool. The empirical results indicate that the effect of shocks on volatility is permanent for Bitcoin during the COVID-19 pandemic, which is supported by the sum of the alpha and beta (0.8288%) obtained from the GARCH model. When the news flow is considered, the effect of positive shocks is found to be stronger than that of negative shocks. However, this interpretation is not supported due to the symmetric structures of the ARCH and GARCH models. Results obtained from the ARCH and GARCH models reveal that cryptocurrency market volatility remains at high levels during and after the pandemic. However, both models are insufficient in predicting extreme volatility increases in crisis periods such as March 2020. This shows that existing volatility models should be reconsidered for extreme situations and high-uncertainty environments. The high volatility observed during the pandemic highlights that cryptocurrency markets are sensitive to global economic developments and should be more closely monitored by regulators. Stronger regulations and security protocols will both protect investors and help the market achieve a more stable structure. In order to reduce speculative activity and stabilize cryptocurrency markets, it may be essential to create precise and binding legal frameworks that require openness in market operations. The lessons learned from this process suggest that more robust volatility management tools should be developed not only for cryptocurrency markets but also for the financial system as a whole. In addition, it is important to focus on education and awareness activities in order to strengthen investors' risk management strategies and be better prepared for market shocks. In this regard, the impact of the pandemic can be a lesson for possible future crises.

8. Conclusion

The COVID-19 pandemic has led to a significant increase in the cryptocurrency market volatility, which, in turn, has affected investor behavior. Understanding the dynamics of cryptocurrency markets and developing investment strategies accordingly is of great importance for both lenders and policymakers. This study provides a crucial understanding regarding the management of the volatility in cryptocurrency markets, alongside providing the basis for future research. Given this importance, the existing study examines the impact of the COVID-19 pandemic on cryptocurrency investments utilizing the ARCH and GARCH models in analyzing the volatility of bitcoin prices. According to the findings, the GARCH model captures long-term volatility trends more consistently, while the ARCH model shows limited accuracy in understanding the short-term dynamics of volatility. However, the impact of shocks on volatility is found to be persistent for bitcoin during the COVID-19 pandemic.

In general speaking, the empirical results show that the volatility in the cryptocurrency market remains at a high level during and after the pandemic. Especially in the early stages of the pandemic, the economic measures taken by governments and the expansionary monetary policies implemented by central banks created a positive atmosphere in the cryptocurrency markets and attracted the attention of investors. During the pandemic, it is observed that the cryptocurrency

markets became more speculative. Investors increased their interest in these markets with high potential returns, which also resulted in market volatility. The fluctuations in bitcoin price movements reveal that the market became more risky and unpredictable during this period.

The low alpha value (0.0180%) obtained from the ARCH model indicates that the effect of previous shocks on current volatility is weak and that sudden increases in volatility are not well captured by this model. The GARCH model has a higher beta (0.7802), indicating that volatility shocks have longer-term effects. However, it can be seen that this model cannot adequately predict sudden increases in periods when extreme shocks such as pandemics are experienced intensely. As a result, based on the model results, it can be said that both the ARCH and GARCH models are insufficient to predict extreme increases in volatility during crisis periods such as pandemics. The results obtained are consistent with the findings of the study by Yıldırım and Bekun (2023). The results of the research provide important clues for understanding the dynamics of cryptocurrency markets and designing investment strategies accordingly. High volatility creates both opportunities and risks for investors. Therefore, investors need to make more careful and strategic decisions by taking volatility into account. Especially in times of uncertainty, it is important for investors to diversify their portfolios and implement effective risk management strategies. Regulation and supervision of cryptocurrency markets are critical to ensuring market stability. Regulators should implement appropriate regulations to reduce volatility in cryptocurrency markets and protect investors. In addition, in future studies, similar analyses using different cryptocurrencies and longer data sets can help to better understand the dynamics of the market. To supplement the knowledge gathered from ARCH and GARCH analysis, future research could take into account EGARCH and TGARCH models. Although the basic volatility patterns during the COVID-19 pandemic were well represented by the ARCH and GARCH models, EGARCH and TGARCH may provide additional insights, especially when examining individual asymmetric effects or distinct market reactions in various circumstances. Future studies could include other high-market-value cryptocurrencies alongside Bitcoin to provide a more comprehensive analysis.

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

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BIST 100 ENDEKSİ BORSA İSTANBUL'UN GENEL PERFORMANSINI YANSITIYOR MU?

Does the BIST 100 Index Reflect the Overall Performance of Borsa Istanbul?

Serkan ÜNAL* **& Yasemin YURTOĞLU****

Öz

Bu çalışmada, BIST 100 Endeksinin Borsa İstanbul'da yatırımcıların elde ettiği getirileri ne ölçüde etkin bir şekilde temsil ettiği araştırılmıştır. Çalışmanın veri seti 2000-2023 dönemindeki çeyreklik bazda BIST 100 Endeksi bileşenlerini, Borsa İstanbul'daki şirketlerin 31.12.1999-15.02.2024 dönemindeki getirilerini ve hisse yoğun yatırım fonlarının 23.02.2019-23.02.2024 dönemindeki performanslarını kapsamaktadır. Araştırma sonuçlarına göre BIST 100 Endeksi performansı, hisse bazlı getiri dağılımında ortalamadan ayrışabilmekte ve uçlarda kalabilmektedir. Hisselerin aşırı tepki hareketinden olumsuz yönde etkilenmektedir. BIST 100 ağırlıklı olarak bankacılık sektörünün etkisi altındadır bu nedenle farklı sektörleri temsil yeteneği güçlü değildir. Özellikle 2008 küresel finans krizinin ardından bankaların zayıf performans gösterdiği ve bu durumun BIST 100 Endeksini olumsuz etkilediği tespit edilmiştir. t testi sonuçlarına göre istatistiksel olarak anlamlı bir şekilde diğer hisselere kıyasla hızla yükselen hisseler endekse dahil olmakta, sonrasında ise negatif performans göstererek endeksi aşağıya çekmektedirler. Endeks birleşenlerinden oluşturulacak sabit bir portföy endeksin üstünde performans gösterecektir. Benzer bir durum endeksi takip eden fonlar için de geçerlidir. Endeksi takip eden fonların getirileri endeksi takip etmeyen fonların getirilerinden düşüktür. Bulgular, BIST 100 Endeksinin Borsa İstanbul'un genel performansını etkin bir şekilde yansıtmadığını göstermektedir.

Anahtar Kelimeler:
BIST 100, Aşırı Tepki Hipotezi, Karşılaştırma Ölçütü

JEL Kodları:
G11, D53, D91

Abstract

This study investigates to what extent the BIST 100 index effectively represents the returns earned by investors in Borsa Istanbul. The data set of the study encompasses quarterly BIST 100 index components spanning from 2000 to 2023, the returns of companies listed on the Borsa Istanbul from December 31, 1999, to February 15, 2024, and the five-year performance of equity-intensive investment funds. Findings indicate that the performance of the BIST 100 index exhibits deviations from the average of the individual stock returns. BIST 100 is largely under the influence of the banking sector, so its ability to represent different sectors is not strong. It has been determined that banks performed poorly, especially after the 2008 global financial crisis, and this negatively affected the BIST 100 index. The index is negatively affected by the overreaction of stocks. According to the t-test results, stocks that rapidly increase in comparison to others are included in the index in a statistically significant manner, but afterward, they exhibit negative performance, dragging the index down. A fixed portfolio created from index components will outperform the index. A similar situation applies to funds that follow the index. The returns of funds that follow the index are lower than the returns of funds that do not follow the index. The findings indicate that the BIST 100 index does not effectively reflect the overall performance of Borsa İstanbul.

Keywords:
BIST100, Overreaction Hypothesis, Benchmarking

JEL Codes:
G11, D53, D91

* Doç. Dr., Ufuk Üniversitesi, İktisadi ve İdari Bilimler Fakültesi, İşletme Bölümü, Türkiye, serkan.unal@ufuk.edu.tr
** Dr. Öğr. Üyesi, Ufuk Üniversitesi, İktisadi ve İdari Bilimler Fakültesi, İşletme Bölümü, Türkiye, yasemin.yurtoglu@ufuk.edu.tr

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1. Giriş

Günümüzde borsalar; yatırımcılar için en önemli yatırım alternatiflerinden biri olarak ön plana çıkmaktadır. Dünya borsalarında çok sayıda şirketin işlem görmesi ve borsanın genel gidişatını temsil eden bir göstergeye ihtiyaç duyulması borsa endekslerin çeşitli kurumlarca hazırlanıp yayınlanmasına neden olmuştur. Günümüzde borsa endeksleri karşılaştırma ölçütü, yatırım analizi, piyasa duyarlılığı, risk yönetimi ve finansal ürünlerin oluşturulması gibi amaçlarla kullanılabilmektedirler. Yatırım fonları borsa endekslerini karşılaştırma ölçütü olarak seçmekte ve performanslarını borsa endeksleri ile kıyaslayarak sunmaktadırlar. Yatırımcılar kendi performanslarını analiz ederken yine borsa endeksinden faydalanabilmekte ve hisse seçiminde başarılı olup olmadıklarını tespit edebilmektedirler. Borsa endeksleri yine piyasadaki duyarlılığı temsil açısından önemli rol üstlenmektedir. Belli bir haberin ya da gelişmenin piyasa koşullarını ne ölçüde etkilediğini anlamanın pratik bir yolu borsa endekslerindeki değişimleri takip etmektir. Risk yönetiminde farklı varlıkların fiyat oynaklığı değerlendirilirken borsa endeksleri ile kıyaslama yapılmaktadır. Bütün bu kullanım amaçları borsa endekslerinin doğru bir şekilde hesaplanmasının ne derece önemli olduğunu ortaya koymaktadır.

Borsa endeksleri oluşturulurken, endeksin hangi ekonomik ihtiyacı karşılamayı hedeflediği açıkça tanımlanmalıdır. Borsa endekslerinin hangi şirket grubunu temsil edeceği belirlenmelidir. Bu amaç doğrultusunda, endekse dahil edilecek şirketlerin taşıması gereken şartlar da dikkatle oluşturulmalıdır. Endeks hesabında temettü ödemelerinin veya sermaye artışlarının nasıl hesaba katılacağı da önem kazanmaktadır. Ayrıca, endeks bileşenlerinin seçim kriterlerinin endeksin amacı ile uyumlu olduğundan emin olmak önemlidir. Örneğin S&P (Standard & Poor's) endekslerin oluşturulması için komiteler kurulmuştur. Bu komitelere hem endekse dahil olacak hisselerin seçilmesinde hem de uygulanacak kuralların değiştirilmesinde yetki verilmiştir. S&P endekslerinde, kural setleri belirlenirken bir hissenin sahip olabileceği maksimum ağırlık ve yine belli büyüklüğü geçen hisselerin toplamda sahip olabileceği maksimum ağırlık gibi sınırlamalara gidilmiştir. S&P500 Endeksine dahil edilen şirketlerin seçiminde sektör bazında dengenin sağlanmasına endeks komitesi tarafından dikkat edilmektedir. Ayrıca sektör bazlı etkilerin kontrolü amacıyla sektör ağırlıklarının da eşitlendiği S&P500 Eşit Ağırlıklı Sektör Endeksi de S&P tarafından yayınlanmaktadır (S&P, 2024).

Bu çalışmada Borsa İstanbul'un performansının değerlendirilmesinde kullanılan ana endeks olan BIST 100 Endeksinin borsa performansını ne derece etkin bir şekilde temsil ettiği araştırılmıştır. İlk olarak borsanın genelindeki uzun vadeli hisse senedi getirileri ile BIST 100 Endeksinin getirisi kıyaslanmıştır. BIST 100 Endeksinin borsadaki hisselerin tümünü temsil etmek için ne derece etkin bir ölçüt olduğu tespit edilmeye çalışılmıştır. İkinci olarak BIST 100 Endeksinin zaman içindeki sektörel birleşiminin Türkiye'deki ve Borsa İstanbul'daki sektörel çeşitliliği ne derece yansıttığı analiz edilmiştir. Üçüncü olarak aşırı tepki kuramının endeks hesaplamasında oluşturduğu sorunlar analiz edilmiştir. Aşırı tepki kuramına göre hisseler yukarı ve aşağı yönde rasyonel seviyelerin ötesinde hareket edebilmektedirler. Aşırı tepki hareketi geçmişte yüksek performans sergilemiş bazı hisselerin endeks hesaplamasına katılmasına, takip eden dönemde de zayıf performans göstererek endeks hesabından çıkmasına neden olabilir. Yükseliş sırasındaki hareket büyük ölçüde endeks hesabına katılmazken, düşüş dönemindeki hareket endeks hesabına yansımaktadır. Bu da endeks performansını aşağı çeken bir faktör olabilir. Dördüncü olarak yatırım fonlarının performansından hareketle, endeks odaklı fonların ve diğer fonların performansları kıyaslanarak endeksin kapsayıcılığı analiz edilmeye çalışılmıştır. Endekse odaklanan fonların endekse odaklanmayan fonlara kıyasla ortalama bir

performans göstermeleri endeksin kapsayıcılığını teyit edecektir. Endekse odaklanan fonların en kötü ya da en iyi performansa sahip olan fonlar olması ise endeksin temsil yeteneğinin zayıf olduğunu gösterecektir.

Bu araştırmanın literatüre katkıları dört maddede özetlenebilir. İlk olarak birçok piyasa analizinde BIST 100 Endeksi temel gösterge olarak kullanılmaktadır. Birçok yatırım fonu BIST 100 Endeksini karşılaştırma ölçütü olarak seçmiştir (Ünal ve Güleç, 2022). Bu yüzden BIST 100 Endeksinin borsayı ne derece etkin temsil ettiğinin tespit edilmesi önem arz etmektedir. İkinci olarak aşırı tepki kuramının endeks hesaplamalarındaki yansımaları analiz edilmiştir. Üçüncü olarak yatırım fonlarının performansında endeks kriterlerinin ne derecede belirleyici olduğu analiz edilmiştir. Son olarak endeks içinde de halka açık piyasa değerinin getiri hesabında ne derece belirleyici olduğu araştırılmıştır.

Bu araştırmanın, BIST 100 Endeksinin değerlendirilmesine yönelik Borsa İstanbul yatırımcılarının yararlanabileceği sonuçlar sunduğu değerlendirilmektedir. Bu araştırma ile Borsa İstanbul A.Ş.'nin endeks hesabında gelecekte yapacağı iyileştirmeler için de referans bilgiler sunulması hedeflenmiştir. 5 bölümden oluşan makalenin ikinci bölümünde literatür, üçüncü bölümünde veri seti ve metodoloji, dördüncü bölümünde çalışmadan elde edilen bulgular, beşinci bölümünde ise sonuç ve tartışma sunulmuştur.

2. Literatür

Literatürdeki çalışmalar incelendiğinde endekslerin genel borsayı ne derecede temsil ettiğine dair çalışmalara rastlanmamaktadır. Literatürdeki çalışmalar daha çok endekse dahil edilen ve endeksten çıkan hisselerin getirilerine, endeks hesaplamasında temettü etkisine ve çeşitlendirme ile endeks performansı arasındaki ilişkiye odaklanmaktadır.

Literatürdeki çalışmaların önemli bir bölümünün endekse dahil edilen ve çıkarılan hisselerin getirilerine odaklandığı görülmektedir. Endekse dahil olan ve endeksten çıkan hisselerin getirilerinin piyasadan ayrışması, endeksin bir anomaliye neden olarak borsayı etkin bir şekilde temsil edememesine yol açacaktır. Chen vd. (2004) çalışmalarında, S&P 500 Endeksine dahil edilen ve çıkarılan pay senetlerinin fiyatları üzerindeki etkisini incelemişlerdir. Endekse eklenen şirketlerin fiyatlarında kalıcı bir artış gözlemlenirken, endeksten çıkarılanlar için kalıcı bir düşüş bulunamamıştır. Bu bulgu, fiyatlarda asimetrik bir tepki olarak yorumlanmış, asimetri ise yatırımcı farkındalığındaki değişimle açıklanmıştır. Çalışmada, yatırımcılar işletme hakkında bilgi edindikçe eklenen pay senetleri için farkındalık artarken, çıkarılan pay senetleri için farkındalığın daha az olduğu ifade edilmiştir. Eklemelerden sonra yatırımcıların farkındalığının arttığı ve daha iyi izlediği belirtilirken, çıkarma işlemlerinin ise olumsuz etkisinin çok daha küçük ya da hiç olmadığı ileri sürülmüştür. Türkiye ile ilgili yapılmış olan çalışmalar da yurtdışındaki bulguları teyit etmektedir. Bayraktar (2009) BIST 100 Endeksine dahil edilen ve çıkarılan hisselerin performansını incelemiştir. Araştırmada 2000-2007 yılları arasındaki veriden faydalanılmıştır. Duyuru tarihi ve işlem tarihten önce 10 gün ve sonraki 20 günde hisse senetlerinin getirileri hesaplanmıştır. Araştırma sonuçları endekse dahil edilen hisselerin pozitif, çıkarılan hisselerin ise negatif performans gösterdiğini ortaya koymuştur. Aydıner ve Altay (2020) çalışmalarında BIST30, BIST50, BIST 100 ve BIST temettü endekslerine dahil olan ve çıkarılan hisselerin takip eden dönemdeki performanslarını incelemişlerdir. Araştırmada 2011-2016 dönemindeki veriden faydalanılmıştır. Araştırmada

getiri hesaplamaları endekse dahil olma işleminden önceki 40 gün ve dahil olduktan sonraki 10 günü kapsamaktadır. Araştırma bulgularına göre araştırma kapsamındaki hisselerin getirileri endeksten çıkış duyurusu ve çıkış işleminden sonra negatif, endekse giriş duyurusu ve giriş işleminden sonra ise pozitif yönde gerçekleşmiştir. Bir diğer çalışmada Yetgin ve Ersoy (2021) firmaların BIST 100 Kurumsal Yönetim Endeksine alınmasının takip eden belli günlerde anormal negatif getirilerle sonuçlandığını bildirmişlerdir.

Literatürdeki çalışmaların bir bölümde ise endeks hesaplamasında temettülerin dikkate alınmamasının önemi vurgulanmıştır. Fisher (1966), çalışmasında, New York Borsası'nda işlem gören pay senetlerinden oluşan Ocak 1926'dan Aralık 1960'a kadar olan dönemi kapsayan yatırım performansı endekslerini tanıtmıştır. Bu endeksler, nakit temettüleri, sermaye ve fiyat kotasyonlarındaki değişimleri dikkate aldığından geleneksel pay senedi fiyat endekslerinden farklılaşmaktadır. Her ay temettü ve sermaye değişimleri için düzeltme yapıldıktan sonra, her bir pay senedinin fiyatındaki yüzde değişim fonksiyonlarına eşit ağırlık verilmiştir. Özellikle endeks, aritmetik ve geometrik ortalamaların ağırlıklı ortalamaları olan bağlantı ilişkilerini hesaplayarak yeni bir yaklaşım sunmaktadır. Bu endeks, S&P Bileşik Endeksi, Dow-Jones Sanayi Ortalaması endeksleriyle karşılaştırıldığında, önerilen endeks piyasa trendine göre 1929 ve 1932'de belirgin dönüm noktaları göstermektedir. Genel olarak bu çalışma, pay senedi portföy performansını değerlendirmek için yeni bir ölçüt sunmakta ve endeks oluşturmada temettülerin ve yöntemde farklılıkların dikkate alınmasının önemini vurgulamaktadır. Schwert (1990) çalışmasında, New York Borsası'nda işlem gören pay senetlerini dikkate alarak nakit temettülerin dahil edildiği yatırım getiri endeksi oluşturmuş, Dow Jones ve S&P günlük pay senedi getirileriyle karşılaştırmıştır. Menkul Kıymet Fiyatları Araştırma Merkezi (CRSP), New York Borsası'nda işlem gören pay senetlerinin dikkate alındığı değer ağırlıklı portföy getirilerini ölçerken temettülerin dikkate alınmasının ortalama getiri tahminlerini etkilediğini ortaya koymuştur.

Çeşitlendirme ile endeks performansı arasındaki ilişki de literatürde üzerinde sıklıkla durulan konulardan biridir. Khorana ve Nelling (1997) çalışmalarında, farklı risk-getiri özelliklerine göre oluşturdukları 147 sektör fonunun performansını S&P 500 Endeksi ve sektör endeksleri ile karşılaştırmışlardır. Çalışmada, sektör fonlarının performansı S&P 500 Endeksi ile karşılaştırıldığında daha düşük performans gösterdiği, ancak sektör endeksleri ile karşılaştırıldığında daha iyi performans gösterdiği ortaya koyulmuştur. Ayrıca, çalışmada metal sektöründe faaliyet gösteren işletmelerin sektör fonu örnekleminden çıkarılmasının sektör fonlarının performansını artırdığı ve sektör fonlarının performansının fonun büyüklüğü ile pozitif ilişkili olduğu vurgulanmıştır. Hauser ve Vermeersch (2002) çalışmalarında, ülke ve sektör bakımından çeşitlendirmenin etkinliğini, zaman içinde nasıl geliştiğini incelemişlerdir. Uluslararası çeşitlendirmede G7 ülkeleri ve İsviçre tercih edilmiştir. Portföy oluşturmada likidite, uluslararası yatırımcılar için erişilebilirlik, piyasa endekslerine orantılı sektör ve küresel ekonomide önemli yer tutan ülkeler gibi kriterler dikkate alınmıştır. Bulgular, uluslararası çeşitlendirmenin, ülkeler arası korelasyonların sektörler arası korelasyonlara kıyasla daha düşük olması nedeniyle daha verimli olduğunu göstermektedir. Çalışmada, küreselleşmenin gelişmiş ülkeler arasında daha yüksek korelasyonlara yol açabileceğinden, uluslararası çeşitlendirmenin etkinliğini azaltabileceği ifade edilmiştir. Bununla birlikte, bu dinamikleri izlemenin hem uluslararası hem de sektör çeşitlendirme stratejilerinin etkinliğini değerlendirmek için daha fazla araştırma yapılması gerektiği ileri sürülmüştür. Gupta ve Basu (2011) çalışmasında, gelişmekte olan ve gelişmiş piyasalar arasındaki korelasyon ve işlem maliyetleri arttıkça, ulusal piyasalar

içinde sektör çeşitlendirmesine odaklanmıştır. Sektörler bakımından çeşitlendirmenin uluslararası çeşitlendirmeye bir alternatif olma düşüncesiyle iki piyasada sektör çeşitlendirmesinin performanslarını incelemiştir. Çalışmada, her iki piyasada da bir yatırım portföyünün sektörler arasında dağıtılmasının faydalı olduğu vurgulanmıştır. Bulgular, sektör bakımından daha iyi çeşitlendirilmiş portföylerin sınırlandırılmış portföylere kıyasla performansların daha üstün sonuçlar verdiğini göstermektedir. Kılıç vd. (2022) yapmış oldukları çalışmada 2008 ve 2021 yılları arasındaki dönemde Türkiye'de yerleşik yatırımcıların uluslararası çeşitlendirme yapmaları durumunda portföy getirilerindeki değişim incelenmiştir. Araştırma bulgularına göre ABD piyasasında yatırım yapmanın gerek Türkiye'de yerleşik yatırımcılar için en uygun çeşitlendirme imkânını sunduğu tespit edilmiştir. Araştırma kapsamında incelenen borsalar içinde Türkiye ve Rusya borsaları en oynak borsalar olarak tespit edilmiştir.

Literatürdeki bir diğer grup çalışmada ise farklı endeks hesaplama yöntemleri üzerinde durulmuştur. Al-khalialeh ve Al-Omari (2004) çalışmalarında, Amman Menkul Kıymetler Borsası'nda (ASE) geliştirilen değer ağırlıklı piyasa endeksi (VWI) ve eşit ağırlıklı piyasa endeksinin (EWI) özelliklerini ve getirilerini ampirik olarak araştırmışlardır. Her iki endeksin piyasa getirilerini hesaplamak için 1992'den 2000'e kadar dokuz yıllık dönemi kapsayan aylık fiyat verileri kullanılmıştır. Parametrik (T-test) ve parametrik olmayan testlerin (Wilcoxon Rank Test) kullanıldığı çalışmada, VWR'nin incelenen zaman aralıkları boyunca sürekli olarak EWR'den daha iyi performans gösterdiği tespit edilmiştir. Maillard vd. (2009) çalışmalarında, Markowitz (1952) tarafından geliştirilen optimal portföy seçiminde Ortalama Varyans Modeli'ne bir alternatif olarak eşit ağırlıklı risk katkıları (ERC) portföyleri olarak bilinen bir yaklaşımı araştırmışlardır. Çalışmada, ERC portföyleri ile minimum varyans ile eşit ağırlıklı portföyler arasında bir denge kurarak portföy bileşenlerinin risk katkılarının eşitlenmesi amaçlanmıştır. Kurumsal yatırımda "risk yönetimi" adı altında yaygın olarak uygulanan bu yöntemin, portföyün kayıplarını öngördüğü ve giderek daha fazla ilgi gördüğü ifade edilmiştir. Ayrıca, ERC portföylerinin optimalliği Sharpe rasyosu kapsamında tartışılmış ve portföy optimizasyonundaki potansiyeli vurgulanmıştır.

3. Araştırma

3.1. Veri Seti

Araştırmada Borsa İstanbul tarafından yayınlanan BIST 100 Endeksi içerik verisi kullanılmıştır. Borsa İstanbul her yıl Ocak, Nisan, Temmuz ve Ekim aylarının başında BIST 100 Endeksi içerik verisini güncellemektedir. Çalışma kapsamında 2000-2023 yılları arasında toplam 96 çeyreklik endeks birleşenleri verisinden faydalanılmıştır. Araştırmada hisse performansları baz alındığı için temettü ve sermaye artırımı etkisine göre düzeltilmiş hisse getirileri kullanılmıştır. Araştırma döneminde BIST 100 Endeksinin hesaplamalarına farklı zaman dilimlerinde dahil edilen toplam şirket sayısı 326'dır.

3.2. Metodoloji

Araştırma dört aşamada gerçekleştirilmiştir. Araştırmanın ilk aşamasında 2000-2024 ve 2014-2024 dönemlerinde Borsa İstanbul'da faaliyet gösteren şirketlerin bileşik getirileri hesaplanmış ve BIST 100 Endeksinin performansı ile kıyaslanmıştır. Buradaki amaç BIST 100

Endeksinin Borsa İstanbul'u uzun vadede ne derece etkin temsil ettiğini ortaya çıkarmaktır. Eğer BIST 100 Endeksi Borsa İstanbul'daki hisselerin genelini temsil yeteneğine sahipse, BIST 100 Endeksinin performansı ile Borsa İstanbul'daki bütün hisselerin ortalama performansının birbirine yakın olması beklenir. Bu doğrultuda ilk aşamada aşağıdaki araştırma sorusuna (AS) yanıt aranmıştır.

AS1: BIST 100 Endeksi Borsa İstanbul'daki hisselerin uzun vadeli getirilerini ne ölçüde temsil edebilmektedir?

İkinci aşamada BIST 100 Endeksinin sektörel bazda birleşimi analiz edilmiştir. BIST 100 Endeksinin hesabında hisselerin halka açık piyasa değerlerinden faydalanılarak ağırlıklandırma yapılmaktadır. Bu yöntem her ne kadar piyasa değeri olarak borsanın temsil edilmesini sağlasa da eğer belli sektörler BIST 100 Endeksinde yüksek paya sahiplerse, sektörel risk dağılımına önem veren yatırımcılar için BIST 100 Endeksi iyi bir gösterge olma niteliğini taşımayacaktır. Ayrıca yabancı payı ile halka açık piyasa değeri arasında pozitif korelasyon söz konusudur (Ünal, 2021a). Nispeten büyük tutarlarla yatırım yapan yabancı yatırımcılar büyük banka ve holding hisselerini tercih etmek zorunda kalabilir. Fakat düşük bütçeli yerli yatırımcı profili düşünüldüğünde birçok küçük ve ortak ölçekli işletmenin yeterli likiditeyi sunduğu görülmektedir. Bu nedenle yerli yatırımcıların ve sektör bazlı risk çeşitlemesi yapan yatırımcıların portföylerindeki sektör dağılımı ile BIST 100 hesabında kullanılan sektör dağılımı birbirinden farklı olabilir. Özellikle 2008 küresel Finans krizinin ardından dünya ölçeğinde bütün bankaların zayıf performans gösterdiği (Weigand, 2016) dikkate alınırsa BIST 100 bundan daha da olumsuz etkilenmiş olabilir. Bu amaçla ikinci aşamada aşağıdaki araştırma sorusuna yanıt aranmıştır.

AS2: BIST 100 hesaplamasındaki halka açık piyasa değeri ağırlıklı sektörel dağılım Borsa İstanbul'u ne derece etkin temsil etmektedir?

Araştırmanın üçüncü aşamasında şirketlerin endekse dahil edilmesi için uygulanan kuralların endeks değerlerini ne ölçüde etkilediği analiz edilmiştir. Borsa İstanbul tarafından 27.12.2023 tarihinde yürürlüğe alınan BIST Piyasa Değeri Ağırlıklı Pay Endeksleri Kural setine göre değerleme dönemleri "Kasım, Şubat, Mayıs ve Ağustos aylarının son işlem gününden geriye doğru 6 ay" olarak belirlenmiştir. Endeks güncellemeleri ise Ocak, Nisan, Temmuz ve Ekim aylarının ilk günlerinde yapılmaktadır. Endekse dahil edilecek paylar değerleme dönemlerindeki ortalama fiili dolaşımdaki piyasa değerlerine ve işlem hacimlerine göre sıralanarak seçilmektedir. Bu nedenle endeks seçim tarihinden önceki dönemde büyük ölçüde yükselmiş hisse senetleri endekse dahil olabilmektedir. Diğer yandan hisselerin endekse katılmadan önceki yüksek performansları endeks hesabına dahil değildir. Ünal (2021b) aşırı tepki hipotezinin Türkiye'deki geçerliliğini test ettiği çalışmasında geçmiş 1, 3 ve 5 yıllık dönemlerde yüksek performans göstermiş hisselerin takip eden dönemde kötü performans göstermeye başladığını, benzer şekilde geçmişte kötü performans göstermiş hisselerin takip eden dönemde iyi performans göstermeye başladığını bildirmiştir. Benzeri şartların BIST 100 Endeksi hesabında da geçerli olması durumunda BIST 100 Endeksinin performansı piyasa performansından daha düşük hesaplanacaktır. Bu nedenle bu aşamada, BIST 100 Endeksini oluşturan firmaların endeks duyurularından önceki 3 ay, sonraki 3 ay, sonraki 1 yıl ve sonraki 3 yıllık düzeltilmiş hisse getirileri hesaplanmıştır. Performansların kıyaslanabilmesi için endekste bulunan hisseler 5 farklı gruba ayrılmıştır. Endekse ilgili çeyrekte giren, endeksten çıkan, 1 yıldır, 3 yıldır ve 5 yıldır endekste bulunan şirketler için ayrı ayrı ilgili dönemlerdeki düzeltilmiş

hisse getirilerinin aritmetik ortalaması hesaplanmıştır. t testleri ile farklı gruplardaki hisselerin performanslarının endekse yeni giren hisselerin performansından ayrışıp ayrışmadığı test edilmiştir. Araştırmanın üçüncü aşamasında yanıt aranan araştırma sorusu aşağıda belirtilmiştir.

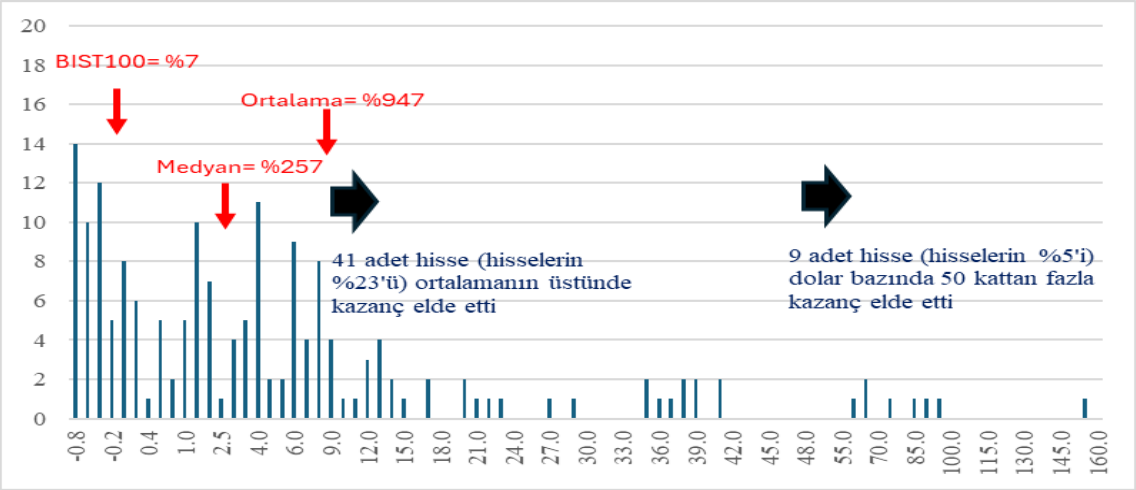
AS3: BIST 100 Endeksine yeni giren, çıkan ve bir yıldan uzun süredir endekste bulunan hisselerin takip eden dönemdeki getirileri arasında ilişki var mıdır?

Araştırmanın dördüncü aşamasında hisse senedi fonlarının son beş yıldaki getirileri incelenmiştir. Bazı hisse fonları endeks ağırlıklı yatırım yapmakta, bazı hisse fonları belli sektöre odaklanmakta, bazı hisse fonları ise serbest şekilde hisse seçmektedirler. Bu yatırım tarz farklılıklarının olası sonuçlara etkisini ortaya koymak endeksin borsayı ne derece etkin şekilde temsil ettiğini anlama noktasında faydalı olabilir. Eğer endeks borsayı etkin bir şekilde temsil ediyorsa endekse yatırım yapan fonların diğer fonlardan performans olarak ayrışmaması ve sıralama olarak ortalarda yer alması beklenir.

AS4: Endekse yatırım yapan fonlar ile diğer fonlar arasında son beş yıllık dönemde performans farkı oluştu mu?

4. Bulgular

2000 yılında Borsa İstanbul'da 315 şirket işlem görmekteydi. Araştırmada kullanılan verilere göre bu hisselerden 174'ü 2024 Şubat ayında da işlem görmektedir. İşleme devam etmeyen şirketlerin büyük kısmı diğer şirketlerle birleşmiş, bir kısmı borsadan çekilmiş, bir kısmı ise iflas etmiştir. 31.12.1999-15.02.2024 döneminde Borsa İstanbul'da işlem gören ve hisse fiyat performansına ulaşılabilen 174 adet hissenin dolar bazında getirileri Şekil 1'de paylaşılmıştır.

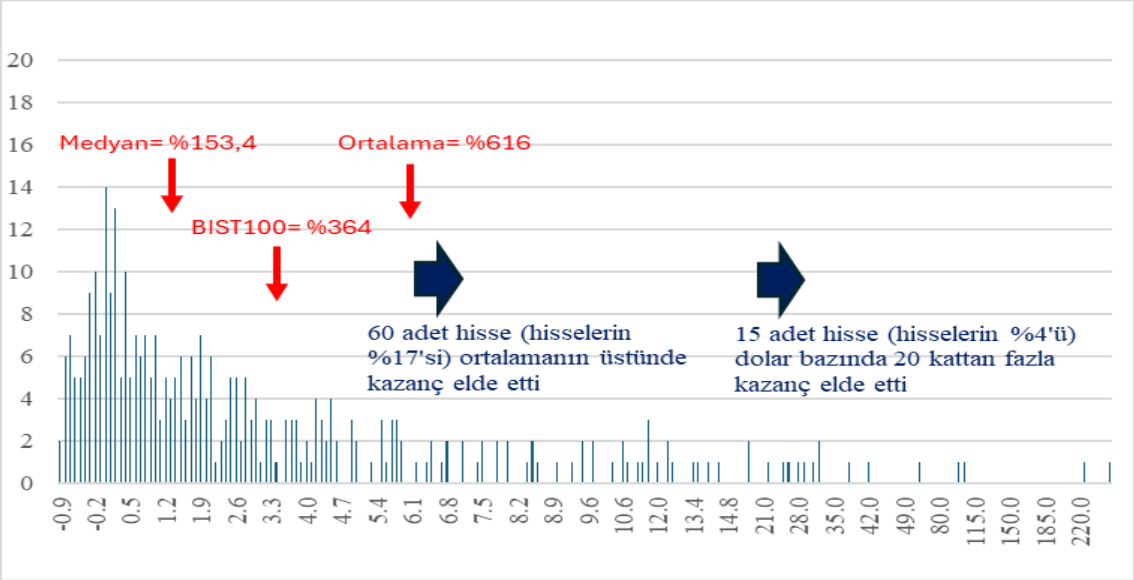


Şekil 1. 31.12.1999-15.02.2024 Döneminde 174 Adet Hissenin Düzeltilmiş Performansı (USD)
Kaynak: Araştırma verisi kullanılarak yazarlar tarafından hazırlanmıştır.
Not: Hisse senedi getirilerine nakit temettü dağıtımları ve sermaye artırımlarının etkisi dahil edilmiştir. 2000 yılında toplam 315 hisse senedi bulunmasına karşın düzeltilmiş hisse senedi getirisi verisine ulaşılabilen 174 adet hisse analize dahil edilmiştir.

Düzeltilmiş fiyat verisine ulaşılamayan 141 şirketin tamamının -%100 oranında performans gösterdiği varsayılsa bile 315 hisseye 2000 yılının başında eşit ağırlıklı yapılan

yatırımın 15.02.2024 tarihindeki dolar bazındaki getirisi %478 olmaktadır. Aynı dönemde BIST 100 Endeksinin getirisi %7 olarak gerçekleşmiştir. 174 adet hisseden yalnızca 50 tanesi BIST 100 Endeksinin getirisinin altında kalırken 124 tanesi BIST 100 Endeksinden daha yüksek getiriye sahip olmuştur. BIST 100 Endeksinin hesaplamasında temettü etkisi dikkate alınmamaktadır. İlgili dönemde BIST 100 Getiri Endeksinin dolar bazında getirisinin de %104'te kaldığı dikkate alınmalıdır. BIST 100 temettü etkisi dikkate alınsa bile Borsa İstanbul'daki şirketlerin uzun vadeli getirileri noktasında geneli temsil yeteneğine sahip olmamıştır.

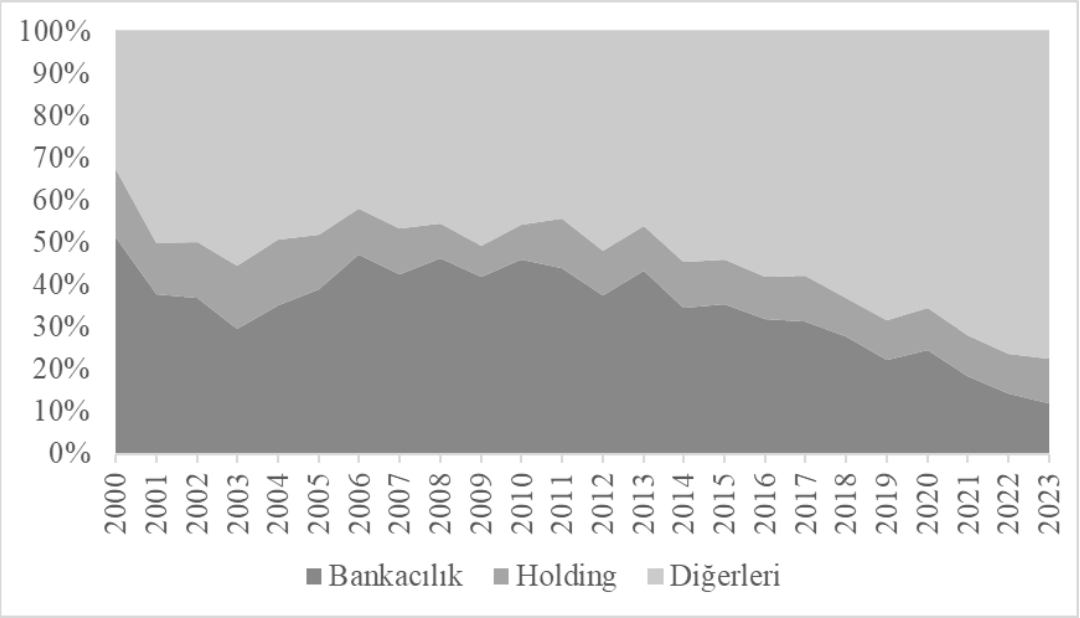
Şekil 2'de Borsa İstanbul'daki hisselerin son 10 yıllık performansları ile BIST 100 Endeksinin performansı kıyaslanmıştır. 2014 yılında Borsa İstanbul'da 427 şirket işlem görmekteydi. Fiyat verisine ulaşılabilen 342 adet hissenin ortalama performansı %616 olarak gerçekleşmiştir. 106 adet hisse BIST 100 Endeksinden daha yüksek performans sergilemiştir. 106 hisse toplamın %31'ini oluştursa da uzun vadede hisse senedi getirilerinin sağa yatık olduğu düşünüldüğünde bu beklenen bir durumdur. Yine ortalama getirilerin BIST 100 Endeksinden oldukça yüksek olduğu ve 10 yıllık bir zaman dilimi için dolar bazında yıllık bileşik %21.7 getiriye işaret ettiği görülmektedir. BIST 100 Endeksi her ne kadar 2000 yılından sonraki dönemde dolar bazında yerinde saysa da hisse bazında çeşitlendirilmiş bir portföy ile dolar bazında da oldukça tatminkâr getirilere Borsa İstanbul'da ulaşılabildiği görülmektedir.



Şekil 2. 31.12.2013-15.02.2024 Döneminde 342 Adet Hissenin Düzeltilmiş Performansı (USD)
Kaynak: Araştırma verisi kullanılarak yazarlar tarafından hazırlanmıştır.
Not: Araştırma verisi kullanılarak yazarlar tarafından hazırlanmıştır. Hisse senedi getirilerine nakit temettü dağıtımları ve sermaye artırımlarının etkisi dahil edilmiştir. 2013 yılında toplam 427 hisse senedi bulunmasına karşın düzeltilmiş hisse senedi getirisi verisine ulaşılabilen 342 adet hisse analize dahil edilmiştir.

Araştırmanın ikinci aşamasında BIST 100 Endeksindeki şirketlerin sektör bazında birleşimleri incelenmiştir. 2000-2023 döneminde sektör bazında BIST 100 Endeksinin ağırlıklarının gelişimi Şekil 3'te gösterilmiştir. 2000 yılında bankacılığın BIST 100 endeks hesaplamasındaki ağırlığı %51 iken, 2013 yılındaki ağırlık %43'tür. Banka hisseleri dışında

holding kategorisinde sınıflanan Koç Holding ve Sabancı Holding gibi şirketlerin ana iştiraklerinin de banka olduğu dikkate alınırsa ve holdinglerin aynı dönem içinde Borsa İstanbul'daki ağırlıklarının %10 ile %16 arasında değiştiği göz önünde bulundurulursa bu süre zarfında bankacılık sektörünün endeks performansını belirleyen temel öğe olduğu sonucuna varılabilir. 2000 yılında Borsa İstanbul'da işlem gören banka sayısı 18, 2014 yılında 16 iken 2023 sonunda bu sayı 10'a düşmüştür. 2023 sonu itibarıyla BIST 100 Endeksine dahil edilen banka sayısı yalnızca 9'dur. Bu az sayıda hissenin BIST 100 Endeksinde ağır bir paya sahip oluşu ve bu hisselerin zayıf performansı BIST 100 Endeksinin ciddi anlamda geri çekmiştir. Örneğin endeksin önemli birleşenlerinden olan Halk Bankasının 31.12.2013-15.02.2024 arasında dolar bazında düzeltilmiş performansı yaklaşık -%90, Vakıfbank'ın ise -%69'dur. Aynı dönemde Garanti bankası -%8'lik, Akbank -%26'lık, ve Yapı Kredi -%8'lik performanslar göstererek endeks performansını aşağı çekmişlerdir.



Şekil 3. 2000-2023 Döneminde Sektör Bazında BIST 100 Endeksinin Ağırlığının Gelişimi
Kaynak: Araştırma verisi kullanılarak yazarlar tarafından hazırlanmıştır.

Şekil 4'te BIST Bankacılık Endeksinin BIST 100 Endeksine kıyasla 1997 ve 2024 yılları arasındaki performansı paylaşılmıştır. Grafikten de görüleceği üzere 1997-2011 yılları arasında bankacılık endeksi Borsa İstanbul getirilerini desteklerken 2011'den sonraki dönemde ciddi bir negatif trend oluşmuştur. Bu da tek bir sektöre bağlı olarak uzun vadeli yatırım yapmanın risklerini ortaya çıkarmaktadır. Bankacılığın ağırlığı dikkate alındığında Borsa İstanbul bu dönemde büyük bir ülkenin piyasa endeksi gibi değil de bir sektör endeksi vasfına sahip olmuştur. Buna karşın Türkiye ekonomisinde yüksek sektörel çeşitlilik (Kaplan ve Tut, 2017) söz konusudur. Şubat 2024 itibariyle Borsa İstanbul'da 49 farklı sektör temsil edilmekte, 4 ana sektör ve 23 sektör için endeks hesaplanmaktadır. Oransal dağılımlar incelendiğinde bu çeşitlilik BIST 100 Endeksinde sağlıklı bir şekilde temsil edilmemektedir.

Şekil 4. BIST Bankacılık Endeksinin BIST 100 Endeksine Kıyasla Performansı
Kaynak: tradingview.com

Araştırmanın üçüncü aşamasında De Bondt ve Thaler (1985) tarafından tanımlanan aşırı tepki kuramının BIST 100 endeks hesaplamasını etkileyip etkilemediği test edilmiştir. Bu amaçla ilk olarak endeks duyurusundan önceki 3 aylık dönemde endeks birleşeni olan şirketlerin getirileri hesaplanmıştır. Elde edilen sonuçlar Tablo 1'de sunulmuştur. Tablodan da görüleceği üzere beklendiği şekilde, diğer şirketlere kıyasla endekse yeni giren şirketler daha yüksek, endeksten çıkan şirketler ise daha düşük performans sahibidir. 1, 3 ve 5 yıldır endekste bulunan şirketlerin ise getirileri birbirlerine yakın bulunmaktadır. Endekse yeni giren şirketlerin yıllık ortalama getirileri ile diğer grupların ortalama getirileri arasındaki farkı t testi yöntemiyle sınadığımızda da istatistiksel olarak %1 anlam derecesinde bu farklılıklar teyit edilmektedir.

Tablo 1. t -3 Aylık Performanslar (Endeks Açıklamasından Önceki 3 Aylık Dönemdeki Getiri)

Yıl	Yeni Girenler	Çıkanlar	1 Yıldır Olanlar	3 Yıldır Olanlar	5 Yıldır Olanlar
2000	33.1%	-17.5%			
2001	-1.5%	15.4%	-7.0%		
2002	35.4%	-4.8%	19.1%		
2003	52.8%	17.1%	8.5%	10.2%	
2004	23.4%	7.1%	15.3%	16.7%	
2005	17.1%	5.1%	10.3%	9.8%	10.7%
2006	25.0%	-13.4%	6.4%	6.2%	6.2%
2007	31.5%	6.1%	10.6%	10.8%	10.0%
2008	12.4%	-22.2%	-11.2%	-11.3%	-10.8%
2009	37.7%	16.1%	16.3%	17.1%	16.1%
2010	35.3%	12.6%	12.2%	9.7%	9.4%
2011	13.9%	-15.2%	0.4%	-0.2%	0.1%
2012	9.6%	5.3%	4.5%	4.2%	4.5%
2013	17.1%	-6.9%	4.1%	4.4%	4.8%
2014	20.2%	-3.1%	1.7%	1.3%	1.6%
2015	33.0%	-4.9%	4.1%	4.4%	5.2%
2016	31.9%	2.3%	4.2%	4.1%	4.2%
2017	33.6%	3.8%	9.4%	9.5%	9.6%
2018	18.6%	5.6%	-0.7%	-1.0%	-1.6%
2019	-6.5%	27.1%	4.0%	4.8%	4.7%
2020	32.2%	20.8%	12.7%	12.6%	12.1%
2021	8.6%	0.0%	10.2%	10.2%	10.1%
2022	18.3%	41.0%	27.2%	29.7%	29.3%
2023	68.8%	-9.9%	33.2%	34.1%	32.9%
Ortalama	24.1%	3.7%	8.4%	8.4%	8.4%
STD (2005-2023)	15.7%	15.3%	9.8%	10.3%	9.9%
Olasılık		0.000	0.000	0.000	0.000
t ist.		-4.1	-5.6	-5.2	-4.9

Not: Her bir yıl için endeksin çeyrek başlarındaki değişimleri dikkate alınmıştır. Yıllık veriler bu dört çeyrekte ilgili gruba giren hisselerin geçmiş 3 aylık getirilerinin ortalamasını sunmaktadır. t testleri yapılırken kıyaslamalar "Yeni Girenler" ile diğer gruplar arasında gerçekleştirilmiştir. Borsa İstanbul'dan alınan endeks birleşen verileri 2000 yılında başlamaktadır. Bu yüzden t testleri yapılırken kıyaslama sırasında "Çıkanlar" grubu için 24 yıllık, "1 Yıldır Olanlar" grubu için 23 yıllık, "3 Yıldır Olanlar" grubu için 21 yıllık ve "5 Yıldır Olanlar" grubu için 19 yıllık test dönemleri kullanılmıştır.

İkinci olarak, endekse dahil edilen şirketlerin takip eden 3 aylık dönemdeki performansları incelenmiştir (Tablo 2). Elde edilen sonuçlara göre farklı gruplar arasında istatistiksel bir farklılık bulunmamaktadır. Bu durum bir yıllık dönemlerde momentum stratejisinin etkinliğini göstermiş olan Jegadeesh ve Titman (1993) çalışmasıyla uyumludur. Belli büyüklükteki hisse senetleri yüksek performans gösterdikleri için endekse dahil olabilmekte, takip eden dönemde de bu momentumun devam etmesi ya da endekse dahil olma sayesinde elde edilen yeni yatırımlarla performans korunabilmektedir.

Tablo 2. t +3 Aylık Performanslar (Endeks Açıklamasını Takip Eden 3 Aylık Dönemdeki Getiri)

Yıl	Yeni Girenler	Çıkanlar	1 Yıldır Olanlar	3 Yıldır Olanlar	5 Yıldır Olanlar
2000	-19.1%	-16.5%			
2001	8.0%	5.9%	23.7%		
2002	-8.0%	4.1%	-2.4%		
2003	-11.9%	11.6%	15.3%	18.3%	
2004	6.8%	8.9%	7.5%	7.9%	
2005	11.3%	18.8%	12.8%	13.1%	13.9%
2006	3.4%	4.2%	0.4%	0.8%	1.5%
2007	7.5%	2.7%	8.1%	8.0%	7.7%
2008	-11.5%	-9.7%	-17.6%	-17.0%	-16.5%
2009	14.6%	18.6%	28.0%	27.9%	27.5%
2010	65.7%	15.6%	10.8%	8.6%	8.9%
2011	2.6%	-7.7%	-6.5%	-7.0%	-6.7%
2012	7.7%	6.7%	10.9%	11.5%	11.7%
2013	-0.2%	-9.1%	-2.7%	-2.8%	-2.2%
2014	6.9%	2.9%	8.5%	8.7%	8.4%
2015	1.6%	-4.0%	-0.5%	-0.3%	-0.2%
2016	-0.9%	8.6%	4.7%	5.2%	5.0%
2017	17.3%	-2.2%	10.2%	11.0%	11.3%
2018	-12.8%	-9.7%	-6.8%	-6.5%	-7.0%
2019	21.5%	-5.9%	13.6%	13.2%	13.2%
2020	-2.1%	31.0%	16.3%	17.2%	17.0%
2021	6.2%	5.0%	8.0%	8.6%	7.3%
2022	34.6%	23.8%	38.4%	39.4%	39.8%
2023	10.3%	36.7%	10.2%	11.2%	11.4%
Ortalama (2005-2023)	9.7%	6.6%	7.7%	7.9%	8.0%
STD (2005-2023)	17.4%	14.0%	12.5%	12.6%	12.6%
Olasılık		0.819	0.862	0.980	0.633
t ist.		0.9	1.1	2.2	0.3

Not: Her bir yıl için endeksin çeyrek başlarındaki değişimleri dikkate alınmıştır. Yıllık veriler bu dört çeyrekte ilgili gruba giren hisselerin takip eden 3 aylık getirilerinin ortalamasını sunmaktadır. t testleri yapılırken kıyaslamalar "Yeni Girenler" ile diğer gruplar arasında gerçekleştirilmiştir. Borsa İstanbul'dan alınan endeks birleşen verileri 2000 yılında başlamaktadır. Bu yüzden t testleri yapılırken kıyaslama sırasında "Çıkanlar" grubu için 24 yıllık, "1 Yıldır Olanlar" grubu için 23 yıllık, "3 Yıldır Olanlar" grubu için 21 yıllık ve "5 Yıldır Olanlar" grubu için 19 yıllık test dönemleri kullanılmıştır.

Ünal (2021b) çalışmasında vade uzadıkça geçmişte yüksek getiriye sahip olmuş şirketlerin takip eden dönemde düşük getiriye sahip olma olasılığının arttığını bildirmiştir. Bu amaçla endeks duyurusunu takip eden bir yıldaki hisse senedi performansları Tablo 3'te sunulmuştur. 3 aylık performansların aksine endekse yeni giren hisselerin diğer gruplara kıyasla yüksek performansı bir yıllık dönemde koruyamadığı görülmektedir. Benzer şekilde endeksten çıkan hisselerin getirileri de diğer gruplara yaklaşmıştır. Bir yıldan uzun süredir endekste bulunan şirketler, yeni giren şirketler ve çıkan şirketlerin 1 yıllık getirileri arasında istatistiksel olarak anlamlı bir farklılık bulunmamaktadır.

Tablo 3. t +1 Yıllık Performanslar (Endeks Açıklamasını Takip Eden 12 Aylık Dönemdeki Getiri)

Yıl	Yeni Girenler	Çıkanlar	1 yıldır olanlar	3 yıldır olanlar	5 yıldır olanlar
2000	-46.1%	-37.8%			
2001	26.7%	41.6%	37.6%		
2002	2.2%	16.5%	12.7%		
2003	13.2%	79.7%	74.5%	85.0%	
2004	37.7%	37.0%	37.0%	40.1%	
2005	63.2%	53.0%	48.7%	50.0%	47.2%
2006	12.6%	7.4%	21.9%	22.7%	22.1%
2007	7.6%	6.8%	-13.6%	-13.3%	-14.7%
2008	-23.6%	-11.6%	-8.4%	-8.7%	-9.3%
2009	99.0%	90.8%	101.7%	99.4%	100.8%
2010	36.4%	31.4%	25.2%	25.9%	27.6%
2011	-11.9%	-24.9%	-7.4%	-6.6%	-5.7%
2012	24.0%	15.0%	28.4%	33.4%	37.9%
2013	-13.3%	-10.3%	-5.1%	-5.2%	-3.9%
2014	35.6%	7.2%	25.7%	25.7%	27.3%
2015	-8.7%	5.2%	3.1%	3.8%	3.9%
2016	23.7%	42.6%	27.1%	28.5%	29.6%
2017	39.4%	8.7%	20.7%	23.2%	22.9%
2018	-21.3%	-17.7%	-7.2%	-7.2%	-8.0%
2019	91.5%	109.3%	54.6%	52.0%	52.0%
2020	89.3%	77.2%	71.9%	73.0%	72.0%
2021	64.6%	43.2%	81.4%	87.4%	84.5%
2022	163.9%	168.5%	168.5%	170.4%	170.2%
2023	22.4%	12.1%	33.7%	35.6%	33.4%
Ortalama (2005-2023)	36.5%	32.3%	35.3%	36.3%	36.3%
STD (2005-2023)	49.0%	49.4%	45.6%	45.9%	45.8%
Olasılık		0.815	0.528	0.492	0.948
t ist.		0.9	0.1	0.0	1.7

Not: Her bir yıl için endeksin çeyrek başlarındaki değişimleri dikkate alınmıştır. Yıllık veriler bu dört çeyrekte ilgili gruba giren hisselerin takip eden 1 yıllık getirilerinin ortalamasını sunmaktadır. t testleri yapılırken kıyaslamalar "Yeni Girenler" ile diğer gruplar arasında gerçekleştirilmiştir. Borsa İstanbul'dan alınan endeks birleşen verileri 2000 yılında başlamaktadır. Bu yüzden t testleri yapılırken kıyaslama sırasında "Çıkanlar" grubu için 24 yıllık, "1 Yıldır Olanlar" grubu için 23 yıllık, "3 Yıldır Olanlar" grubu için 21 yıllık ve "5 Yıldır Olanlar" grubu için 19 yıllık test dönemleri kullanılmıştır.

De Bondt ve Thaler (1985) çalışmalarında 3 yıllık frekansta aşırı tepki hareketlerinin tespit edildiğini bildirmişlerdir. O halde endekse yeni giren, çıkan ve bir yıldan uzun süredir endekste bulunan şirketlerin takip eden dönemdeki 3 yıllık performanslarını kıyaslamak; endekse giriş ve çıkışların endeks getirilerine etkisini analiz etmek açısından faydalı olacaktır. Elde edilen sonuçlar, Tablo 4'te sunulmuştur. 3 yıllık vadelerde endekse yeni giren şirketlerin, endeksten çıkan ve bir yıldan uzun süredir endekste bulunan şirketlere kıyasla daha düşük performansa sahip olduğunu göstermektedir.

Tablo 4. t +3 Yıllık Performanslar (Endeks Açıklamasını Takip Eden 36 Aylık Dönemdeki Yıllık Bileşik Getiri)

Yıl	Yeni Girenler	Çıkanlar	1 Yıldır Olanlar	3 Yıldır Olanlar	5 Yıldır Olanlar
2000	-9.1%	-2.4%			
2001	16.9%	26.8%	43.2%		
2002	25.5%	38.7%	43.1%		
2003	28.6%	72.2%	55.9%	57.6%	
2004	43.1%	44.5%	35.0%	35.9%	
2005	14.4%	19.3%	16.0%	14.3%	12.5%
2006	-9.1%	-4.2%	-4.5%	-4.6%	-4.3%
2007	15.9%	7.6%	8.3%	8.6%	9.1%
2008	19.8%	37.9%	25.9%	27.7%	27.1%
2009	25.6%	22.2%	32.6%	34.4%	34.9%
2010	8.8%	27.0%	15.1%	17.6%	18.8%
2011	2.1%	-10.2%	5.1%	7.9%	9.2%
2012	21.9%	20.7%	15.0%	18.0%	20.0%
2013	5.2%	10.6%	7.2%	7.9%	8.6%
2014	20.1%	7.0%	19.1%	20.0%	21.4%
2015	7.2%	33.0%	18.0%	18.9%	20.4%
2016	-5.2%	5.5%	13.4%	13.6%	13.1%
2017	23.6%	25.8%	19.3%	18.3%	16.7%
2018	32.8%	41.7%	33.7%	32.6%	31.8%
2019	63.7%	59.7%	63.6%	63.2%	63.4%
2020	91.3%	98.5%	98.5%	97.6%	97.4%
2021	45.1%	70.7%	75.8%	72.8%	72.3%
Ortalama (2005-2021)	22.6%	27.8%	27.2%	27.6%	27.8%
STD (2005-2021)	25.1%	27.9%	27.3%	26.5%	26.3%
Olasılık		0.016	0.013	0.030	0.026
t ist.		-2.3	-2.4	-2.0	-2.1

Not: Her bir yıl için endeksin çeyrek başlarındaki değişimleri dikkate alınmıştır. Yıllık veriler bu dört çeyrekte ilgili gruba giren hisselerin takip eden 3 yıldaki yıllık bileşik getirilerinin ortalamasını sunmaktadır. t testleri yapılırken kıyaslamalar "Yeni Girenler" ile diğer gruplar arasında gerçekleştirilmiştir. Borsa İstanbul'dan alınan endeks birleşen verileri 2000 yılında başlamaktadır. Bu yüzden t testleri yapılırken kıyaslama sırasında "Çıkanlar" grubu için 22 yıllık, "1 Yıldır Olanlar" grubu için 21 yıllık, "3 Yıldır Olanlar" grubu için 19 yıllık ve "5 Yıldır Olanlar" grubu için 17 yıllık test dönemleri kullanılmıştır.

Son aşamada endeksi takip eden ve endeksi takip etmeyen fonların performansları kıyaslanmıştır. 23.02.2024 tarihinde TEFAS sisteminde halka açık olarak işlem gören ve son beş yıllık performans verisine TEFAS sisteminden ulaşılabilen 54 adet Hisse Senedi Yoğun fonun son beş yıldaki getirileri Tablo 5'te sunulmuştur. Bu fonların ilgili dönemdeki ortalama getirisi %1231 ve medyan getirisi %1207 düzeyindedir. Sıralamada en son 11'de bulunan fonların 5'i BIST30 Endeksine, ikisi bankacılık sektörüne yatırım yapmaktadır. BIST30 ve BIST 100 Endeksine odaklı yatırım yapan 6 adet fonun ortalama getirisi %717; bankacılık sektörüne yatırım yapan 2 adet fonun ortalama getirisi %698 olmuştur. İlgili dönemde BIST30 Endeksinin performansı %661, BIST 100 Endeksinin performansı %798 ve XTUMY Endeksinin performansı ise %2589 olmuştur. Elde edilen sonuçlar BIST30 ve BIST 100 endekslerinin borsanın genelini yansıtma noktasında başarılı olamadığı tezini desteklemektedir. Sadece fonların getirileri değil XTUMY Endeksinin getirisi de BIST30 ve BIST 100 endekslerinden ayrışmaktadır.

Tablo 5. 23.02.2024 Tarihinde TEFAS'da Halka Açık İşlem Gören Hisse Senedi Yoğun Fonların Son Beş Yıllık Performansları

Fon Kodu	Fon Adı	5 Yıl	Fon Kodu	Fon Adı	5 Yıl
MAC	Marmara Capital Portföy	2555%	TI3	İş Portföy İş Bankasi İştirakleri Endeksi	1207%
GMR	Inveo Portföy İkinci	2530%	TLH	Aura Portföy	1201%
EID	Qinvest Portföy	2274%	YHS	Yapi Kredi Portföy Birinci	1136%
TTE	İş Portföy Bist Teknoloji	2155%	AK3	Ak Portföy	1128%
TKF	Tacirler Portföy	1877%	AFT	Ak Portföy Yeni Teknolojiler Yabanci	1098%
ST1	Strateji Portföy Birinci	1838%	DAH	Deniz Portföy	1093%
HVS	Hsbc Portföy	1772%	YAY	Yapi Kredi Portföy Yabanci Teknoloji	1020%
RBH	Albaraka Portföy Katilim	1639%	TZD	Ziraat Portföy	1009%
GL1	Azimut Pyş Birinci	1617%	GSP	Azimut Pyş Kar Payi Ödeyen	978%
ACC	İstanbul Portföy Dördüncü	1613%	DPT	Deniz Portföy Bist Temettü 25 Endeksi	941%
FPH	Fiba Portföy	1597%	AFA	Ak Portföy Amerika Yabanci	849%
UPH	Ünlü Portföy	1585%	AYA	Ata Portföy Kar Payi Ödeyen	846%
AAV	Ata Portföy İkinci	1580%	DZE	Deniz Portföy Bist 100 Endeksi	825%
AHI	Atlas Portföy Birinci	1557%	ALC	Ak Portföy Kar Payi Ödeyen Şirketler	816%
ZPE	Ziraat Portföy Katilim	1452%	TMG	İş Portföy Yabanci	795%
MPS	Aktif Portföy Katilim	1448%	ACK	İstanbul Portföy	787%
GHS	Garanti Portföy	1428%	HBU	Hsbc Portföy Bist 30 Endeksi	734%
YDI	Yapi Kredi Portföy İkinci	1413%	AFS	Ak Portföy Sağlik Sektörü Yabanci	730%
FYD	Qnb Finans Portföy Birinci	1409%	ADP	Ak Portföy Bist Banka Endeksi	707%
TYH	Teb Portföy	1376%	YEF	Yapi Kredi Portföy Bist 30 Endeksi	704%
ICF	Icbc Turkey Portföy	1362%	AKU	Ak Portföy Bist 30 Endeksi	700%
KYA	Kare Portföy	1301%	TAU	İş Portföy Bist Banka Endeksi	690%
TI2	İş Portföy	1296%	AFV	Ak Portföy Avrupa Yabanci	689%
EC2	Global Md Portföy Birinci	1237%	TIE	İş Portföy Bist 30 Endeksi	674%
OHB	Oyak Portföy Birinci	1235%	GAE	Garanti Portföy Bist30 Endeksi	668%
YAS	Yapi Kredi Portföy Koç Holding	1228%	GBG	Inveo Portföy G-20 Ülkeleri Yabanci	648%
GAF	Inveo Portföy Birinci	1226%	AOY	Ak Portföy Alternatif Enerji Yabanci	196%

Gerek BIST30 Endeksinde gerekse BIST 100 endekslerinde performans hesabında pay bazında halka açık piyasa değeri ağırlıklandırılması yapılmaktadır. Bu da halka açık piyasa değeri daha yüksek olan şirketlerin daha belirleyici olmasını sağlamaktadır. Fama ve French (1995) çalışmalarında küçük piyasa değerine sahip şirketlerin daha yüksek riske ve daha yüksek getiriye sahip olduklarını belirtmişlerdir. BIST30 ve BIST 100 endeksleri Borsa İstanbul'da büyük ölçekli şirketleri temsil etmektedirler. Diğer yandan 2000 yılından beri sürekli olarak Borsa İstanbul'da işlem gören şirket sayısı 300'ün üstündedir. Buna rağmen endeksin içinde de piyasa değeri faktörü belirleyici olabilir. Bu amaçla çeyreklik endeks birleşenleri dikkate alınarak hisse senetleri halka açık piyasa değerlerine göre sıralanmış ve içinde eşit sayıda hisse bulunan beş farklı gruba ayrılmıştır. Daha sonrasında takip eden bir yıldaki getirileri hesaplanarak yıl bazında her bir gruba giren hisselerin ortalama getirileri hesaplanmıştır. Elde edilen sonuçlar Tablo 6'da sunulmuştur. En büyük hisselerin bulunduğu 1. grup diğer gruplardan daha düşük getiriye sahiptir. Bankacılık hisselerinin ağırlıklı olan 1. grupta yer alması nedeniyle bu beklenen bir sonuçtur. Diğer yandan diğer gruplar arasında belirgin bir performans farkı bulunmamaktadır. Ortalama getiriler arasındaki farklılıkların istatistiksel olarak anlamlı olmadığı t testleri ile gösterilmiştir.

Tablo 6. BIST 100 Endeksinde Bulunan Şirketlerin Halka Açık Piyasa Değerine Bağlı Olarak Yıllık Bileşik Performansları

Yıl	1 (En Büyük)	2	3	4	5 (En Küçük)
2000	-13.4%	-13.1%	-16.1%	-17.2%	-0.9%
2001	9.4%	13.7%	5.9%	11.6%	12.7%
2002	2.7%	3.7%	4.4%	5.8%	2.9%
2003	23.7%	18.9%	19.0%	17.6%	17.7%
2004	11.8%	10.4%	17.6%	9.7%	10.8%
2005	11.5%	12.0%	15.2%	15.9%	18.4%
2006	7.8%	8.1%	5.8%	5.8%	1.0%
2007	-2.6%	-5.5%	-6.7%	-3.0%	-6.0%
2008	-2.7%	-4.8%	-3.3%	-1.9%	5.1%
2009	23.2%	26.3%	25.6%	34.3%	27.7%
2010	4.9%	8.5%	6.8%	12.5%	16.4%
2011	0.0%	0.9%	-0.5%	-2.5%	-7.7%
2012	11.9%	13.2%	7.7%	5.6%	-1.6%
2013	-1.0%	-0.4%	-3.0%	-0.3%	-1.2%
2014	4.6%	7.1%	5.3%	9.9%	15.2%
2015	-1.5%	2.1%	1.6%	1.9%	0.9%
2016	6.5%	9.2%	6.6%	7.9%	9.9%
2017	6.1%	11.2%	5.8%	6.4%	2.6%
2018	-3.0%	-0.4%	-3.4%	-5.2%	-4.3%
2019	1.9%	11.1%	17.6%	21.5%	25.8%
2020	9.7%	15.0%	24.9%	20.2%	29.6%
2021	25.8%	18.9%	21.1%	18.2%	15.1%
2022	37.4%	38.4%	41.2%	41.8%	34.6%
2023	11.1%	11.1%	11.2%	4.5%	5.5%
Ortalama	7.7%	9.0%	8.8%	9.2%	9.6%
STD	11.1%	10.8%	12.4%	12.7%	11.9%
Olasılık		0.089	0.354	0.270	0.334
t ist.		-1.4	-0.4	-0.6	-0.4

Not: Her bir yıl için endeksin çeyrek başlarındaki değişimleri dikkate alınmıştır. Şirketler her bir çeyrekteki halka açık piyasa değerlerine göre sıralanmış ve içinde eşit sayıda hisse bulunan beş farklı gruba ayrılmışlardır. Yıllık veriler her bir çeyrekte ilgili gruba giren hisselerin takip eden 1 yıldaki getirilerinin ortalamasını sunmaktadır. t testleri yapılırken kıyaslamalar 1 nolu en büyük hisseler grubu ile diğer gruplar arasında gerçekleştirilmiştir.

5. Sonuç

Bu araştırmada BIST 100 Endeksinin Borsa İstanbul'un performansını temsil edip edemediği 4 farklı araştırma sorusuna yanıt aranarak cevaplanmaya çalışılmıştır. İlk olarak BIST 100 Endeksinin ne derece Borsa İstanbul'da yatırım yapan yatırımcıların uzun vadeli kazançlarını temsil ettiği araştırılmıştır. Borsa İstanbul'da işlem gören şirketlerin getirileri 2000-2024 ve 2014-2024 dönemlerinde incelenerek BIST 100 Endeksinin performansıyla kıyaslanmıştır. Elde edilen sonuçlar her iki dönemde de BIST 100 Endeksinin Borsa İstanbul'daki genel hisse performansını tam olarak temsil etmediğini ve hisse bazında çeşitlendirilmiş bir portföy ile daha yüksek getirilere ulaşılabileceğini göstermektedir. Özellikle 31.12.1999-15.02.2024 döneminde BIST 100 Endeksinin dolar bazında bileşik getirisi %7 seviyesinde kalırken 40 adet hissenin dolar bazında 10 kattan fazla, 9 adet hissenin ise dolar bazında 50 kattan fazla kazanç elde etmesi dikkat çekicidir. BIST 100 Endeksinin getirisi bireysel hisse performanslarından uzun vadede ciddi anlamda ayrışabilmekte ve merkezi bir konumu temsil etmek yerine getiri dağılımında uç noktalarda yer alabilmektedir.

Araştırmanın ikinci aşamasında, BIST 100 Endeksi içindeki şirketlerin sektörel dağılımı analiz edilmiştir. Endeksin hesaplanmasında hisselerin halka açık piyasa değerlerinden faydalanılarak ağırlıklandırma yapılmaktadır. Ancak, belirli sektörlerin BIST 100 Endeksinde yüksek bir paya sahip olması, sektörel risk dağıtımı yapan yatırımcılar için endeksin doğru bir gösterge olmasını zorlaştırmaktadır. Özellikle, yabancı yatırımcıların büyük banka ve holding hisselerini tercih ettiği, ancak yerli yatırımcıların portföylerinde çeşitli sektörlere yatırım yaptığı bilinmektedir. Bu durum, yerli ve yabancı yatırımcıların portföylerindeki sektör dağılımının farklı olabileceğini göstermektedir. Araştırma, bankacılık sektörünün BIST 100 Endeksindeki ağırlığının zaman içinde önemli ölçüde değiştiğini ve banka hisselerinin endeksin performansını belirleyen temel unsurlardan biri olduğunu ortaya koymuştur. Özellikle 2008 küresel finans krizinin ardından bankaların zayıf performans gösterdiği ve bu durumun BIST 100 Endeksini olumsuz etkilediği tespit edilmiştir. BIST 100 Endeksinin Türkiye ekonomisindeki ve Borsa İstanbul'daki yüksek sektörel çeşitliliği yansıtmadığı görülmektedir.

Araştırmanın üçüncü aşamasında, BIST 100 Endeksine yeni giren, çıkan ve bir yıldan uzun süredir endekste bulunan hisselerin takip eden dönemdeki getirileri arasındaki ilişki incelenmiştir. Bu analizde De Bondt ve Thaler (1985) tarafından öne sürülen aşırı tepki kuramının BIST 100 endeks hesaplamalarını etkileyip etkilemediği test edilmiştir. Araştırma bulgularına göre çok yüksek performans gösteren şirketler endekse dahil olduktan sonra takip eden 3 yılda zayıf performans göstermekte ve endeksi aşağı çekmektedirler. Aşırı tepki nedeniyle olması gereken fiyatın üstüne çıkan hisseler yükseldikleri dönemde endeks performansına katkı sağlamazken, zayıf performans gösterdikleri düzeltme döneminde endeks hesabına dahil olmaktadırlar. Bu da endeks getirisinin piyasa getirisinden negatif yönde ayrışmasına neden olmaktadır. Literatürdeki diğer çalışmalar çok kısa dönemleri dikkate aldıkları için bu çalışmadan farklı sonuçlara sahiptirler (Bayraktar, 2009; Aydıner ve Altay, 2020).

Araştırmanın dördüncü aşaması, hisse senedi fonlarının son beş yıldaki performansını kıyaslamaktadır. Bu kıyaslama, BIST30 ve BIST 100 endekslerinin borsayı ne kadar etkin bir şekilde temsil ettiğini anlamak için önemlidir. Çünkü eğer endeks borsayı etkin bir şekilde temsil ediyorsa, endeks odaklı yatırım yapan fonların diğerlerinden performans açısından belirgin bir şekilde ayrışmaması ve ortalamada yer almaları beklenir. Öncelikle, araştırmanın sonuçlarına göre, endeksi takip eden fonlar ile diğer fonlar arasında belirgin farklar mevcuttur. Örneğin, endeksi takip eden fonların ortalama performansı %717 iken, hisse senedi yoğun fonların genel ortalama performansı %1231'dir. Belli bir endekse ve sektöre odaklanmayan fonların neredeyse tamamının BIST30 ve BIST 100 Endeksine odaklanan fonlardan daha yüksek performans göstermiş olması endeksin fonların performansını belirlemede ne kadar zayıf kaldığını göstermektedir. Araştırma sonuçları, endeksin borsayı etkin bir şekilde temsil edemediğini ve bu durumun endeks bazlı yatırım stratejilerinin performansını olumsuz etkilediğini ortaya çıkarmaktadır.

Bu makalede BIST 100 Endeksinin borsayı temsildeki yetersizlikleri açıklanmaya çalışılmıştır. BIST 100 Endeksi yatırımcıların kendi performansları ile kıyaslama amacıyla, fonların performanslarını kıyaslama amacıyla ve hatta bazı fonların yöneticilerinin alacağı primleri hesaplama amacıyla kullanılabilmektedir. Araştırma sonuçlarına göre BIST 100 Endeksi dışında eşit ağırlıklı endekslerin ve XTUMY gibi endekslerin de performans kıyaslaması amacıyla kullanılmasının yaygınlaşması etkinliği artıracaktır. Bu nedenle araştırma bulgularının yatırımcılar, fon yöneticileri ve düzenleyici otoriteler açısından faydalı olabileceği

düşünülmektedir. Bu konuda gelecekte yapılacak araştırmalarda Borsa İstanbul'un genel performansını temsil edebilecek yaklaşımlar üzerinde durulabilir.

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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DOES THE BIST 100 INDEX REFLECT THE OVERALL PERFORMANCE OF BORSA ISTANBUL?

EXTENDED SUMMARY

Aim of the study

In this study, it was investigated how effectively the BIST 100 Index represents the stock market performance. The contributions of this research to the literature can be summarized in four items. First of all, this article is a comprehensive criticism of the Borsa Istanbul Index calculation method. The BIST 100 Index is used as a basic indicator in many market analyses. Therefore, it is important to determine how effectively the BIST 100 Index represents the stock market. Secondly, the reflections of the overreaction theory in index calculations were analyzed. Thirdly, the efficiency of the index related to the representation of the performance of investment funds was analyzed. Finally, it has been determined to what extent the public market value is decisive in the return calculation within the index.

The Literature

When the studies in the literature are examined, it is seen that a significant part of them focuses on the returns of the stocks included and excluded from the index. Studies in the literature generally report that the effect of index changes on stock returns is negative after the index exit announcement and exit transaction, and positive after the index entry announcement and entry transaction. On the other hand, a group of studies touched upon the effect of diversification in indices. Findings in the literature show that portfolios that are better diversified in terms of different sectors provide superior performance compared to limited portfolios.

Methodology

In the research, firstly, long-term stock returns of the overall stock market were compared with the returns of the BIST 100 Index. It has been tried to determine how effective the BIST 100 Index is to represent all stocks in the stock market. Secondly, it was analyzed how effectively the sectoral composition of the BIST 100 Index over time represents the sectoral diversity in Turkey and Borsa Istanbul. Thirdly, the problems caused by the overreaction theory in index calculation were analyzed. According to overreaction theory, stocks can move up and down beyond rational levels. Overreaction may cause some stocks that have shown high performance in the past to be included in the index calculation, and in the following period, they may show poor performance and be removed from the index calculation. While the movement during the price increase is largely not included in the index calculation, the movement during the decrease period is reflected in the index calculation. This may be a factor that reduces the index performance. Fourthly, based on the performance of investment funds, the comprehensiveness of the index was tried to be analyzed by comparing the performances of index-focused funds and other funds. The fact that funds focusing on the index and funds that

do not focus on the index have similar performance on average will confirm the comprehensiveness of the index.

Results

The return of the BIST 100 Index may differ significantly from individual stock performances in the long term and may be at the extreme points of the return distribution rather than representing a central position. The research revealed that the weight of the banking sector in the BIST 100 Index has changed significantly over time and that bank shares are one of the main factors determining the performance of the index. It appears that the BIST 100 Index does not reflect the high sectoral diversity in the Turkish economy and Borsa Istanbul. According to research findings, companies with very high past performances show poor performance in the following 3 years after being included in the index and reduce the index performance. While stocks that exceed their fair value due to overreaction do not contribute to the index performance during the period when they rise, they are included in the index calculation during the correction period when they perform poorly. This causes the index return to diverge negatively from the market return. On the other hand, the fact that almost all of the funds that do not focus on a particular index or sector have performed better than the funds that focus on the BIST30 and BIST 100 Index shows how weak the BIST30 and BIST 100 indices are as an indicator of the performance of the funds.

Conclusion

According to the research results, using equally weighted indices other than the BIST 100 Index and indices such as XTUMY and XUTUM for performance comparison purposes will increase efficiency. Therefore, it is thought that the research findings may be useful for investors, fund managers, and regulatory authorities. Future research on this subject may focus on approaches that can be used for the representation of the overall performance of Borsa Istanbul.

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TÜRKİYE'DE DEVLET İÇ BORCU, KREDİ PİYASASI VE DIŞLAMA ETKİSİ

Government Domestic Debt, Credit Market and Crowding-Out Effect in Türkiye

Süleyman KASAL*

Anahtar Kelimeler:
Devlet Borcu, Borç Yönetimi, Bankalar, Kredi Kanalı, Dışlama Etkisi

JEL Kodları:
E62, H63, H81, G21

Öz

Devlet borcu mali, ekonomik ve finansal etkileriyle politika yapıcılar açısından önemli bir maliye politikası aracıdır. Bu noktada önemli olan unsurlardan biri yatırımcı tabanıdır. Devlet farklı kaynaklardan finansman ihtiyacını karşılamakta ve farklı kanallar üzerinden ekonomik etkilere yol açmaktadır. Günümüzde bu etkilerin gerçekleşmesinde önemli kaynaklardan birisi de bankalardır. Bu çalışmanın amacı Türkiye'de borcun ekonomik etkisini bankacılık kredi kanalı üzerinden incelemektir. Çalışmanın amacını gerçekleştirmek adına 2006:Ç1-2023:Ç4 arası dönem için reel GSYH, merkezi yönetim iç borç stokunun GSYH'ye oranı, toplam kredi hacmi ve 5 yıllık Devlet tahvil faizi değişkenleriyle bir yapısal VAR (SVAR) modeli oluşturulmuştur. Çalışma sonuçları, iç borçtaki artışın kısa vadede dışlama etkisi yarattığını ancak devlet destekli kredi benzeri uygulamalarla orta vadede bu etkinin kaybolduğunu ve kısa vadede faizde ortaya çıkan düşüşün orta vadede etkisini yitirdiğini göstermektedir. Analiz sonuçları devlet tahvil faizindeki artışın kredi hacmi ve üretim üzerinde daraltıcı etkisine de işaret etmektedir. Bu çalışma Türkiye'de borç yönetiminde bankaların ve kredi kanalının önemini göstermektedir.

Keywords:
Government Debt, Debt Management, Banks, Credit Channel, Crowding-Out Effect

JEL Codes:
E62, H63, H81, G21

Abstract

Government debt is an important fiscal policy tool for policymakers with its fiscal, economic, and financial effects. At this point, the investor base is one of the most important factors. The government obtains its financing needs from a variety of sources and generates economic effects through various channels. Banks are one of the most important sources for realizing these effects today. The purpose of this study is to investigate the economic impact of debt in Türkiye through the banking credit channel. To fulfill the study's goal, a structural VAR (SVAR) model was developed using the variables real GDP, the ratio of central government domestic debt stock to GDP, total credit volume, and 5-year government yield from 2006:Q1 to 2023:Q4. The study's findings indicate that a short-term increase in domestic debt leads to a crowding-out effect, which state-supported credit-like activities mitigate in the medium term. They also demonstrate that the short-term decrease in interest rates loses its effect in the medium term. The analysis also shows that the increase in government bond interest has a contractionary effect on credit volume and production. This study emphasizes the role of banks and the credit channel in debt management in Türkiye.

* Dr. Öğr. Üyesi, Anadolu Üniversitesi, İktisadi ve İdari Bilimler Fakültesi, Maliye Bölümü, Türkiye, skasal@anadolu.edu.tr

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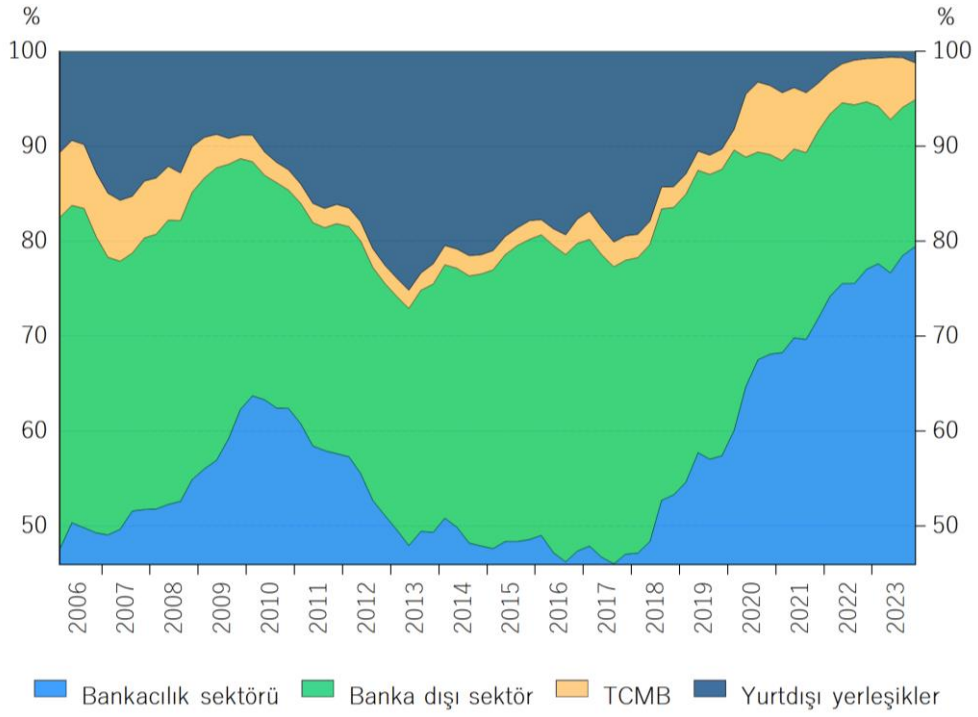
1. Giriş

Borcun miktar ve bileşimi kamu borç yönetiminin temel bileşenleri olup, borcun ekonomik etkileri açısından büyük önem taşımaktadır. Bu unsurların yanı sıra borç stokunu elinde bulunduranların dağılımının ekonomik etkilerinin incelenmesi, özelde borç politikalarının genelde maliye politikalarının etkinliği açısından belirleyici bir rol oynar.

Tarihsel tecrübeler borç yönetiminin ekonomik ve finansal etkilerinin iyi ve kötü örneklerini içermektedir. Çünkü 1990'lar sonrası kamu borçlanmasının sağlıksız yapıda olması 1994'te Meksika ve Türkiye'de, 1998'de Rusya'da, 2001'de Arjantin'de ve 2008'de küresel ölçekte olduğu gibi çok sayıda finansal krize neden olmuştur (Cangöz ve Balıbek, 2012: 22) (Bu tür borç krizlerine yönelik tarihsel bir çalışma, Reinhart ve Rogoff (2011) tarafından yapılmıştır). Nitekim kamu borçlanmasının uzun vadede sürdürülebilirliği sorgulandığında, yüksek borç finansal piyasalar üzerindeki belirsizliği arttırmakta ve ekonomi üzerinde olumsuz etkiler yaratabilmektedir. Benzer şekilde finansal piyasalarda meydana gelen belirsizlikler de yatırımcıların risk algısını değiştirerek finansal piyasalar üzerinden ekonomik dalgalanmaları tetikleyebilmektedir. Bu tecrübeler ışığında günümüzde devletler borç politikalarının ekonomik ve finansal etkileşimlerinin incelenmesine özel önem vermektedir. Bu etkileşimler içinde önemli bir payı bankacılık sektörü almaktadır. Özellikle günümüzde bankaların ekonomi ve finans alanında oynadığı kilit rol, kamu borç yönetimi açısından bu rolün analiz edilmesini gerektirmektedir.

Devlet günümüzde mali ve mali olmayan birçok sebeple borçlanma yoluna gitmektedir. Burada borç yönetimi açısından kritik konu maliyet ve risklerin minimum seviyede tutularak borçlanmanın gerçekleştirilmesi ile ilgilidir. Maliyet tarafında faiz, borcun ve risk priminin bir karşılığı olarak ortaya çıkmaktadır. Dolayısıyla faiz birden fazla faktörden etkilenme potansiyeli olan devletin borcu karşılığında ödemesi gereken bir maliyettir. Bu maliyetin düşük veya yüksek olması mevcut mali, ekonomik ve finansal koşulların yanı sıra borç piyasasının durumundan da etkilenmektedir. Borç piyasasından kasıt, devlet tahvil ve bonolarının arz ve talep dengesini etkileyen ve bu piyasayı oluşturan aktörlerdir. Bu aktörlerin başında bankalar gelmektedir. Bankalar günümüz finansal sistem içerisindeki en temel yapı taşlarıdır. Nitekim ülkemiz de dahil olmak üzere gelişen ülkelerde aktiflerin büyük bir payı bankalarda tutulmaktadır (Parasız, 2005: 79). Benzer durum merkezi yönetim borç stoku açısından da geçerlidir. Şekil 1'de yer alan Türkiye'de merkezi yönetim borcunun dağılımı incelendiğinde, bankacılık kesiminin 2006 yılında yaklaşık %50 olan payının 2023 yılının son çeyreğinde %80'e ulaştığı görülmektedir. Şekil 1'de dikkat çeken bir başka olgu 2008 finansal kriz ve 2020 pandemisi döneminde yurtdışı yerleşiklerin veya yabancı yatırımcıların, bankacılık sektörüyle ödünleşmesidir. Kriz dönemlerinde yabancı yatırımcıların risk algısının bozularak daha güvenli liman arayışları, devlet iç borçlanma senetlerini (DİBS) elinde tutan kesimin değişmesine neden olmuştur. Bu nedenle devletin borç yönetimi açısından bankacılık kesiminin önemi büyüktür.



Şekil 1. Merkezi Yönetim Borç Stokunu Elinde Bulunduranlara Göre Dağılımı
Not: Grafik 2006-2023 çeyreklik verilerini kullanarak yazar tarafından oluşturulmuştur. Veriler T.C. Hazine ve Maliye Bakanlığı'ndan elde edilmiştir.

2001 yılı öncesi Türkiye'de bankalar kamu sektörünü sürekli olarak fonlamış ve özellikle 90'ların ikinci yarısından itibaren bankaların aktif büyüklükleri içinde kamu kâğıdı oranı yüksek seviyelerde oluşmuştur (Gürkaynak vd., 2023: 130). Türkiye'de bankacılık sektörü kamu borçlanmasını finanse etmek zorunda kalmış ve bu süreçte bankalar doğrudan faiz oranı ve dolaylı olarak döviz kuru risklerine maruz kalmıştır. Bu durum, bankaların makroekonomik şoklardan etkilenmesine ve özel sektöre kredi verme oranlarının ciddi dalgalanmalar göstermesine yol açmıştır (Aydın ve İgan, 2010: 7). Bu eğilim, 2001 krizi sonrasında gerçekleştirilen kamu maliyesi ve bankacılık reformlarıyla azalmaya başlamış, ancak son yıllarda bu davranış tersine dönmeye başlamıştır. (Geçmişe yönelik tarihsel bir inceleme için Tokgöz (2023) çalışmasına bakılabilir. Nitekim yazar, Osmanlı dönemi de dahil olmak üzere Türkiye'de devletin ekonomi politikalarındaki farklı yaklaşımlarının, bankacılık sektörüne yansımalarını tarihsel bir perspektifle incelemiştir.). Bu önemli olguya dayanarak, bu çalışma, bankacılık kesiminin borç piyasası açısından oynadığı önemli rolü makro, mali ve finansal bağlantılar çerçevesinde araştırmayı amaçlamaktadır. Bu çerçevede çalışmada iç borç stokundaki ve devlet tahvil faizlerindeki artışın bankaların kredi verme davranışını ve böylece üretimi nasıl etkilediği analiz edilmektedir. Böylece çalışma şu sorulara cevap vermiş olacaktır: i) İç borç stoku/GSYH oranındaki artış kredileri ve üretimi nasıl etkilemektedir? Bir diğer deyişle çalışma dışlama etkisinin gerçekleşip gerçekleşmediğini bankacılık kredi piyasası üzerinden araştırmaktadır. Bu durum, özel yatırımların dışlanmasının "miktar kanalı" olarak da adlandırılmaktadır (Emran ve Farazi, 2009: 3) ii) Devlet tahvil faizindeki artışın etkileri nelerdir? Türkiye için bu soruların cevabı yapısal VAR (SVAR) yöntemi kullanılarak 2006-2023 çeyreklik verileriyle araştırılmıştır.

İlk bölüm çalışmanın teorik çerçevesini içermekte, ikinci bölümde konuyla ilgili literatür yer almakta, devam eden bölümde ise çalışmada kullanılan yöntem ve veri açıklanmaktadır. Sonraki bölümde analiz sonuçlarına yer verilmektedir. Çalışma, sonuçların potansiyel politika etkilerinin yer aldığı sonuç bölümüyle tamamlanmaktadır.

2. Teorik Çerçeve

Mevcut çalışmanın teorik çerçevesi iki temel yapı üzerine inşa edilmiştir. İlk yapı, geleneksel dışlama etkisi teorisine dayanmaktadır. İkinci yapı ise borç otoritesi ile bankalar arasındaki ilişkinin kredi piyasası üzerindeki etkilerini ele almaktadır. Dışlama etkisi, genellikle özel ekonomik faaliyetlerin yerini kamu ekonomik faaliyetlerinin alması şeklinde tanımlanmaktadır. (Buiter, 1990; aktaran Gümüş, 2003: 24). Blanchard (2018) dışlama etkisini, borçla finanse edilen genişletici maliye politikasının üretim üzerinde az veya hiç etki yapmadığı, hatta üretimi olumsuz etkilediği bir durum olarak tanımlamaktadır (Blanchard (2018: 2497).

Kamu borcunun ekonomi üzerindeki etkisine yönelik çok fazla görüş mevcut olmakla birlikte bir görüş borçlanmanın ekonomiyi olumlu etkilediğini ileri sürerken, bir görüş ekonomi üzerinde olumsuz etkileri olduğunu ileri sürmektedir (Gümüş, 2003: 23). Klasik iktisadi yaklaşım ve devamındaki iktisat okulları bütçe açıkları ve borçlanmanın ekonomi üzerinde dışlama etkisi yarattığını iddia ederken, Keynesyen yaklaşımın savunucuları bu etkinin olmadığını ileri sürmektedirler.

Bernheim'a (1989) göre Neoklasik yaklaşım bütçe açıklarının tam istihdam düzeyinde tasarrufları azaltarak faiz oranlarının yükselmesine ve böylece özel sermaye birikiminin azalmasına neden olacağını ileri sürmektedirler. Ancak burada bütçe açıklarının geçici olup olmadığı önemlidir. Nitekim yazara göre Neoklasik yaklaşımda geçici bütçe açıklarının etkileri ihmal edilebilir olup, kalıcı bütçe açıklarının ise sermaye birikimini azaltarak dışlama etkisine yol açacağı fikri mevcuttur (Bernheim, 1989: 59-60).

Ricardo-Barro teoreminin (borcun nötrlüğü veya eşdeğerlilik teoremi) temelinde ise nesiller arası yaklaşım ve sonsuz yaşam varsayımı altında bugünkü bütçe açıklarının borçla finanse edilmesinin gelecekteki vergi yükünü arttıracağını bilen ekonomik aktörler tarafından tasarruf artışı ile dengeleneceğini ve böylece faiz oranlarının değişmeyeceği yer almaktadır. Ancak bu teorem, piyasa koşullarının tam rekabetçi olduğu ve bireylerin gelecekteki vergi yükümlülüklerini tam olarak öngörebildiği şeklindeki çok katı kısıtlamalara tabidir. Hatta bu konudaki ilk çalışmalar kesin sonuçlar vermemekte ve temel olarak bazı sonuçlar Ricardo eşdeğerlilik teoremini desteklerken, bazıları desteklememektedir (Barro, 1989; aktaran Thia, 2020: 101).

Keynesyen yaklaşımda ise bu iki görüşün aksine bir durum söz konusudur. Bu görüşlerin dışında, uluslararası sermaye hareketlerini de dikkate alan farklı bir model üzerinde tartışmalar devam etmektedir. Bu tartışmanın temel odak noktası, tasarrufların bütçe açıkları nedeniyle azalmasının, yabancı sermaye girişiyle telafi edilerek faiz oranlarının sabit kalacağına yöneliktir (Gürgür ve Karaca, 2007: 10). Keynesyen yaklaşımda toplam talep çok önemli olup, kamu harcamaları ve vergiler toplam talebi belirledikleri için bir ekonomideki istikrarsızlığı, işsizliği ve enflasyonu önlemekte faydalıdır. Ayrıca Keynesyenler tasarruf düzeyinin gelir tarafından belirleneceğini, yatırımın ise faiz oranı yanında sermayenin marjinal verimliliğine bağlı

olacağını ileri sürmektedir. Dolayısıyla faiz oranlarındaki düşüş yatırım ve tasarrufun dengeye gelmesi konusunda etkisiz olabilecektir (Ataç, 2013: 8-9)

Bütçe açığının kamu borçlanması ile finanse edilmesi mal ve para piyasalarından hangisinde servet etkisinin yüksek olduğuna bağlı olarak dışlama etkisini ortaya çıkarır. Ancak günümüzde devlet, finansman ihtiyacının büyük çoğunluğunu borçlanma araçları çerçevesinde bankalardan gerçekleştirmektedir. Nitekim gelişmekte olan ülkelerdeki devlet borçlarının büyük oranda sahipleri bankalar ve emeklilik fonlarıdır. Emeklilik fonlarının rolü Şili gibi birkaç ülke dışında hala nispeten küçüktür. Dolayısıyla bankaların varlıklarının büyük kısmını devlet borçlarında tutması istikrarlı borç yönetiminin finansal istikrar için kritik bir önemde olduğunu göstermektedir (Kumhof ve Tanner, 2005: 7). Böylesi bir olgu iktisadi yaklaşımların dışlama etkisine yönelik teorilerinin borç stokunu elinde bulunduranlara göre dağılımını da dikkate alarak incelenmesi gerekliliğine işaret etmektedir.

Günümüzde bankalar devlet borçlanma senetlerine; risksiz olmaları, getirilerinin yüksek olması, kolayca paraya çevrilebilmeleri ve devlet tarafından alıcılara birtakım kolaylıklar sağlanması nedeniyle aşırı ilgi göstermektedirler (Ulusoy, 2013: 280). Bu ilgi borç yönetimi açısından olumludur. Çünkü likidite riski açısından değerlendirildiğinde, finansman ihtiyacının uygun vade ve maliyetle karşılanması borcun çevrilememesi riskini azaltır. Ancak bankaların DİBS'leri elinde bulunduranlar açısından önemli bir paya sahip olması ve bu payın artması bazı muhtemel sorunları da ortaya çıkarabilmektedir. Arslanalp ve Tsuda (2014: 4) bankaların yüksek oranda devlet borcu tutmalarının finansal istikrarı tehdit edeceğini ileri sürmektedir. Bu konuda yine Türkiye'den önemli bir örnek verilebilir. 2000 yılında Demirbank, özellikle kısa vadeli borçlanma stratejisiyle ön plana çıkmış ve piyasada "tahvil bankası" olarak anılmıştır (Somçağ, 2006: 107; Özatay, 2009: 91). Ancak banka faizlerin artmasıyla finansal yükümlülüklerini karşılayamamış ve 2000 yılının aralık ayında devlet tarafından tasfiye edilmiştir. (Bu konuya ilişkin daha detaylı bilgi için TMSF tarafından hazırlanan "Raf Temizliği Demirbank" çalışmasına, Türk bankacılık sektörünün temel sorunları için ise Parasız'a (2005, 132-138) bakılabilir.) Bankacılık kesiminden kamunun aldığı payın çeşitli dönemlerde yüksek olması faizlerde artışlara neden olmaktadır. Nitekim Bağcı'ya (2001) göre banka bilançolarının yarıdan fazlası kolaylıkla nakde çevrilemeyecek fonlardan oluşmakta, kalan likit fonlar ise özel ve kamu sektörü arasında paylaştırılmaktadır. Dolayısıyla kamu sektörünün aldığı payın artması, aktiflerdeki çeşitliliğin azalması nedeniyle bankaların daha fazla faiz talep etmesine neden olacaktır. Kredi piyasası açısından bakıldığında ise bankaların bilançolarındaki DİBS oranının artması bankaların kredi verme davranışlarına yönelik iki olası duruma yol açma potansiyeline sahiptir: Tembel banka davranışı ve risk çeşitlendirmesi yapan banka davranışı (Bağcı, 2001: 87).

Risk çeşitlendirmesi modeline göre, bankaların portföylerinde daha fazla DİBS bulundurmaları bankaların daha fazla risk almasına ve özel sektöre daha fazla kredi vermesine yol açmaktadır. Tembel banka modeline göre ise bankaların portföylerindeki DİBS artışının bankaların özel sektöre yönelik kredi miktarını azaltmalarına neden olmaktadır (Emran ve Farazi, 2009: 4-5). Bu çerçevede kredi arzının maliye politikasının bir fonksiyonu olduğu ileri sürülebilir. Nitekim Aydın ve İgan'a (2010) göre Türkiye ve diğer gelişmekte olan ülkelerde, bütçe açıklarının genellikle kısa vadeli borçlanma yoluyla finansmanı kredi piyasalarından özel sektörün dışlanmasına neden olabilir. Ancak sıkı maliye politikaları ise, bankaların DİBS tutma oranlarını azaltarak özel sektöre kredi arzını arttırabilir. Buradaki temel vurgu devletin ödünç verilebilir fonlar piyasasına yaptığı baskının azalmasından kaynaklanmaktadır. Bir diğer deyişle

büyük bir alıcı olarak devletin fon talebinin azalması, sonucunda özel sektörün sahip olacağı fonların serbest kalmasına ve dışlama etkisinin azalmasına sebep olabilecektir.

3. Literatür

Dışlama etkisine yönelik literatürdeki çalışmalar incelendiğinde çalışmaların dışlama etkisini kamu harcamaları, kamu borcu ve bütçe açıkları açısından analiz ettiği görülmektedir. Özellikle çalışmaların kamu harcamaları ve yatırım ilişkisi üzerine odaklandığı anlaşılmaktadır. Diğer taraftan kamu borcu ve bütçe açıkları üzerine görece çalışma sayısı azdır. Bu bölümde de literatürde dışlama etkisini kamu borcu ve bütçe açıkları açısından analiz eden çalışmalar incelenmiştir.[1]

Christensen (2004) Sahra Altı Afrika ülkeleri için 20 yıllık (1980-2000) dönemi baz alarak iç borç ve özel sektör kredileri arasındaki ilişkiyi analiz etmişlerdir. Nitekim çalışmadaki panel regresyon analizinde iç borcun özel sektör kredilerini önemli ölçüde dışladığı (azalttığı) bulunmuştur. Yazar iç borçlanmaya aşırı başvurulmasının ekonomi üzerinde; yatırımcı tabanının sığ olduğu bir durumda faiz oranlarını arttırarak borç otoritesini belirli bir yatırımcı grubuna mahkûm edebileceğini ileri sürmektedir. Bu durum, özellikle yatırımcı tabanının büyük oranda ticari bankalar tarafından domine edilmesi durumunda dışlama etkisinin artmasına yol açabilir. Dolayısıyla yazarlar dışlama etkisinin önlenmesi için yatırımcı tabanının genişletilmesini önermektedir.

Emran ve Farazi (2009) devletin bankacılık sektöründen borçlandığı durumda özel kesim kredilerini ne kadar azaltacağını gelişmekte olan ülkeler için 1975-2006 dönemine yönelik araştırmışlardır. Kurdukları modeldeki temel hipotez; borçlanmanın, bankaların özel sektöre kredi verme kapasitesini azaltacağıdır. Bu noktada modelde borcun özel kesim kredisi üzerindeki etkisine ait katsayıya yönelik 4 temel beklenti oluşturmuşlardır. Katsayının 0'dan küçük olması dışlama etkisine işaret etmektedir. Katsayının negatif ancak mutlak değerinin 1'den küçük olması risk çeşitlendirme modeline, katsayının negatif ancak mutlak değerinin 1'den büyük olması tembel bankalar modeline, katsayının sıfıra yakın veya sıfır olması Ricardian eşdeğerlilik teoremine (nötr etki), katsayının yaklaşık -1 olması ise kısmi dengeye işaret etmektedir. Yazarlar çalışmada gelişmekte olan ülkelerdeki bankacılık sektörünün tembel banka davranışı sergilediğini kanıtlamıştır. Nitekim panel regresyon analizi sonuçlarına göre borçlanmadaki artış (+1 $), özel kesim kredilerini azaltmaktadır (-1.4 $).

Shetta ve Kamaly (2014) Mısır'ın bütçe açığı ve devlet borcunun özel sektöre yönelik kredi hacmini ve yatırımları nasıl etkilediğini analiz etmişlerdir. Yazarlar, 2000'li yılların başında Mısır'ın yüksek bütçe açıkları ve devlet borcunun daha sonraki yıllarda azaldığını ancak 2011 yılındaki Arap Baharı ile birlikte tekrar arttığını belirtmişlerdir. 1970-2009 dönemini çeyreklik olarak inceleyen yazarlar, özel kesim kredileri, devlet borcu, GSYH ve enflasyon arasındaki ilişkileri VAR yöntemiyle analiz etmişlerdir. Etki tepki fonksiyonu sonuçlarına göre; borçlanmadaki artış bankaların kredi verme eğilimlerini azaltmaktadır. Bu sonuç bankaların tembel banka modeline göre davrandıklarına işaret etmektedir. Yazarlar politika önerileri olarak bütçe açıklarının mali konsolidasyon politikalarıyla azaltılması gerektiğini ve bankaların özel sektöre kredi verme kapasitelerini teşvik edici çalışmaların gerçekleştirilmesi gerektiğini vurgulamaktadır.

[1] Dışlama etkisine yönelik kapsamlı bir literatür çalışması için Gümüş'e (2003) bakılabilir.

Ayturk (2017) devlet borcunun kurumsal finansman üzerindeki etkilerini 1989-2014 yılları arasında 15 Avrupa ülkesi için incelemiştir. Çalışmanın temel savı; gelişmiş Avrupa ülkeleri için devlet borcu ile kurumsal finansman arasında negatif bir ilişki olduğuna yöneliktir. Bu sav; borçlanmanın faiz oranlarını arttırarak bankaların kaynaklarını devlet borç senetlerine yönlendirmesiyle özel sektör kredilerini daraltacağı varsayımına dayanmaktadır. Yazar bağımlı değişken olan kurumsal finansman göstergesinin temsilcisi olarak çok çeşitli değişkenler (firmaların toplam borç/toplam varlıklar oranı, firmaların net borç/toplam varlıklar oranı gibi) kullanırken, açıklayıcı değişkenler olarak ise başta devlet borcu/GSYH olmak üzere, ekonomik büyüme oranı, faiz oranı, enflasyon oranı, firma büyüklüğü gibi değişkenler kullanmıştır. Yazar çalışması için kurduğu hipotezi reddedememiş ve devlet borcu ile kurumsal finansman arasında negatif bir ilişki bulmuştur. Dolayısıyla yazar dışlama etkisini kanıtlamakta ve politika önerisi olarak devletin borçlanma stratejilerini özel sektör üzerindeki olumsuz etkileri dikkate alarak tasarlaması gerektiğini ileri sürmektedir.

Thia (2020) 1990-2017 yılları arasındaki geniş bir sendikasyon kredi veri setini kullanarak kredi spreadleri, hükümet gelirleri ve harcamaları arasındaki ilişkiyi analiz etmiştir. Çalışma sonuçları GSYH'nin %1'i kadar artan hükümet harcamalarının kredi spreadlerini 8.5 baz puan arttırdığını göstermektedir. ABD örneğinde %1'lik bütçe açığı ise kredi spreadlerini yaklaşık 22 baz puan arttırmakta ve kredi piyasasında %3.4'lük bir daralmaya yol açmaktadır.

Özdemir ve Gomez (2020) Gambiya'da iç borçların özel yatırımlar üzerindeki dışlama etkisini Gecikmesi Dağıtılmış Otoregresif Modeli (ARDL) yöntemiyle analiz etmişlerdir. Çalışma iç borcun kısa vadede özel yatırımları dışladığını, uzun vadede ise dışlama etkisinin ortadan kalktığını bulmuşlardır.

Zhang vd. (2022) mahalli idarelerin borçlanmasının merkezi yönetime göre özel sektör kredileri üzerindeki etkilerinin daha az olacağı savından hareketle Çin'deki yerel ve merkezi yönetim borcunun özel sektör kredileri üzerindeki etkilerini 2008-2019 yılları için incelemişlerdir. Çalışma sonuçları yerel yönetimlerin borçlanmasının merkezi hükümete göre az veya hiç dışlama etkisi yaratmadığını, hatta merkezi borçlanmadan farklı etkiler yaratabileceğini göstermektedir. Bunun nedeni yerel yönetimlerin borçlanma sebeplerinin temelinde altyapı yatırımları gibi uzun vadeli projelerin yer alması ve bu nedenle özel sektör yatırımlarını teşvik edebilmesidir.

Bai vd. (2024) Çin'de yerel yönetimlerin borçlanmasının kurumsal şirketlerin finansmanı üzerinde dışlama etkisi yaratıp yaratmadığını 2006-2022 yılları için analiz etmiştir. Çalışmada ayrıca yerel hükümet borcunun ekonomik büyüme üzerindeki etkisi de analiz edilmiştir. Çalışma sonuçları yerel yönetim borcunun, kurumsal şirketlerin finansmanı üzerinde bir dışlama etkisi yarattığını göstermektedir. Bu etki özellikle ticari bankalar kanalıyla işlemektedir. Son olarak borç, başlangıçta ekonomik büyümeyi arttırırken, borcun devamlı yükselmesi özel sektör borcu üzerindeki dışlama etkisini arttırmakta ve ekonomik büyümeyi olumsuz etkilemektedir. Yazarlar bu sonuçlara dayalı olarak; şirketlerin finansman seçeneklerinin genişletilmesi, borcun uzun vadeli bir yapıya kavuşturulması ve borç yönetiminin etkin bir şekilde yapılması gerekliliğini önermektedirler.

Yu vd. (2024) Çin'de yerel yönetimlerin borcunun kurumsal finansman üzerindeki dışlama etkisini 2006-2015 yılları için analiz etmişlerdir. Yazarlar çalışmalarında, yerel yönetim borcundaki artışın ticari finansman kullanımında artış yaratıp yaratmadığını, bu mekanizmanın nasıl işlediğini ve ticari kredi finansmanının kullanımını nasıl etkilediğini soruşturmuşlardır.

Sonuçlar, yerel yönetim borcunun şirketlerin finansman kısıtlarını arttırarak dışlama etkisi yarattığını göstermektedir. Bu etkiler devlet tarafından kontrol edilen işletmeler için daha belirgin olup, diğer işletmelere göre farklı finansman zorluklarını beraberinde getirmektedir. Ayrıca yazarlar, ticari krediler üzerindeki dışlama etkisinin bölgesel olarak farklılaştığına işaret etmişlerdir. Dolayısıyla politika yapıcıların, finansal kaynak tahsisine yönelik verimliliğindeki artışı ve kurumsal finansman kanallarını çeşitlendirmesi gerekmektedir. Uluslararası çalışmalar incelendiğinde kamu borçlanmasının özel sektör üzerinde genellikle olumsuz etkiler yarattığı anlaşılmaktadır.

Türkiye için yapılan çalışmalar detaylı olarak incelendiğinde ilk başta belirtildiği gibi dışlama etkisine yönelik çalışmaların kamu harcamaları ve yatırımlar ekseninde araştırıldığı anlaşılmaktadır. Günaydın (2006), Cural vd. (2012), Şen ve Kaya (2014), Kesbiç vd. (2016) bu eksendeki çalışmalar arasındadır. Günaydın (2006), Cural vd. (2012) ve Şen ve Kaya (2014) çalışmaları kamu yatırımlarının özel yatırımlar üzerinde çekme etkisi yarattığını bulurken, Kesbiç vd. (2016) kamu yatırımlarının özel sektör yatırımları üzerinde dışlama etkisi yarattığını bulmuşlardır. Diğer taraftan Türkiye için dışlama etkisini kamu borcu ve bütçe açığı ekseninde araştıran çalışma sayısı görece azdır. Yaraşır-Tülümce ve Buyrukoğlu (2013), Türkiye için 1980-2010 yılları arasında iç borçlanmanın özel yatırımlar üzerinde çekme etkisi olduğunu bulurken, iç borçlanma faiz oranlarının özel sektör yatırımları üzerinde dışlama etkisi yarattığını bulmuşlardır. Çaşkurlu (2020) ise 1975-2016 dönemini Türkiye için dışlama etkisini analiz etmek için incelemiş, kamu kesimi borçlanma gereği ve iç borç ödemelerinin özel sektör yatırımlarını negatif etkileyerek dışlama etkisi yarattığına ulaşmıştır. Serin ve Demir (2023) Türkiye'de kamu yatırım ve kamu borcunun özel sektör yatırımlar üzerinde dışlama etkisi yaratıp yaratmadığını 1975-2020 yılları arasında ARDL yöntemiyle analiz etmişlerdir. Yazarlar, iç borcun özel sektör yatırımlarını dışladığını ancak dış borcun çekme etkisi yarattığını bulmuşlardır. Yazarların bulduğu bir diğer sonuç kamu yatırımlarının özel sektör yatırımlar üzerinde dışlama etkisi yaratmasıdır. Yazarlar Türkiye'de kamu borç yönetimi açısından mali disiplinin sağlanması gerektiğine vurgu yapmaktadır.

Türkiye için yukarıdaki çalışmalardan farklı olarak ve çalışmamızla benzerlik taşıyan en yakın çalışma Aydın ve İgan (2010) ve Yılmaz (2017) tarafından yapılmıştır. Aydın ve İgan (2010) Türkiye'deki bankaların kredi büyümesi üzerindeki para ve maliye politikalarının etkilerini 2002-2008 çeyreklik verileriyle analiz etmişlerdir. Yazarların temel savı, daraltıcı para politikasının kredi arzını azaltırken, daraltıcı maliye politikasının kredi arzını arttıracağı (özellikle yerli para birimi cinsinden kredilerde) yönündedir. Çalışma sonuçları temel hipotezleri doğrulamakla birlikte, bu etkinin kısa vadeli ve zayıf olduğunu göstermektedir. Bir diğer deyişle sonuçlar, Türkiye'de banka kredi kanalının zayıf olduğunu ve maliye politikasının krediler üzerindeki doğrudan etkilerinin kısa vadede sınırlı kaldığını işaret etmektedir. (Burada önemli bir not kredi piyasasının para politikası açısından önemli bir etkiye sahip olmasıdır. Bu konudaki ilk çalışma Bernanke ve Blinder (1988) tarafından yapılmıştır. Yazarlar, geleneksel para politikası aktarım kanallarının ötesinde kredi kanalının para politikasının etkilerini değiştirdiğini ortaya koymuşlardır.). Yılmaz (2017) ise Türkiye'de bankaların portföylerinde tuttukları devlet borçlanma senetlerinin kredi davranışlarını nasıl etkilediğini ve dışlama etkisi yaratıp yaratmadığını analiz etmiştir. Yazar analizini 2002-2016 yılları arasında çeyreklik olarak gerçekleştirmiştir. Çalışmada bankaların aktiflerinde tutuğu DİBS miktarının bankaların kredi davranışını, bütçe açığını, reel GSYH büyümesini ve kredi-mevduat faiz farkını nasıl etkilediği araştırılmıştır. Sonuçlar, bankaların aktiflerinde yer alan DİBS miktarındaki artışın özel kesim

kredi miktarını geçici olarak azalttığına işaret etmektedir. Yazarın yapmış olduğu bir diğer önemli vurgu Kredi Garanti Fonuyla (KGF) ilgilidir. Özellikle Fon'un, devletin finansman ihtiyacının bankalar üzerinde yarattığı baskıyı hafifleterek, kredi verme iştahlarını arttırdığına dikkat çekilmektedir. Dolayısıyla KGF bankaların kredi arzlarının azalmasının önüne geçmiştir.

Özetle Türkiye eksenindeki çalışmalar dışlama etkisinin varolup olmadığını çoğunlukla kamu harcamaları, kamu yatırımları ve kısmen kamu borcu çerçevesinde analiz etmektedir. Çalışmalar karmaşık sonuçlara işaret etmektedir. Bu durum politika önerilerini güçleştirmektedir. Çünkü birçok çalışmanın borçlanma piyasasını ve bu piyasada önemli bir faktör olan bankaları dikkate almadığı görülmektedir. Ayrıca bu etkinin kredi piyasası üzerinden çalışmayacağını varsaymak çalışmalar açısından bir eksiklik olarak görülmektedir. Çalışma bu eksikliği doldurmak adına Türkiye için dışlama etkisinin gerçekleşip gerçekleşmediğini bankacılık kanalı üzerinden analiz etmektedir.

4. Metodoloji

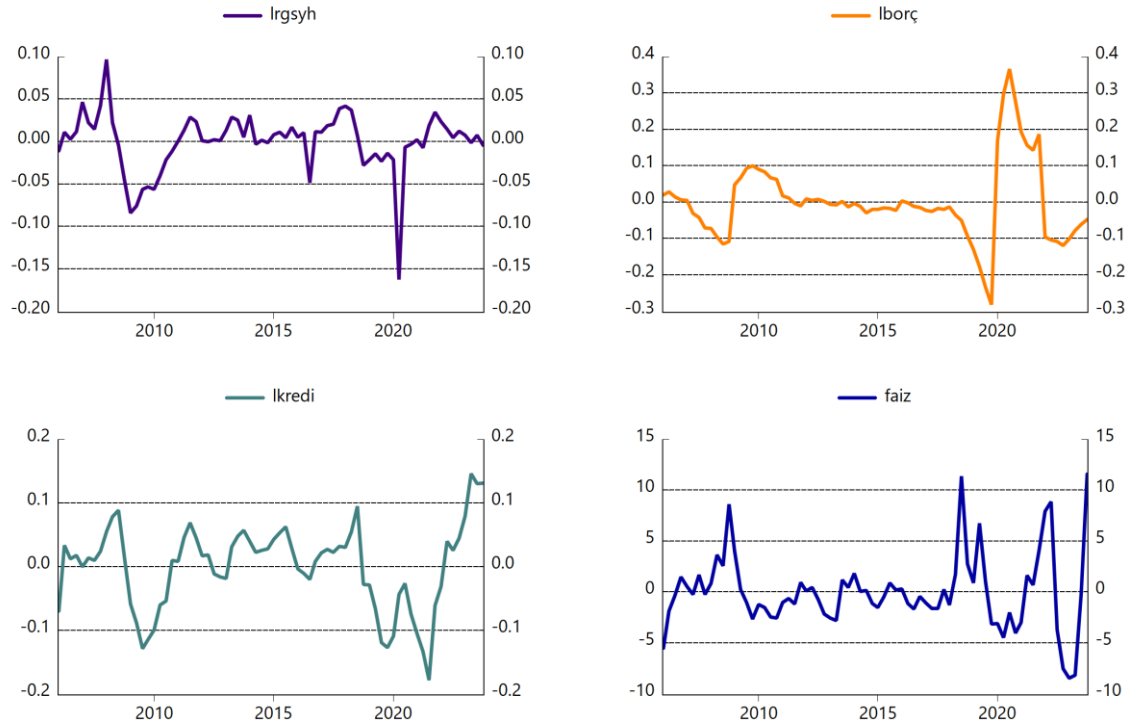
4.1. Veri

Çalışmada ekonomik büyümenin göstergesi olarak zincirlenmiş hacim endeksine dayalı harcama yöntemine göre hesaplanmış GSYH değişkeni kullanılmıştır. Kredi değişkeni olarak ise toplam kredi hacmi değişkeni kullanılmıştır. Modelde maliye politikasını temsil eden değişken olarak iç borç stokunun GSYH'ye oranı kullanılmıştır. Toplam borç stokunun kullanılmama nedeninin altında, iç borcun, dış borçtan daha sık maliye politikası aracı olarak kullanılmasında yatmaktadır. Ayrıca iç borç ülke içi kaynaklardan yapılan borçlanma olduğu için çalışmamızın bankacılık kanalı üzerinden araştırmaya çalıştığı soruyla uygunluk taşımaktadır. Çalışmada borçlanma maliyetini gösteren 5 yılık Devlet tahvil faizi kullanılmıştır. Son olarak TCMB, kredi faizleri ve kredi büyümesine yönelik olarak 2022 Haziran ayında, bankaların verecekleri ticari kredilerde faiz oranlarına bağlı olan bir katsayıyı dikkate alarak menkul kıymet (DİBS ve kira sertifikası) tutma zorunluluğu ve ayrıca Mart 2023'de ihtiyaç kredilerini de menkul kıymet tesisi kapsamına alan düzenleme getirmişti. Ancak bu durum bankaları yüksek enflasyon ortamında enflasyondan düşük sabit getirili tahvil tutmaya zorladığı için eleştirilmişti. Nihayetinde TCMB bu uygulamaya Mayıs 2024 yılında son verdi. Çalışmada bu çerçevede TCMB'nin 2022 yılında "Liralaşma Stratejisi" amacıyla Haziran 2022-Mayıs 2024 arasında uyguladığı "Menkul Kıymet Tesis Yükümlülüğü"nü temsil eden bir kukla değişkene yer verilmiştir. Faiz değişkeni hariç olmak üzere tüm değişkenlerin logaritması alınmış, TRAMO-SEATS yöntemiyle mevsimsellikten arındırılmış ve Hodrick-Prescott (HP) filtreleme yöntemiyle trend değerlerinden ayrıştırılmıştır (HP filtresinde kullanılan λ parametre değeri 1600'dür). Çalışmada kullanılan değişkenlere ilişkin bilgiler Tablo 1'de yer almaktadır.

Tablo 1. Modelde Kullanılan Değişkenler

Değişken	Kısaltma	Açıklama	Kaynak
Reel GSYH	$lrgsyh$	Zincirlenmiş hacim endeksine göre hesaplanmış GSYH'nin logaritması alınmış ve HP filtreleme yöntemiyle trendden ayrıştırılmıştır.	TCMB-EVDS
Krediler	$lkredi$	Bankaların toplam kredi hacmi elde edilmiş, ardından logaritması alınmış ve HP filtreleme yöntemiyle trendden ayrıştırılmıştır.	TCMB-EVDS
Merkezi yönetim iç borç stokunun GSYH oranı	$lborç$	Merkezi yönetim iç borç stoku GSYH'ye oranlanmış, logaritması alınmış ve HP filtreleme yöntemiyle trendden ayrıştırılmıştır.	TCMB-EVDS
5 yıllık Devlet tahvil faizi	$faiz$	5 yıllık Devlet tahvil faizi HP filtreleme yöntemiyle trendden ayrıştırılmıştır.	DataStream

Çalışmada kullanılan değişkenlerin grafikleri ise Şekil 2'de gösterilmektedir. Değişkenlerin grafikleri incelendiğinde tüm değişkenlerde 2008 küresel finans krizi ve 2020 yılında başlayan pandeminin etkileri görülmektedir. 2008 küresel finans krizinin ve 2020 pandemisinin yarattığı dalgalanmaların boyutunun oldukça büyük olduğu görülmektedir. 2008 krizi finansal piyasalardaki likiditeyi daraltmış ve kredi olanaklarını neredeyse yok etmiştir. Bu dönemde batamayacak kadar büyük bankalar batmış (too big to fail) ve devletin ekonomiye müdahalesi sonucunda borç sürdürülebilirliği tehlikeye girmiştir. 2020 pandemisinin de kamu borcu ve ekonomik aktiviteyi de derinden etkilediği bilinen bir gerçektir. Pandemi döneminde hükümetlerin ekonomik, mali ve sosyal destek paketlerini finanse edebilmek için borçlanmaya başvurmaları borç oranlarını yeni rekor seviyelere taşımıştır. Burada her iki krizin de borç dinamiklerini, ekonomik aktiviteyi ve kredi piyasasını olumsuz etkilediği görülmekte ancak 2020 pandemisinin 2008 küresel krizine göre göstergeleri daha olumsuz etkilediği anlaşılmaktadır. $lrgsyh$'de bu dönemlerde belirgin bir düşüş gerçekleşmiş ve $lborç$, $lkredi$ ve $faiz$ değişkenlerinde artış gözlemlenmiştir.



Şekil 2. Değişkenlerin Grafikleri, 2006-2023 (Çeyreklik)

4.2. Yöntem

Çalışmada değişkenler arasındaki ilişki yapısal VAR (SVAR) yöntemiyle analiz edilmiştir. n değişkenli ve p gecikmeli standart bir SVAR modeli aşağıdaki gibi gösterilmektedir:

$$AY_t = B(L)Y_t + \varepsilon_t \quad (1)$$

Burada Y_t; n boyutlu $(n\,x\,1)$ değişkenler vektörünü, A; $n\,x\,n$ boyutundaki katsayı matrisini, $B(L)$; $n\,x\,n$ boyutundaki gecikmeli değişkenlerin katsayı matrislerini, ε_t ise n boyutlu yapısal şok vektörünü göstermektedir. SVAR modelinde kullanılan değişkenler ve şoklar aşağıdaki gibi tanımlanmıştır:

$$Y_t = \left[lrgsyh_t + lborç_t + lkredi_t + faiz_t\right] \quad (2)$$

$$\varepsilon_t = \left[\varepsilon_t^{lrgsyh} + \varepsilon_t^{lborç} + \varepsilon_t^{lkredi} + \varepsilon_t^{faiz}\right] \quad (3)$$

4 değişkenli p gecikmeli sabit terimli bir SVAR modeli ise aşağıdaki gibidir:

$$A\begin{bmatrix} lrgsyh_t \\ lborç_t \\ lkredi_t \\ faiz_t \end{bmatrix} = c_0 + B_1\begin{bmatrix} lrgsyh_{t-1} \\ lborç_{t-1} \\ lkredi_{t-1} \\ faiz_{t-1} \end{bmatrix} + \cdots + B_p\begin{bmatrix} lrgsyh_{t-p} \\ lborç_{t-p} \\ lkredi_{t-p} \\ faiz_{t-p} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \\ \varepsilon_{4t} \end{bmatrix} \quad (4)$$

SVAR yöntemindeki önemli bir konu teorik varsayımlar doğrultusunda oluşturulacak kısıtların belirlenmesidir. Standart VAR yöntemi değişkenler arasındaki dinamik ilişkileri analiz eden "indirgenmiş form" modelleri olarak tam olarak ekonomik teoriye atıfta bulunmayan tahmincilerdir (Breitung vd., 2004: 159). Bu nedenle çalışmalarda sıklıkla SVAR modelleri tercih edilmektedir. Tabi SVAR modelinde yapısal şokların etkilerini belirleyebilmek için Eşitlik (1)'deki A matrisinin tersinin alınması (A^{-1}) gerekmektedir. Böylece indirgenmiş form elde edilmiş olur. Böylece yapısal şokların indirgenmiş formdaki hata terimleriyle olan ilişkisi analiz edilebilir $(\varepsilon_t = A^{-1}u_t)$. Çalışmamızda teorik varsayımlar çerçevesinde yapısal şokların etkilerini belirleyebilmek için oluşturulan SVAR modelinin katsayı matrisi (A) ise aşağıdaki gibi belirlenmiştir:

$$A = \begin{pmatrix} 1 & 0 & 0 & 0 \\ c_{21} & 1 & 0 & 0 \\ c_{31} & 0 & 1 & 0 \\ c_{41} & c_{42} & 0 & 1 \end{pmatrix} \quad (5)$$

A matrisindeki varsayımlar $lrgsyh$ değişkenin dışsal olduğu ve diğer değişkenlerden eş zamanlı değil gecikmeli olarak etkilendiğini göstermekte ve modelde dışsal olarak kabul edilmektedir. $lborç$ ve $lkredi$ değişkenleri eş zamanlı olarak sadece $lrgsyh$'den etkilenmektedir. Son olarak $faiz$ değişkeni eş zamanlı olarak sadece $lrgsyh$ ve $lborç$ değişkeninden etkilenmekte ancak $lkredi$ değişkeninden gecikmeli olarak etkilenmektedir.

5. Analiz Sonuçları

SVAR modelini tahmin etmeden önce ilk adımda değişkenlerin hangi düzeyde durağan olduğunun test edilmesi gerekmektedir. Çalışmada değişkenlerin durağanlık düzeyleri

Genişletilmiş Dickey-Fuller (ADF) testi ile test edilmiştir. ADF test sonuçları Tablo 2'de gösterilmektedir. Tablo 2'de ADF test istatistikleri incelendiğinde tüm değişkenlerin düzey değerlerinde durağan olduğu sonucuna ulaşılmıştır. $lrgsyh$, $lborç$ ve $faiz$ değişkenleri %1 düzeyinde istatiksel olarak anlamlı bir şekilde durağan bir sürece sahipken, $lkredi$ değişkeni istatiksel olarak %5 anlamlılık düzeyinde durağan bir sürece sahiptir. Böylece durağan bir SVAR modeli üzerinden analiz gerçekleştirilecektir.

Tablo 2. ADF Birim Kök Test Sonuçları

Değişkenler	ADF Test İstatistiği
$lrgsyh$	-4.479*** (0) [0.000]
$lborç$	-3.754*** (1) [0.000]
$lkredi$	-3.428** (2) [0.013]
$faiz$	-6.269*** (3) [0.000]

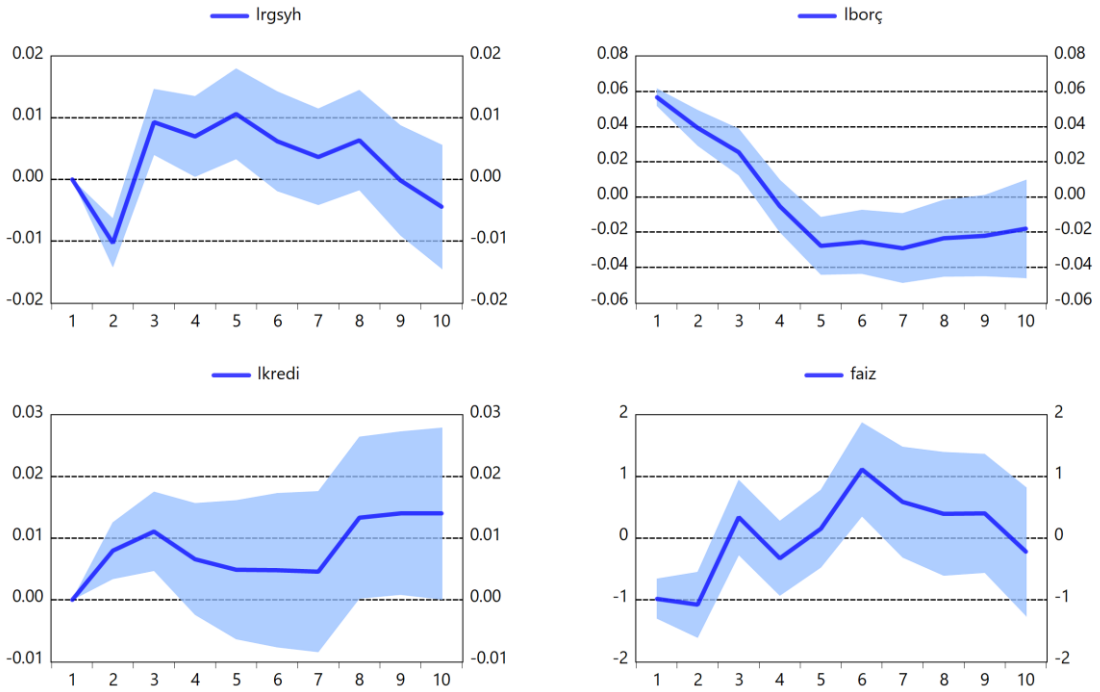
Not: Gecikme uzunluğunun seçiminde Schwarz Bilgi Kriteri kullanılmış ve maksimum gecikme uzunluğu 11 olarak belirlenmiştir. Modellerde sadece sabit terim yer almaktadır. ***, **, ve * işaretleri sırasıyla %1, %5 ve %10 düzeylerinde istatiksel olarak anlamlılık düzeylerini göstermektedir. (…) gecikme uzunluğunu, […] olasılık değerlerini göstermektedir.

SVAR tahmininin ikinci aşamasında uygun gecikme uzunluğunun seçilmesi, SVAR modelinin istikrarlılığı ve spesifikasyon testlerinin (otokorelasyon ve değişen varyans testleri) gerçekleştirilmesi gerekmektedir. Çalışmada uygun gecikme uzunluğunun seçiminde çeşitli bilgi kriterlerinden yararlanılmıştır. Bu çerçevede nihai tahmin hatası (FPE) ve Akaike bilgi kriteri (AIC) test istatistiklerine göre en uygun gecikme uzunluğunun 6 (altı) olduğuna karar verilmiştir. Sonraki aşamada SVAR(6) modeli tahmin edilerek, modelin istikrarlılığı gözden geçirilmiş, otokorelasyon ve değişen varyans testleri gerçekleştirilmiş ve modelin tahmin edilebilir olduğuna karar verilmiştir. Gecikme uzunluğuna yönelik bilgi kriterleri test istatistikleri, otokorelasyon ve değişen varyans test sonuçları sırasıyla Ek-1, Ek-3 ve Ek-4'te yer almaktadır.

VAR yönteminin en önemli özelliklerinden birisi değişkenlerin birisinden gelen şoka diğer değişkenlerin verdiği tepkinin analiz edilmesidir. Bir diğer deyişle değişkenler arasındaki etki-tepkilerin analiz edilmesidir. Çarpan etkisinin ölçülmesi (Lütkepohl, 2005: 51) olarak da adlandırılan bu aşamada, çarpanların zaman içinde izlediği yolun tahmin edilmesi etki-tepki fonksiyonu olarak adlandırılmaktadır (Enders, 2015: 22). Çalışmanın amacı iç borç stoku/GSYH oranındaki artışın kredi piyasası üzerinden üretimde bir dışlama etkisi yaratıp yaratmadığını analiz etmektir. Bu sebeple $lborç$ değişkeninde ortaya çıkan yapısal bir şokun diğer değişkenler üzerinde gösterdiği tepkiler Şekil 3'te gösterilmektedir.

Şekil 3'e göre devletin finansman ihtiyacındaki artışın GSYH üzerindeki etkisinin başlangıçta negatif olduğu ve sonrasında bu etkinin kalıcı olmadığı görülmektedir. Nitekim 2 (iki) çeyrek sonrasında bu tepki pozitife dönmektedir. Bu sonuç başlangıçta Türkiye'de devletin artan finansman ihtiyacının bankalar tarafından karşılanmasına rağmen, toplam kredi hacmini azaltmadığını ve kısa vadeli dışlama etkisinin orta vadede devletin ekonomiyi teşvik edici politikalarıyla ortadan kalktığını göstermektedir. Ayrıca burada yapılabilecek bir başka yorum, devletin finansman ihtiyacının bankalar aracılığıyla karşılanmaya zorlanmasının kısa vadede faizleri düşürüp kredi talebindeki artışa yol açarak ekonomik büyümeye olumlu katkı sağlamasıdır. Bu sonuç farklı ülke ve örneklem için de olsa Özdemir ve Gomez (2020) çalışmasıyla benzerlik göstermektedir. Ancak Şekil 3'te görüleceği üzere düşük faiz ortamının

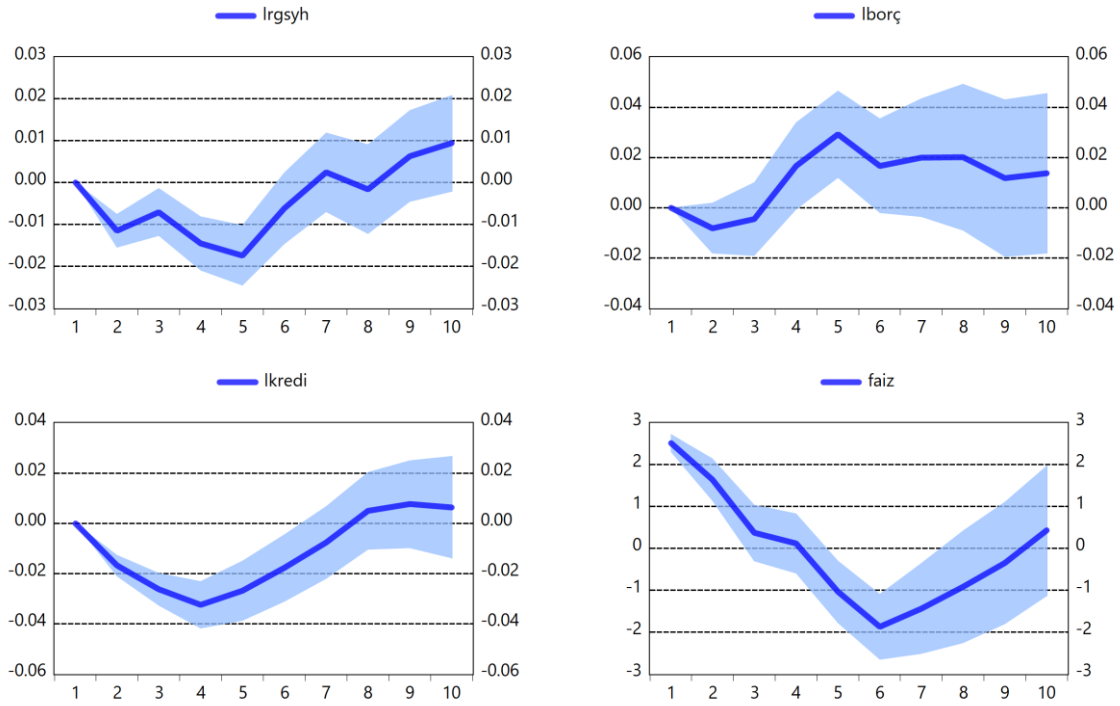
orta vadede ortadan kalkmasıyla birlikte GSYH üzerindeki pozitif etki azalmaktadır. Kredi piyasası üzerindeki etkiler incelendiğinde ise bankaların kredi miktarına yönelik arzının GSYH'deki gecikmeli etkileri takip ettiğine yöneliktir. Bu durum kısa vadede düşük faizle talep edilen kredi miktarının orta vadede üretim ve tüketime dönüştüğünü göstermektedir.



Şekil 3. Etki Tepki Grafikleri ($\varepsilon_t^{lborç} \rightarrow \varepsilon_t^{lrgsyh}, \varepsilon_t^{lkredi}, \varepsilon_t^{faiz}$)

Not: Mavi bantlar Monte Carlo yöntemiyle 1000 tekrar sonucu oluşturulmuş %68 düzeyindeki güven aralıklarını göstermektedir.

Çalışmanın temel araştırma sorularından ikincisine yönelik elde edilen etki tepki fonksiyonları Şekil 4'te yer almaktadır. Şekil 4'teki sonuçlar standart makroekonomik teoriyi doğrular niteliktedir. Modelde yer alan $faiz$ değişkeninde meydana gelen yapısal bir şokun $lrgsyh$ üzerindeki negatif etkisi 5 (beş) çeyrek sürmekte ve sonra bu şokun etkisi sönümlenmektedir. Bu sonucu $faiz$ değişkenin $lkredi$ değişkeni üzerindeki etkisiyle birlikte değerlendirmek gerekmektedir. Çünkü faizdeki artışın, bankaların kredi maliyetlerini etkileyerek kredi miktarı üzerinden ekonomiyi etkilediğini göstermektedir. Standart bir yatırım-tasarruf dengesi açısından incelendiğinde faizlerin artması sonucunda dışlama etkisinin gerçekleştiği söylenebilir. Ancak modelimiz kamu harcamalarını dikkate almadığı için dışlama etkisinin doğrudan kamu harcamalarındaki bir artıştan kaynaklandığını söylemek zor olsa da borçla finanse edilen kamu harcamaları varsayımı çerçevesinde yatırım-tasarruf dengesinin ödünç verilebilir fon piyasasındaki yorumu üzerinden dışlama etkisinin gerçekleştiği ileri sürülebilir. Bir diğer deyişle artan faiz oranları GSYH'yi düşürür.



Şekil 4. Etki Tepki Grafikleri ($\varepsilon_t^{faiz} \rightarrow \varepsilon_t^{lrgsyh}, \varepsilon_t^{lborç}, \varepsilon_t^{lkredi}$)
Not: Mavi bantlar Monte Carlo yöntemiyle 1000 tekrar sonucu oluşturulmuş %68 düzeyindeki güven aralıklarını göstermektedir.

Faizdeki yükselişin $lborç$ üzerindeki etki ise daha ilginçtir. Borç yönetimi çerçevesinden bakıldığında tahvil faizindeki yükseliş başlangıçta finansman talebini azaltmakta ve sonrasında şokun ortadan kalkmasıyla birlikte bu etki pozitife dönmektedir. Ancak burada dikkatli bir yorum yapmak gerekmektedir. Çünkü $lborç$'daki değişim ya iç borç stokundaki ya da GSYH'deki değişimlerin büyüklüğüne bağlıdır. Grafik incelendiğinde şokun $lrgyh$ değişkeni üzerinde $lborç$ değişkenine göre daha büyük etki yarattığı görülmektedir. Dolayısıyla $lrgsyh$'deki düşüş derinleştikçe $lborç$ değişkeni daha fazla artmaktadır. Çalışmada ayrıca $lrgsyh$ ve $lkredi$ değişkenlerinin etkileri de incelenmiş ve sırasıyla Ek-5 ve Ek-6'da sunulmuştur. Çalışmadaki sonuçların güvenilirliğini arttırmak adına dirençlilik analizi de gerçekleştirilmiştir. Bu çerçevede GSYH yerine sanayi üretimi, toplam kredi hacmi yerine mevduat bankalarının sektörel bilançosundan elde edilmiş kredi miktarı kullanılmış ve temel model tekrar tahmin edilmiştir. Model tahmin edildikten sonra etki-tepki fonksiyonları incelendiğinde sonuçların değişmediği bulunmuştur.

6. Tartışma ve Sonuç

Türkiye'de bankaların merkezi yönetim borç stoku içindeki oranı dikkate alındığında, borçlanmada ortaya çıkan artışların etkilerinin incelenmesi literatürde daha önce çok üzerinde durulmamış bir konu olmuştur. Bu çerçevede çalışma, Türkiye'de iç borç stoku/GSYH oranındaki artışların bankalar üzerinden ekonomiyi nasıl etkilediğini SVAR yöntemiyle 2006-2023 yıllarında çeyreklik verilerle analiz etmiştir. Araştırma soruları çerçevesinde analiz sonuçları önemli cevapları ortaya koymuştur. İç borç stoku/GSYH oranındaki artışın kredileri

ve üretimi nasıl etkilediğine yönelik tahmin sonuçları iç borç stoku/GSYH'deki artışın ekonomi üzerindeki etkilerinin geçici olduğunu göstermektedir. Bu sonuç Türkiye'de devlet destekli kredi uygulamalarının GSYH'yi arttırıcı etkilerini göstermektedir. Tabi buradaki önemli konu Türkiye'ye özgü durumla ilgilidir. Nitekim Yılmaz'ın (2017) da vurguladığı gibi devletin KGF benzeri yapılarla ekonomik büyümeyi sürdürmeye yönelik politikaları, kredi genişlemesinin artarak devam etmesine neden olmaktadır. Ayrıca bu tür kredi programlarının özellikle kamu bankaları üzerinden gerçekleştirildiği bilinmektedir. Nitekim kamu bankalarının arz ettiği kredi miktarı diğer banka türlerine göre daha büyüktür. Bu noktada temel SVAR(6) modeli, mevduat bankalarının vermiş olduğu kredi miktarının banka türlerine göre (kamu, yerli ve yabancı mevduat bankaları, Ek-7) ayrıştırılarak tekrar tahmin edilmiştir. Tahmin edilen modellerden elde edilen etki-tepki fonksiyonları sadece $lkredi$ değişkeni için Ek-8'de sunulmuştur. Bu etki-tepki fonksiyonları sonuçları $lborç$ değişkeninde meydana gelen yapısal şokun kredi miktarına etkisinin kamu bankaları açısından istatiksel olarak anlamlı ve belirgin olduğunu göstermektedir. Nitekim Bi ve diğerlerinde (2023) de belirtildiği şekilde devlet destekli kredi garantileri orta ve uzun vadede mali çarpan etkisini kuvvetlendirerek altyapı üretimini arttırmaktadır. Ancak Tosunoğlu (2020) devletin kredi garanti programları benzeri uygulamalarıyla koşullu yükümlülüklerini arttırmasının, koşullu yükümlülüklerin ortaya çıktığı durumda Hazine nakit yönetiminde önemli risklere neden olarak borçlanma gereksinimini arttıracağını ve mali krizleri tetikleyebilme potansiyeline sahip olduğunu belirtmektedir. Bu sorun asimetrik bilgi durumunun bir sonucudur. Asimetrik bilgi kamu maliyesinin en önemli işlevlerinden birisi olan "kaynak tahsisinde etkinliğin sağlanması" konusu içinde yer almaktadır. Asimetrik bilgi, Neo-klasik iktisadın tam bilgi varsayımının aksine, bilginin taraflar arasında dengeli dağılmadığını ifade eder. Nitekim Akerlof, Limon Piyasası makalesiyle asimetrik bilginin piyasa başarısızlığına yol açtığını ortaya koymuştur (Akerlof, 1970: 490; aktaran Oluklulu, 2023: 26). Bu sorun ortaya işlem öncesi ve sonrası iki problem çıkartır: Ters seçim ve ahlaki tehlike. Bu iki problem ise kredi piyasasında kredi tayınlamasına yol açmaktadır.

Devlet tahvil faizindeki artışın etkileri nelerdir sorusuna yönelik elde edilen sonuçlara göre 5 yıllık devlet tahvil faizindeki artışın ekonomi üzerinde daraltıcı etkileri ortaya çıkmaktadır. Bu sonuç bankaların kredi maliyetlerindeki artışın, kredi talebine yansıdığını ve üretim ve tüketim üzerinden GSYH'yi düşürdüğünü göstermektedir. Bu durum Türkiye ekonomisi açısından bankacılık kredi kanalının önemini göstermektedir.

Kısacası mevcut çalışmanın sonuçları, Türkiye özelinde değerlendirildiğinde bankaların devletin borçlanma ihtiyacının en önemli finansman kaynağı olması nedeniyle kısa vadede faizlerde düşüş yaratarak kredi talebini arttırdığını ve orta vadede GSYH üzerindeki olumlu etkilerini göstermektedir. Ancak, bu sonucun orta vadede faiz oranlarında bir artışa yol açtığı gerçeğinin de göz ardı edilmemesi gerektiğini vurgulamak önemlidir.

Çalışmanın sonuçlarına dayalı olarak dışlama etkisinin gerçekleşmemesi adına çeşitli politika önerileri sunulabilir. Christensen (2004) dışlama etkisinin gerçekleşmemesi için yatırımcı tabanı, faiz ve vade açısından önemli öneriler sunmaktadır. Borç otoriteleri kısıtlı miktardaki fona olan talebini sınırlı tutarak faizler üzerindeki baskıyı hafifletmeli ve borçlanma ihtiyacını ise geniş sayıda bir yatırımcı tabanına yayarak ve yatırımcı tabanını genişletmeye çalışarak gerçekleştirmelidir. Bunun yanı sıra borç portföyünün yeterli miktarda hem kısa ve hem de uzun vadeli menkul kıymetleri içermesi gerekmektedir.

Bir diğer öneri kamu politikaları aracılığıyla desteklenen kredi artışlarının risk boyutunun azaltılması amacıyla alınacak önlemlere ilişkindir. Bu risk selektif (tercihli) politikalar aracılığıyla azaltılabilir. Çalışma içerisinde değinilmemiş ancak buradan yola çıkılarak sunulabilecek bir başka öneri, koşullu yükümlülükler çerçevesinde kredi riskinin görevlendirme bedeline neden olarak bütçeye yükleyeceği maliyetle ilgilidir. Nitekim Türkiye’de bu duruma iyi bir örnek olarak, kredi riskinin kontrol edilebilmesine yönelik her yıl Bütçe Kanunu çerçevesinde belirlenen limit (garantili imkân) verilebilir. Dolayısıyla kamu borç yönetimi çerçevesinde, kredi risk yönetimi buna benzer iyi örneklerle geliştirilmeli ve güçlü bir mekanizma oluşturulmalıdır.

Çalışma, kredi kanalının banka bilançoları ve devlet bütçesi açısından daha detaylı incelenmesi çerçevesinde ilerletilebilme potansiyeline sahiptir. Bunun yanı sıra çalışma, para politikası uygulamalarının bankaların kredi verme davranışları üzerindeki etkilerinin olduğu düşünüldüğünde bu etkilerin incelenmesi açısından da yeni çalışmalar ortaya çıkarabilecek fikri barındırmaktadır. Son olarak dışsal finansal koşulların etkilerinin de ayrıştırılmasıyla devletin borçlanma piyasasında ödünç verilebilir fonlara olan talebini ve böylece bankalar üzerindeki mali baskınlığın kredi kanalı üzerinden ekonomiyi nasıl etkilediği araştırılabilir.

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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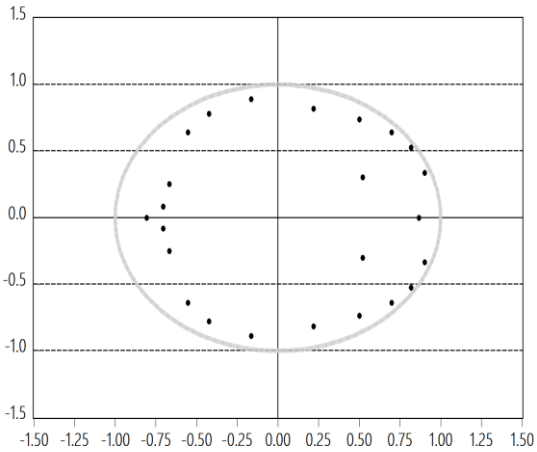
EKLER

Ek-1. Gecikme Uzunluğuna Yönelik Test İstatistikleri

Gecikme	LogL	LR	FPE	AIC	SC	HQ
0	105.1626	NA	6.19e-07	-2.944320	-2.678907	-2.839443
1	205.0478	181.6096	4.88e-08	-5.486298	-4.690060*	-5.171667
2	236.9001	54.05232	3.04e-08	-5.966670	-4.639606	-5.442284
3	260.0767	36.52078	2.49e-08	-6.184144	-4.326255	-5.450004
4	283.2312	33.67919	2.06e-08	-6.400945	-4.012231	-5.457051*
5	303.4818	27.00079*	1.91e-08	-6.529751	-3.610211	-5.376102
6	323.9947	24.86414	1.79e-08*	-6.666506*	-3.216141	-5.303103

Not: LogL; log olasılığı, LR; sıralı değiştirilmiş log olasılığı, FPE; nihai tahmin hatasını, AIC; Akaike bilgi kriterini, SC; Schwarz bilgi kriterini, HQ; Hannan-Quinn bilgi kriterini ifade etmektedir.



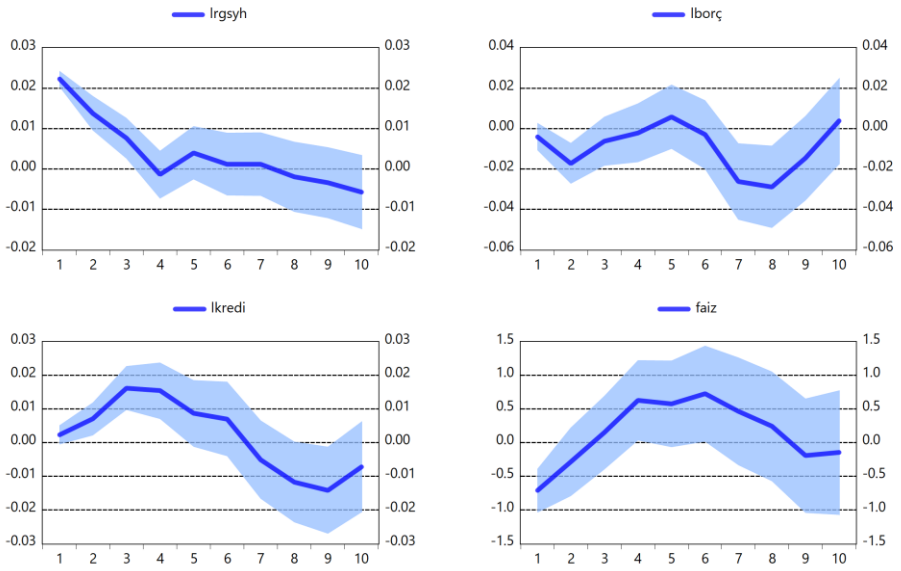
Ek-2. SVAR(6) Modelinin İstikrarlılığı

Ek-3. SVAR(6) Modeli Otokorelasyon Test Sonucu

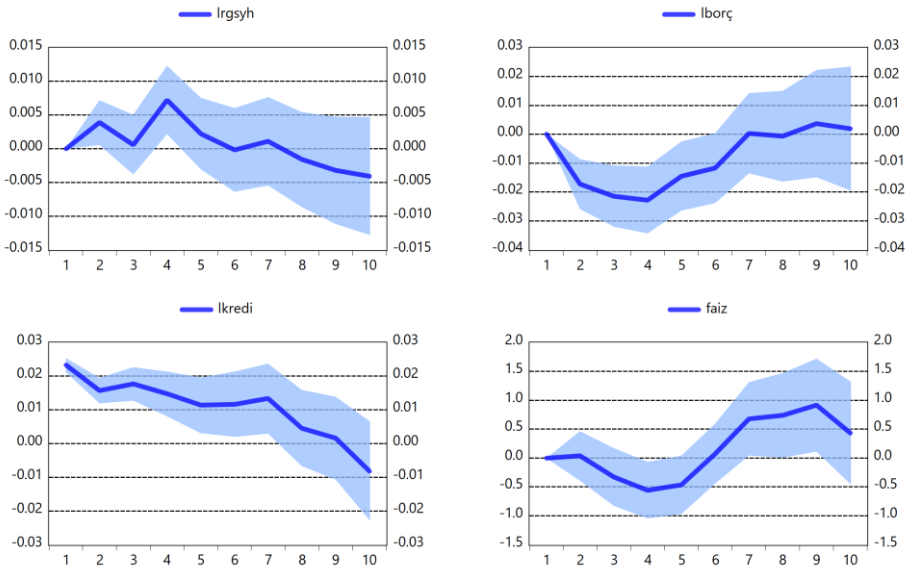
Gecikme	LRE* ist.	df	Olasılık	Rao F-ist.	df	Olasılık
1	30.26859	16	0.0167	2.041306	(16, 101.5)	0.0170
2	10.84710	16	0.8188	0.666986	(16, 101.5)	0.8198
3	29.72519	16	0.0195	1.999414	(16, 101.5)	0.0199
4	30.34854	16	0.0163	2.047488	(16, 101.5)	0.0166
5	19.51355	16	0.2429	1.249958	(16, 101.5)	0.2447
6	21.81834	16	0.1492	1.413000	(16, 101.5)	0.1506
7	15.78714	16	0.4679	0.993573	(16, 101.5)	0.4698

Ek-4. SVAR(6) Modeli Değişen Varyans Test Sonucu

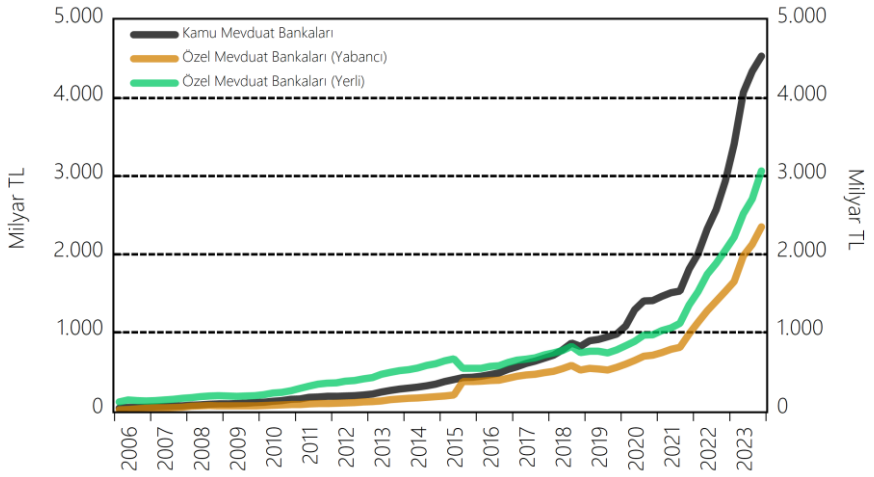
$\varkappa^2$	df	Olasılık
496.0080	490	0.4159



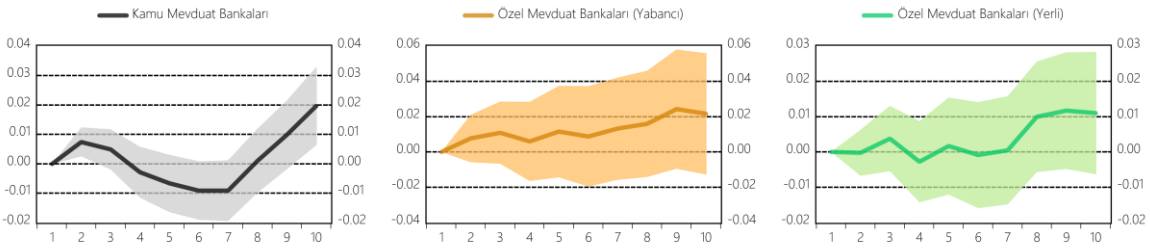
Ek-5. Etki Tepki Grafikleri ($\varepsilon_t^{lrgsyh} \rightarrow \varepsilon_t^{lborç}, \varepsilon_t^{lkredi}, \varepsilon_t^{faiz}$)
Not: Mavi bantlar Monte Carlo yöntemiyle 1000 tekrar sonucu oluşturulmuş %68 düzeyindeki güven aralıklarını göstermektedir.



Ek-6. Etki Tepki Grafikleri ($\varepsilon_t^{lkredi} \rightarrow \varepsilon_t^{lrgsyh}, \varepsilon_t^{lborç}, \varepsilon_t^{faiz}$)
Not: Mavi bantlar Monte Carlo yöntemiyle 1000 tekrar sonucu oluşturulmuş %68 düzeyindeki güven aralıklarını göstermektedir.



Ek-7. Mevduat Banka Türlerine Göre Kredi Miktarı (2006-2023 Çeyreklik)
Not: Mevduat bankalarının türlerine göre elde edilmiş kredi miktarı verileri BDDK'dan elde edilmiştir.



Ek-8. Banka Türlerine Göre Etki Tepki Grafikleri ($\varepsilon_t^{libor_{ç}} \rightarrow \varepsilon_t^{lkredi_{kamu,yabancı,yerli}}$)
Not: Gri, turuncu ve yeşil bantlar Monte Carlo yöntemiyle 1000 tekrar sonucu oluşturulmuş %68 düzeyindeki güven aralıklarını göstermektedir.

GOVERNMENT DOMESTIC DEBT, CREDIT MARKET AND CROWDING-OUT EFFECT IN TÜRKİYE

EXTENDED SUMMARY

The Aim of the Study

The government is actively borrowing for a variety of reasons, both fiscal and nonfiscal. The primary challenge in debt management is to meet borrowing requirements while minimizing costs and risks. In addition to these issues, the distribution of debt holders influences the success of debt policies in particular, as well as fiscal policies generally. How banks, which hold a substantial amount of government debt, affect the economy through credit markets is a critical issue that must be addressed. Because the topic is essential in terms of both economic and financial consequences, this work addresses an important gap in the literature. Furthermore, the study sheds light on how risks originate in debt management. Bank-related problems, in particular, have an impact on both public finance and the economy through the debt market. With this objective in mind, this study aims to bridge a significant gap in the literature for Türkiye by addressing the following questions: i) How does the rise in the domestic debt-to-GDP ratio affect credit and output? ii) What are the economic and financial implications of the increase in government bond interest rates? The first question examines whether or not the crowding-out effect has occurred through the banking credit market. This situation is also referred to as the “quantity channel” for crowding out private investments. The second question investigates the economic impact of rising government bond interest rates.

Literature

The majority of studies on Türkiye focus on whether the crowding-out effect exists within the context of government expenditures, government investments, and partial government debt. Studies provide complex findings. This condition complicates policy recommendations. It has been seen that many studies do not take into consideration the debt market and banks, which are key players in this market. Furthermore, presuming that this influence will not manifest itself in the credit market is viewed as a research shortcoming. To address this gap, the study examines whether Türkiye experiences crowding out through the banking channel.

Data and Methodology

The answers to the above questions for Türkiye are investigated using the structural VAR (SVAR) method with the 2006-2023 quarterly data. The GDP variable, calculated according to the expenditure method based on the chained volume index, is used as an indicator of economic output in the study. The credit variable is based on the total credit volume. In the model, fiscal policy is represented by the ratio of domestic debt stock to GDP. The study uses the 5-year government bond interest rate to indicate the borrowing cost. The SVAR method estimates the relationship between the variables.

Results

The impulse-response functions have indicated key findings. Although a structural shock to Türkiye's domestic debt stock/GDP ratio has a short-term crowding-out effect, this effect fades in the medium term. Banks' increased demand in the bond and bill market results in a decrease in interest rates and an increase in credit demand. Low interest rates boost credit demand, leading to an increase in production and consumption over the medium term. This situation shows that the amount of credit demanded with low interest in the short term turns into production and consumption in the medium term. The results found for the second question of the study show the importance of the banking credit channel for Türkiye. The findings demonstrate the economy's contraction due to the rise in interest rates on government bonds. This result shows that the increase in credit costs is reflected in the credit demand and decreases GDP through production and consumption. In short and briefly, the study results show that the increase in domestic debt creates a crowding-out effect in the short term, but this effect disappears in the medium term with government-supported credit-like practices, and the decrease in interest in the short term loses its effect in the medium term.

Policy Recommendations

Based on the study's findings, a variety of policy recommendations can be made to prevent the crowding-out effect. Debt authorities should limit their demand for limited funds and address their borrowing needs by distributing them to a broad investor base and by trying to expand the investor base. In addition, the debt portfolio should include sufficient amounts of both short-term and long-term securities. Public policies support measures to reduce the risk dimension of credit increases. This risk can be reduced through selective policies. The study has the potential to be advanced within the framework of a more detailed examination of the credit channel in terms of bank balance sheets and the government budget.

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TÜRKİYE'DE EKONOMİK ŞOKLAR VE KRİZLER BAĞLAMINDA ENFLASYON ÖNGÖRÜSÜ: XGBOOST VE ARMA YÖNTEMLERİNİN KARŞILAŞTIRMASI

Inflation Forecasting in the Context of Economic Shocks and Crises in Türkiye: Comparison of XGBoost and ARMA Methods

Savaş GAYAKER*

Anahtar Kelimeler:
Enflasyon Öngörüsü,
XGBoost,
ARMA Modeli.

JEL Kodları:
B22, C22, C53.

Öz

Enflasyon, ekonomik istikrar ve büyüme üzerinde derin etkiler yaratan, temel bir makroekonomik göstergedir. Fiyatlar genel düzeyindeki süreklilik arz eden artışlar, yalnızca bireylerin satın alma güçlerini zayıflatmakla kalmayıp, ulusal ekonominin çeşitli sektörleri üzerinde de ciddi tehditler oluşturmaktadır. Dolayısıyla, enflasyonun doğru tahmini hem merkez bankaları hem de hükümetler için stratejik bir önem taşımaktadır. Bu çalışma, Türkiye'deki ekonomik şoklar ve kriz dönemlerinde, enflasyon tahmininde XGBoost ve ARMA modellerinin performansını incelemektedir. 1994 ekonomik krizi, 2001 finansal krizi, 2008 küresel finansal krizi ve 2018 döviz krizi gibi sık yaşanan krizler ve Türkiye'nin özgün makroekonomik koşulları göz önüne alındığında, enflasyonun doğru tahminini zorlaştırmaktadır. Çalışmada, kriz dönemleri de dahil olmak üzere farklı zaman dilimlerinde XGBoost makine öğrenimi algoritması ile ARMA modelinin performansı karşılaştırılmaktadır. Ampirik bulgular, XGBoost'un büyük veri setleri ve kriz dönemlerinde güçlü performans gösterdiğini, ancak geleneksel ARMA modelinin daha küçük veri setlerinde daha iyi sonuçlar verdiğini ortaya koymaktadır. Özellikle, ARMA modelinden gelen gecikmeli değişkenlerin XGBoost'a entegre edilmesiyle elde edilen tahmin modeli, kriz dönemlerinde ve tüm örneklem dönemi olan 1990:02-2024:06 arasında en etkili yöntem olarak belirlenmiştir. Bu sonuçlar, enflasyon tahmini için kullanılan modellerin veri yapısına duyarlılığını vurgulamakta ve farklı dönemlerdeki etkinliklerini ortaya koymaktadır.

Keywords:
Inflation Forecast,
XGBoost,
ARMA Model.

JEL Codes:
B22, C22, C53.

Abstract

Inflation is a key macroeconomic indicator with profound implications for economic stability and growth. Persistent increases in the general level of prices not only weaken individuals' purchasing power but also pose serious threats to various sectors of the national economy. Accurate inflation forecasting is therefore of strategic importance for central banks and governments. This paper examines the performance of XGBoost and ARMA models in forecasting inflation during economic shocks and crisis periods in Türkiye. The 1994 economic crisis, 2001 financial crisis, 2008 global financial crisis, and 2018 currency crisis, along with Türkiye's unique macroeconomic conditions, complicate accurate inflation forecasting. This study compares the performance of the XGBoost machine learning algorithm and the ARMA model over different periods, including crises. The findings show XGBoost performs well for large datasets and crisis periods, while ARMA performs better for smaller datasets. Particularly, the forecasting model integrating ARMA's lagged variables into XGBoost proves most effective during crises and across the entire sample period, 1990:02-2024:06. These results highlight the models' sensitivity to data structure and their efficiency in different periods.

* Dr. Öğr. Üyesi, Ankara Hacı Bayram Veli Üniversitesi, İktisadi ve İdari Bilimler Fakültesi, Türkiye, savas.gayaker@hbv.edu.tr

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1. Giriş

Enflasyon, ekonomik istikrar ve büyüme üzerinde belirleyici etkiler yaratan temel bir makroekonomik göstergedir. Fiyatlar genel düzeyindeki sürekli artış, sadece bireylerin satın alma gücünü değil, aynı zamanda ulusal ekonominin çeşitli sektörlerini de riske atmaktadır (Niyimbanira, 2013). Yüksek enflasyon, tüketicilerin satın alma gücünü aşındırarak tüketimin azalmasına ve genel ekonomik aktivitenin yavaşlamasına yol açmaktadır (Girdzijauskas vd., 2022). Enflasyonun kalıcı yükselişi, sadece bireylerin alım gücüne zarar vermekle kalmamakta, aynı zamanda işletmelerin kârlılığına ve genel ekonomik büyümeye de ciddi riskler oluşturmaktadır.

Enflasyonun ekonomi üzerindeki etkileri çok yönlüdür. Enflasyon, faiz oranlarını etkilemekte olup, merkez bankaları genellikle artan enflasyona karşı harcamaları ve borçlanmayı sınırlamak için faiz oranlarını artırmaktadır (Noh vd., 2023). Bu durum ekonomik büyümeyi daha da yavaşlatmakta, çünkü yüksek faiz oranları, tüketiciler ve işletmeler için kredileri daha pahalı hale getirmektedir (Dwumfour, 2019). Bunun yanı sıra, enflasyon yatırım kararlarında belirsizlik yaratmakta ve hızla değişen fiyatların olduğu bir ortamda işletmelerin yatırım yapmaktan imtina etmelerine neden olmaktadır. Ayrıca, enflasyonun oluşturduğu belirsizlik ortamı, özellikle gelişmekte olan ülkelerde, sürdürülebilir yatırım stratejilerini zorlaştırmaktadır. Bunun yanı sıra, enflasyon, ücret-fiyat sarmalı denilen bir duruma da yol açabilmektedir. Artan fiyatlar, işçilerin satın alma güçlerini koruyabilmek için daha yüksek ücret talep etmesine sebep olmaktadır. Bu durum, ekonomiyi istikrarsızlaştırmakta ve önemli sosyal ve ekonomik sorunlara yol açabilmektedir. Dolayısıyla, enflasyonun doğru ve zamanında tahmini hem merkez bankaları hem de hükümetler için stratejik bir önem taşımaktadır. Güvenilir enflasyon tahminleri, ekonomik karar alıcıların gelecekteki potansiyel dengesizlikleri öngörmesini ve bu dengesizliklere karşı zamanında önlem almasını sağlamaktadır.

Literatürde enflasyon tahmini için kullanılan yöntemler, geleneksel ekonometrik modellerden (örneğin, Otoregresif Entegre Hareketli Ortalama- ARIMA, Phillips Eğrisi) modern makine öğrenmesi algoritmalarına kadar geniş bir yelpazede yer almaktadır. Geleneksel yöntemler, tarihsel verilere dayalı öngörüler sunarken, makine öğrenmesi yöntemleri özellikle büyük ve karmaşık veri setlerinde daha yüksek tahmin doğruluğu sunma potansiyeline sahiptir (Salkuti, 2020; Ji, 2023; Li vd., 2023). Bu çerçevede, XGBoost (eXtreme gradient boosting) gibi gelişmiş makine öğrenmesi algoritmaları, öznitelik seçimi, model optimizasyonu ve aşırı öğrenmeyi önleme konularında sunduğu avantajlar ile öne çıkmaktadır. XGBoost, özellikle verinin karmaşık yapısını öğrenmede ve hızlı hesaplama yetenekleri ile enflasyon tahmini gibi zor problemlerde güçlü bir alternatif olarak literatürde kendine yer bulmuştur (Chen ve Guestrin, 2016; Aras ve Lisboa, 2022; Rizinski vd., 2022; Gono, 2023; Ivaşcu, 2023). Ancak, Türkiye gibi gelişmekte olan ülkelerdeki enflasyon tahmini süreci, sıklıkla yaşanan ekonomik şoklar ve krizlerle daha da karmaşık bir hal almaktadır. Türkiye ekonomisi, son birkaç on yılda birçok ekonomik kriz ve şok yaşamıştır; 1994 krizi, 2001 finansal krizi, 2008 küresel finansal kriz ve 2018 döviz krizi gibi dönemler, enflasyon dinamiklerinde ciddi dalgalanmalara yol açmıştır. Bu tür ekstrem durumlar, geleneksel zaman serisi yöntemlerinin tahmin yeteneğini sınırlayarak, yeni yöntemlerin uygulanabilirliğini test etmek için ideal bir ortam sunmaktadır. Bu bağlamda, XGBoost gibi modern yöntemlerin performansı, özellikle kriz dönemlerinde büyük önem taşımaktadır.

Bu çalışmada, 1990:02-2024:06 dönemine ait aylık veriler kullanılarak, XGBoost yönteminin Türkiye'deki ekonomik şoklar ve kriz dönemlerinde enflasyon tahminindeki performansı incelenmiştir. XGBoost yönteminin, bu tür ekstrem durumlarda ne ölçüde güvenilir tahminler yapabildiği değerlendirilmiş, aynı zamanda klasik zaman serisi yöntemlerinden biri olan otoregresif hareketli ortalama (ARMA) modeli ile karşılaştırılmıştır. Bu çerçevede, çalışmanın iki temel katkısı olacaktır: Birincisi, XGBoost'un kriz ve şok dönemlerinde tahmin performansını analiz ederek literatürdeki boşluğu doldurmak; ikincisi, geleneksel yöntem olan ARMA modeli ile bu yeni yöntemin performanslarını karşılaştırarak, hangi şartlar altında hangi yöntemin daha etkin olduğuna dair pratik öneriler sunmak. Elde edilen sonuçlara göre, XGBoost yöntemi, öncesinde büyük bir zaman penceresi olan kriz dönemlerinde güçlü tahmin performansı sergilerken, geleneksel ARMA modeli daha küçük veri setlerinde daha etkili sonuçlar vermektedir. Özellikle XGBoost modeline gecikmeli değişkenlerin eklenmesiyle tahmin doğruluğunun önemli ölçüde arttığı, kriz dönemlerinde daha tutarlı öngörüler sağladığı görülmüştür. Bu bulgular, Türkiye gibi gelişmekte olan ve sık ekonomik şoklara maruz kalan ekonomilerde, farklı tahmin yöntemlerinin uygulanabilirliğine dair önemli içgörüler sunmaktadır.

Çalışmanın ilerleyen bölümlerinde ilk olarak literatür taraması sunulmuş, ardından veri seti ve metodoloji detaylandırılmıştır. Takip eden bölümde bulgulara yer verilmiş, son bölümde ise tahmin sonuçları değerlendirilerek çeşitli önerilerde bulunulmuştur.

2. Literatür Taraması

Bu bölümde, enflasyon tahmininde kullanılan çeşitli ekonometrik ve makine öğrenimi yaklaşımları ile bu yöntemlerin doğruluğunu artırmaya yönelik uygulamalar incelenmiştir. Literatürde enflasyon tahminine yönelik çalışmalar, geleneksel ekonometrik yöntemler ile yeni nesil yapay zekâ ve makine öğrenimi tekniklerini kullananlar olmak üzere ikiye ayrılmaktadır.

Stock ve Watson (1999), 1959:01-1997:09 döneminde ABD'de enflasyon tahminlerini Phillips eğrisi çerçevesinde incelemiştir. Çalışmada, işsizlik oranına dayalı geleneksel Phillips eğrisi modeli ile diğer makroekonomik değişkenler ve ekonomik aktivite göstergelerine dayalı alternatif Phillips eğrisi modelleri karşılaştırılmıştır. Sonuçlar, işsizlik oranına dayalı Phillips eğrisi tahminlerinin diğer değişkenlere dayalı modellerden genellikle daha iyi performans gösterdiğini, ancak bazı ekonomik aktivite göstergelerinin (özellikle konut başlangıçları ve üretim kapasitesi kullanımı gibi) enflasyon tahminlerinde iyileştirmeler sağlayabileceğini göstermiştir. Chen vd. (2001), 1948:01-1995:04 döneminde ABD enflasyonunu tahmin etmek için yarı-parametrik ARX yapay sinir ağı modellerini kullanmıştır. Çalışmada, üç farklı aktivasyon fonksiyonu (sigmoid, radyal bazlı ve ridgelet) kullanılmış ve bu modeller, doğrusal modellerle karşılaştırılmıştır. Sonuçlar, yarı-parametrik ridgelet ARX modelinin tahmin doğruluğu açısından en iyi performansı gösterdiğini ve geleneksel doğrusal modelleri geride bıraktığını ortaya koymuştur. Hubrich (2005), 1992:01-2001:12 döneminde Avrupa Bölgesi enflasyon tahminlerini bileşenlere dayalı alt-indeks tahminlerinin doğruluğunu incelemek amacıyla tek değişkenli ve çok değişkenli doğrusal zaman serisi modellerini kullanarak analiz etmiştir. Çalışmada, HICP (Tüketici Fiyatları Harmonize Endeksi) bileşenlerinin (gıda, enerji, endüstriyel ürünler vb.) tahminlerinin, genel HICP enflasyonu tahmin etmekte ne kadar etkili olduğu araştırılmıştır. Sonuçlar, bileşen bazlı tahminlerin genel HICP tahminine kıyasla uzun vadede daha yüksek doğruluk sağlamadığını ortaya koymuştur.

Nakamura (2005), 1960:01-2003:03 döneminde ABD'deki enflasyon tahminlerini yapay sinir ağı (NN) modeli kullanarak analiz etmiştir. Çalışma, NN modelini ve tek değişkenli otoregresif (AR) modellerini karşılaştırarak, kısa vadeli (bir ve iki çeyrek) tahminlerde sinir ağı modelinin AR modellerine kıyasla daha iyi performans gösterdiğini ortaya koymuştur. Çalışmada, erken durdurma prosedürü gibi sinir ağı modelleme tekniklerinin tahmin başarısına katkıda bulunduğu tespit edilmiştir. McAdam ve McNelis (2005), 1970:01-2003:12 döneminde ABD, Japonya ve Avrupa bölgesindeki enflasyon tahminlerini doğrusal ve NN tabanlı kalın modelleri (thick models) kullanarak analiz etmişlerdir. Çalışmada, Phillips eğrisi formülasyonuna dayalı modeller karşılaştırılmış ve özellikle hizmet fiyat endeksleri tahmininde NN modellerinin, bootstrap ve gerçek zamanlı tahminler açısından doğrusal modellerden daha başarılı olduğu tespit edilmiştir. Stock ve Watson (2007), 1960:01-2004:12 döneminde ABD enflasyon tahminlerinin zorlaşmasının nedenlerini incelemek amacıyla, gözlenemeyen bileşenler (UC) modeli ve zamanla değişen parametrelerle çalışan bir trend-döngü modeli kullanarak analiz yapmışlardır. Çalışma, enflasyonun yapısal değişiklikler geçirdiğini ve bu değişikliklerin tahmin zorluklarına katkıda bulunduğunu göstermiştir. Özellikle, 1984 sonrası dönemde Phillips eğrisi gibi çok değişkenli tahmin modellerinin performansında düşüş olduğu, ancak basit tek değişkenli modellerin tahmin hatalarının azaldığı bulunmuştur. Stock ve Watson (2008), 1953:01-2008:01 döneminde ABD'de enflasyon tahminlerini değerlendirmek amacıyla Phillips eğrisi tahminlerini ve çeşitli tek değişkenli tahmin modellerini sözde (pseudo) örneklem dışı yöntemi ile incelemiştir. Çalışmada, enflasyonun aktivite değişkenleri ile tahmin edilip edilemeyeceği araştırılmıştır. Sonuçlar, Phillips eğrisi tahminlerinin zaman zaman tek değişkenli modelleri geride bırakabildiğini, ancak genel olarak bu performansın belli bir zaman dönemi ile sınırlı olduğunu ve çoğu zaman tek değişkenli tahminlerden daha iyi sonuç vermediğini göstermiştir. Koop (2013), 1959:Q1-2008:Q3 döneminde ABD makroekonomik verilerini kullanarak orta ve büyük boyutlu Bayesyen VAR modelleri ile tahmin yapmıştır. Çalışmada, Bayesyen VAR'ların faktör yöntemlerine göre daha iyi tahmin yapabildiği ve Minnesota önselleri ile stokastik arama değişken seçimi (SSVS) yöntemlerinin performanslarının karşılaştırıldığı analizler gerçekleştirilmiştir. Sonuçlar, orta boyutlu VAR'ların büyük boyutlu VAR'lara kıyasla daha iyi tahminler üretebildiğini ve Minnesota önselleri ile SSVS yaklaşımlarının tahmin performanslarının genellikle benzer olduğunu ortaya koymuştur. Faust ve Wright (2013), 1985:01-2011:04 döneminde ABD'deki enflasyon tahminlerini geleneksel ve yeni geliştirilen modelleri karşılaştırarak analiz etmiştir. Çalışmada, subjektif tahminlerin model bazlı tahminlere göre üstün olduğu, özellikle enflasyonun düşük frekanslı yerel ortalaması dikkate alınarak yapılan tahminlerde daha başarılı sonuçlar elde edildiği tespit edilmiştir. Sonuçlar, makroekonomik modelleme yöntemlerinin yanı sıra piyasa bazlı enflasyon tahminlerinin de önemli katkılar sunduğunu göstermiştir.

Stock ve Watson (2016), 1959:01-2015:06 döneminde ABD'deki temel ve trend enflasyonu dinamik faktör modelleri kullanarak analiz etmiştir. Çalışmada, kişisel tüketim harcamaları (PCE) fiyat endeksinin 17 bileşenine dayalı dinamik bir faktör modeli geliştirilmiş ve zamana bağlı ağırlıklar ile sektörler arası ortak hareketlilik dikkate alınmıştır. Sonuçlar, çok değişkenli trend enflasyon tahminlerinin, manşet enflasyonuna dayalı tahminlerden daha kesin olduğunu ve temel enflasyon ölçütlerinin, 1-3 yıllık enflasyon tahminlerinde önemli iyileşmeler sağladığını ortaya koymuştur. Garcia vd. (2017), 2003:01-2015:12 döneminde Brezilya enflasyon tahminlerini yüksek boyutlu modeller ve makine öğrenimi teknikleri kullanarak analiz etmiştir. Çalışmada, LASSO, rastgele ormanlar (RF) ve tam alt küme regresyon gibi yöntemler kullanılmıştır. Sonuçlar, kısa vadeli tahminlerde LASSO'nun, uzun vadeli tahminlerde ise tam alt küme

regresyonunun en iyi performansı gösterdiğini ortaya koymuştur. Ayrıca, model kombinasyonu kullanılarak tahmin doğruluğunda önemli iyileşmeler sağlanmıştır. Domit vd. (2019), 2000:Q1-2012:Q3 döneminde Birleşik Krallık'taki ekonomik göstergeleri tahmin etmek için orta ölçekli bir Bayesyen VAR (BVAR) modeli kullanmıştır. Çalışmada, BVAR modeli ile GSYH büyüme oranı ve enflasyon tahmin edilmiş ve bu tahminler İngiltere Merkez Bankası'nın DSGE modeli olan COMPASS ile karşılaştırılmıştır. Sonuçlar, BVAR modelinin GSYH büyümesi tahminlerinde COMPASS'a göre daha iyi performans gösterdiğini, ancak enflasyon tahminlerinde iki modelin performansının benzer olduğunu ortaya koymuştur. Carriero vd. (2019), 1993:Q1-2013:Q4 döneminde ABD, Birleşik Krallık, Avrupa bölgesi, Almanya, Fransa, İtalya ve Japonya'da çıktı büyümesi ve enflasyon tahminlerini değerlendirerek, faktör modelleri, BVAR modelleri, MIDAS modelleri ve DSGE modelleri arasında karşılaştırmalar yapmışlardır. Çalışma, geniş veri setlerini kullanan modellerin tahmin performanslarını, özellikle faktör modelleri ve MIDAS modelleri ile değerlendirirken, BVAR modellerine kıyasla daha yüksek doğruluk sağladığını göstermiştir. Ayrıca, DSGE modellerinin uzun vadeli enflasyon tahminlerinde özellikle ABD ve Birleşik Krallık'ta başarılı sonuçlar elde ettiği bulunmuştur. Medeiros vd. (2021), 1960:01-2015:12 döneminde ABD'deki enflasyon tahminlerini makine öğrenimi yöntemleri kullanarak analiz etmiştir. Çalışmada, RF, LASSO ve Ridge regresyon gibi çeşitli makine öğrenimi modelleri uygulanmıştır. Sonuçlar, RF modelinin enflasyon tahminlerinde diğer yöntemlere göre daha yüksek doğruluk sağladığını ve özellikle verilerin doğrusal olmayan yapısını iyi yakaladığını göstermiştir. Çalışma, geniş veri setleriyle çalışmanın tahmin doğruluğunu %30'a kadar artırabileceğini ortaya koymuştur. Peirano vd. (2021), 1958:01-2019:06 döneminde Latin Amerika ülkelerindeki enflasyonu tahmin etmek için mevsimsel otoregresif entegre hareketli ortalama (SARIMA) ve uzun kısa süreli bellek (LSTM) modellerini birleştirerek analiz etmişlerdir. Çalışmada, SARIMA ve LSTM modellerinin doğrusal ve doğrusal olmayan yönlerini birleştirerek daha yüksek tahmin doğruluğu elde edilmiştir. Sonuçlar, önerilen SARIMA-LSTM modelinin, diğer tekil modellerden daha iyi tahmin performansı sağladığını göstermiştir.

Clark vd. (2024), 1980:Q1-2021:Q1 döneminde ABD enflasyon tahminlerini esnek, parametrik olmayan modeller kullanarak analiz etmişlerdir. Çalışmada, Gaussian süreç regresyonu ve Dirichlet süreç karışımı modelleri kullanılmış ve bu yöntemlerin enflasyon tahminlerinde doğruluğu artırdığı görülmüştür. Özellikle, pandemi dönemi gibi oynak dönemlerde bu modellerin geleneksel modellere göre daha iyi performans sergilediği tespit edilmiştir. Almosova ve Andresen (2023), 1960:01-2020:06 döneminde ABD enflasyonunu tahmin etmek için LSTM ve diğer makine öğrenimi yöntemlerini kullanarak analiz etmişlerdir. Çalışmada, LSTM, SARIMA, Markov-switching ve NN modelleri karşılaştırılmış ve sonuçlar, LSTM'nin özellikle ayarlanmış ve sezonluk düzeltilmemiş veriler üzerinde en iyi performansı gösterdiğini ortaya koymuştur. Ayrıca, modelin büyük şokların ardından enflasyon eğilimlerini doğru şekilde tahmin ettiği bulunmuştur. Hauzenberger vd. (2023), 1963:01-2021:01 döneminde ABD enflasyon tahminlerini doğrusal olmayan boyut indirgeme tekniklerini kullanarak analiz etmişlerdir. Çalışmada, makine öğrenimi teknikleriyle elde edilen gizli faktörler, zamanla değişen parametre (TVP) regresyonları ile modelleme yapılmıştır. Sonuçlar, özellikle resesyon dönemlerinde doğrusal olmayan boyut indirgeme yöntemlerinin, doğrusal yaklaşımlara kıyasla daha rekabetçi enflasyon tahminleri sağladığını göstermiştir.

Türkiye'de enflasyon tahmini, ülkenin benzersiz ekonomik koşulları ve enflasyon oranlarındaki oynaklık nedeniyle kritik bir çalışma alanı olmaktadır. Enflasyon tahminlerinin

doğruluğunu artırmak için geleneksel ekonometrik modeller, makine öğrenmesi teknikleri ve hibrit yaklaşımlar dahil olmak üzere çeşitli metodolojiler kullanılmaktadır. Ogunc vd. (2013), 2003:Q1-2011:Q2 döneminde Türkiye'de kısa vadeli enflasyon tahminlerini bir dizi ekonometrik model kullanarak analiz etmiştir. Çalışmada, tek değişkenli modeller, frekans ve zaman alanı ayrışmasına dayalı yaklaşımlar, Phillips eğrisi temelli zamanla değişen parametre modeli, VAR ve Bayesian VAR modelleri ile dinamik faktör modelleri kullanılmıştır. Sonuçlar, daha fazla ekonomik bilgi içeren modellerin rastgele yürüyüş modeline kıyasla tahmin doğruluğunu %30 oranında artırdığını göstermiştir. Ayrıca, tahminlerin birleştirilmesiyle elde edilen sonuçlar, bireysel modellere göre hata payının azaldığını ortaya koymuştur. Bulut (2018), 2006:04-2016:12 döneminde Türkiye'de 12 aylık ve 24 aylık enflasyon beklentilerini belirlemek için otoregresif dağıtılmış gecikmeli (ARDL) modelini kullanarak analiz etmiştir. Çalışmada, geçmiş enflasyon oranı, enflasyon hedefi, çıktı açığı, USD/TL döviz kuru, petrol fiyatı ve EMBI değişkenleri kullanılmıştır. Sonuçlar, 12 aylık enflasyon beklentisinin geçmiş enflasyon oranı, enflasyon hedefi, çıktı açığı, USD/TL kuru ve petrol fiyatı ile pozitif, gelişmekte olan piyasalar tahvil endeksi (EMBI) ile negatif ilişkili olduğunu, 24 aylık enflasyon beklentisinin ise sadece geçmiş enflasyon oranı ve USD/TL kuru ile pozitif, enflasyon hedefi ve EMBI ile negatif ilişkili olduğunu göstermiştir.

Deka ve Reşatoğlu (2019), 2018 döviz krizi sonrası dönemde Türkiye'deki döviz kuru ve enflasyon tahminlerini ARIMA modeli kullanarak analiz etmiştir. Çalışmada, ARIMA(3,1,3) modelinin Türkiye'nin döviz kuru tahmini için en uygun model olduğu ve ARIMA(1,1,4) modelinin ise TÜFE tahmininde en iyi performansı sağladığı tespit edilmiştir. Sonuçlar, ARIMA modelinin döviz kuru ve enflasyon tahminlerinde güvenilir bir yöntem olduğunu ortaya koymuştur. Akbulut (2022), 2006:01-2020:12 döneminde Türkiye'de enflasyon tahminlerini makine öğrenimi ve zaman serisi modellerini kullanarak analiz etmiştir. Çalışmada, Ridge, Lasso ve çok katmanlı algılayıcı (MLP) modelleri ile VAR modelinin tahmin performansları karşılaştırılmıştır. Sonuçlar, MLP algoritmasının doğrusal modellerden daha iyi tahmin sonuçları verdiğini, ancak VAR modelinin en iyi performansı gösterdiğini ortaya koymuştur. Ayrıca, oynaklığın yüksek olduğu dönemlerde doğrusal olmayan modellerin enflasyon tahminlerinde daha başarılı olduğu tespit edilmiştir. Özgür ve Akkoç (2022), 2007:03-2019:07 döneminde Türkiye'deki enflasyon tahminlerini makine öğrenimi algoritmaları (ridge, lasso, ada lasso ve elastic net) kullanarak analiz etmişlerdir. Çalışmada, ARIMA ve VAR gibi geleneksel ekonometrik modeller ile makine öğrenimi teknikleri karşılaştırılmıştır. Sonuçlar, lasso ve elastic net algoritmalarının, özellikle yüksek enflasyon ve oynaklık dönemlerinde daha iyi tahmin performansı sağladığını göstermiştir. Enerji üretimi, inşaat sektörü göstergeleri ve reel efektif döviz kuru enflasyon tahminlerinde öne çıkan değişkenler olmuştur.

Rayner ve Bolhuis (2020), 2012:Q1-2019:Q4 döneminde Türkiye'deki makroekonomik büyüme tahminlerini, geleneksel en küçük kareler tabanlı yöntemler yerine makine öğrenimi teknikleri kullanarak analiz etmişlerdir. Çalışmada, RF, Gradyan Destekli Ağaçlar ve Destek Vektör Makineleri gibi makine öğrenimi algoritmaları kullanılmıştır. Sonuçlar, makine öğrenimi yöntemlerinin geleneksel modellerden %30 daha düşük tahmin hatası verdiğini göstermiştir. Özellikle ekonomik büyümede büyük dalgalanmaların yaşandığı dönemlerde bu yöntemlerin daha iyi performans sergilediği ortaya konmuştur. Aras ve Lisboa (2022), 2007:01-2021:08 döneminde Türkiye'deki enflasyon tahminlerini makine öğrenimi ve ekonometrik yöntemler kullanarak analiz etmişlerdir. Çalışmada, Ridge, Lasso, RF, XGBoost gibi makine öğrenimi algoritmaları ile VAR gibi geleneksel ekonometrik modeller karşılaştırılmıştır. Sonuçlar, RF ve

XGBoost modellerinin tahmin doğruluğu açısından diğer yöntemlere göre üstün performans sergilediğini göstermiştir. Ayrıca, tahminlerde Shapley değerleri kullanılarak, değişkenlerin etkilerini açıklayıcı bir modelleme sunulmuştur. Ivaşcu (2023), 2000:01-2020:08 döneminde Romanya'daki enflasyonu tahmin etmek için makine öğrenimi modellerini kullanarak analiz yapmıştır. Çalışmada, Destek Vektör Regresyonu, Sinir Ağları, LSTM, RF, XGBoost ve Hafif Gradyan Artırma Makinesi (LightGBM) gibi popüler makine öğrenimi algoritmaları tek değişkenli ve çok değişkenli analizlerde test edilmiştir. Sonuçlar, verinin az olduğu ortamlarda bu yöntemlerin basit otoregresif modelleri geçemediğini göstermiştir.

Sonuç olarak, literatürde hem Türkiye'de hem de uluslararası düzeyde enflasyon tahmini üzerine yapılan çalışmalar, çeşitli model ve yaklaşımların etkinliğini ortaya koymakta ve bu alanda yapılacak yeni çalışmaların hem geleneksel yöntemlerle hem de modern makine öğrenmesi yaklaşımlarıyla karşılaştırmalı olarak ele alınmasının önemli katkılar sağlayacağını göstermektedir.

3. Veri Seti ve Metodoloji

3.1. Veri Seti

Enflasyon, talep enflasyonu, maliyet enflasyonu ve yapısal enflasyon olarak kategorize edilebilecek çeşitli faktörlerden etkilenen karmaşık bir makroekonomik olgudur. Enflasyonu kapsamlı bir şekilde anlamak için para arzı, faiz oranları, döviz kurları ve ekonomik büyüme göstergeleri gibi makroekonomik verilerin analiz edilmesi gerekmektedir. Enflasyonun başlıca belirleyicilerinden biri olan para arzı, enflasyon oranları üzerinde önemli bir etkiye sahiptir. Araştırmalar, para arzındaki artışın enflasyon oranlarını yükselttiğini, çünkü dolaşımdaki para miktarının artmasının mal ve hizmetlere olan talebi artırarak fiyatları yukarı çektiğini göstermektedir. Malezya'da yapılan bir çalışmada, toplam para arzının enflasyon oranları üzerinde önemli ve pozitif bir etkiye sahip olduğu vurgulanmış ve bu durum, para politikasının enflasyon kontrolündeki kritik rolünü öne çıkarmıştır (Yusof vd., 2021). Benzer şekilde, Endonezya'da yapılan bir araştırma, para arzının enflasyonu pozitif ve anlamlı bir şekilde etkilediğini bulmuş ve bu bulgu, enflasyonist eğilimleri anlamada parasal faktörlerin önemini pekiştirmiştir (Jumhur vd., 2018). Türkiye'de yapılan başka bir çalışmada, kısa ve uzun vadede para arzı ile enflasyon arasında anlamlı ilişkiler tespit edilmiştir (Tursoy ve Mar'i, 2020). Benzer şekilde, Pakistan ve Endonezya'da yapılan araştırmalar da para arzının enflasyonun başlıca belirleyicisi olduğunu ortaya koymuştur (Kemal, 2022; Honoré, 2018).

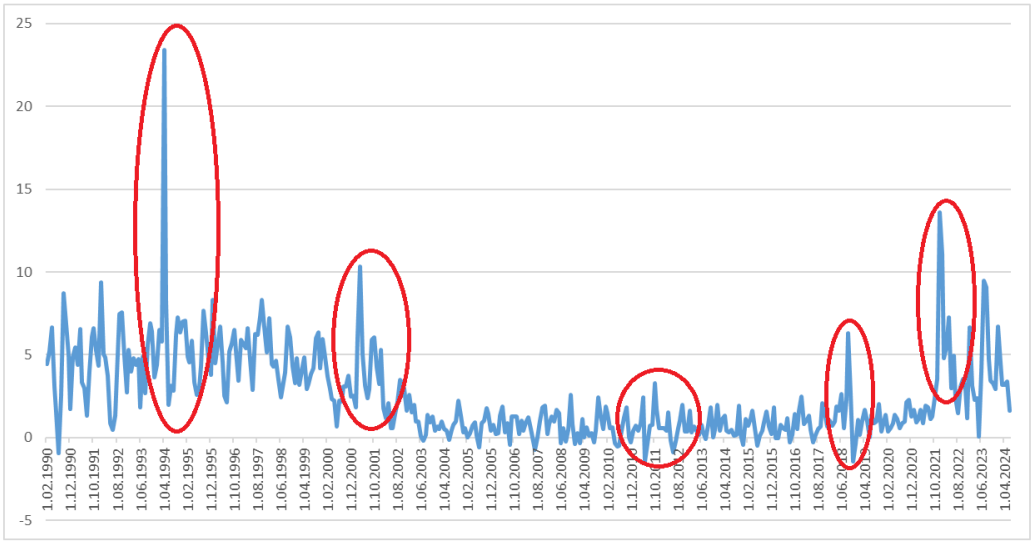
Faiz oranları da enflasyon üzerinde belirleyici bir rol oynamaktadır. Yüksek faiz oranları genellikle borçlanmayı ve harcamayı caydırarak enflasyonun düşmesine neden olabilirken, düşük faiz oranları ekonomik faaliyetleri teşvik ederek enflasyonu artırabilir. Faiz oranları ve enflasyon arasındaki ilişkiyi Taylor Kuralı belirlemektedir. Taylor Kuralı, merkez bankalarının enflasyon ve diğer ekonomik koşulları hesaba katmak için faiz oranlarını nasıl değiştirmesi gerektiğini önermektedir (Berument ve Taşçi, 2004; Yazgan ve Yilmazkuday, 2007; Kose vd., 2012).

Döviz kurları, enflasyonu etkileyen bir diğer kritik faktördür. Yerel para biriminin değer kaybetmesi, ithalat fiyatlarının artmasına ve bu durumun da enflasyona katkıda bulunmasına yol açabilmektedir. Literatürde bu durum döviz kurundan fiyatlara geçişkenlik olarak bilinmektedir (Kara vd., 2007; Ha vd., 2020). Kamber ve Wong'un (2020) araştırması, küresel faktörlerin enflasyonu etkilediğini, ancak döviz kurları gibi yerel faktörlerin de farklı ekonomilerde

enflasyon oranlarını belirlemede önemli bir rol oynadığını öne sürmüştür. Son olarak, ekonomik aktivite, enflasyonla karmaşık bir şekilde ilişkilidir. Ekonomik aktivite, talep artışına yol açabilir ve arz bu talebe ayak uyduramazsa fiyatlar artabilir. Yılmaz'ın (2023) ABD'deki enflasyon üzerine yaptığı araştırma, özellikle talep genişlemesi bağlamında ekonomik aktivitenin enflasyonu etkileyen önemli bir faktör olduğunu göstermektedir.

Sonuç olarak literatür incelendiğinde, enflasyonun, para arzı, faiz oranı, döviz kurları ve ekonomik aktiviteden etkilendiği görülmektedir. Bu çalışmada 1994:01-2024:06 dönemi için aylık frekansta tüketici fiyat endeksi (2015=100), belirleyicileri olarak sanayi üretim endeksi (2015=100) (ekonomik aktivite göstergesi olarak), döviz kuru ve faiz oranı (TCMB gecelik borç verme faiz oranı) verileri kullanılmıştır. Veriler, Türkiye Cumhuriyet Merkez Bankası (TCMB) Elektronik Veri Dağıtım Sistemi'nden alınmıştır. Sanayi üretim endeksi (2015=100), Tramo-Seats yöntemi kullanılarak mevsimsellikten arındırılmıştır. Döviz kuru verileri, 1999 öncesinde ABD doları ve Alman markı, 1999 sonrasında ise dolar ve avro üzerinden oluşturulmuştur. 1999 sonrası dönem için, avro ve dolar kurlarının Türk lirası karşılıklarının ortalaması alınarak hesaplanırken, 1994-1999 dönemi için avro ile Alman mark (DM) arasındaki resmi dönüşüm oranı kullanılarak (döviz kuru 0.5 USD + 0.974027 DM şeklinde) hesaplanmıştır (Berument vd., 2014).

Çalışmanın literatüre önemli katkısı kriz dönemlerinin öngörüsünde XGBoost yönteminin başarısının tespit edilmesi olduğu için 1990-2024 arası Türkiye'de gerçekleşen kriz dönemlerinin belirlenmesi gerekmektedir. Bu kriz dönemleri, 1994 ekonomik krizi, 2001 finansal krizi, 2008 küresel finansal krizi ve 2018 döviz krizi olarak belirlenmiştir. Ayrıca 2021 yılının başından itibaren TCMB tarafından başlanan faiz indirimlerinden sonra oluşan yüksek enflasyon dönemi de ele alınmıştır. Grafik 1'de 1990-2024 arasında aylık enflasyonun değişimi ve seçili kriz dönemleri verilmiştir.



Grafik 1. Tarihsel Enflasyon Verileri ve Seçili Dönemler

Grafik 1'de kırmızı ile gösterilen bölgeler XGBoost ve ARMA modelinin performanslarının test edileceği bölgeleri göstermektedir. Ayrıca Tablo 1'de bu dönemler açıkça verilmiştir.

Tablo 1. Seçili Dönemler

Tarih	Enflasyon	Tarih	Enflasyon	Tarih	Enflasyon
01.04.1994	23.38	01.09.2001	5.89	01.12.2018	-0.4
01.05.1994	8.25	01.10.2001	6.07	01.01.2019	1.06
01.06.1994	1.96	01.01.2010	1.85	01.02.2019	0.16
01.07.1994	3.13	01.02.2010	1.45	01.03.2019	1.03
01.08.1994	2.84	01.03.2010	0.58	01.12.2021	13.58
01.09.1994	6.19	01.04.2010	0.6	01.01.2022	11.1
01.10.1994	7.26	01.05.2010	-0.36	01.02.2022	4.81
01.04.2001	10.33	01.06.2010	-0.56	01.03.2022	5.46
01.05.2001	5.05	01.07.2010	-0.48	01.04.2022	7.25
01.06.2001	3.13	01.09.2018	6.3	01.05.2022	2.98
01.07.2001	2.39	01.10.2018	2.67	01.06.2022	4.95
01.08.2001	2.94	01.11.2018	-1.44		

3.2. Metodoloji

XGBoost algoritması, 2016 yılında Chen ve Guestrin (2016) tarafından oluşturulan bir Gradient Boosting (gradyan artırma) yöntemidir. Çeşitli veri madenciliği senaryolarında ve algoritma yarışmalarında yaygın olarak kullanılmaktadır. Algoritmanın temel avantajları hassasiyet, esneklik ve eksik değerlerin otomatik olarak işlenmesidir. XGBoost algoritmasını anlamak için öncelikle gradyan artırma yöntemi açıklanmıştır.

Gradyan artırma, zayıf tahmin modellerinin bir araya getirilmesiyle oluşturulan doğrusal eklemeli bir modeldir. Nihai model F_M'yi elde etmek için süreç, *M* adımda gerçekleştirilmektedir. Her adımda yeni bir temel model $h_{m+1}(x)$ eğitilmektedir. Ardından eğitilen model, önceki modelin tahmin hatalarına dayanan artık değerleri $y - F_m$ ile optimize edilmektedir. Bu yöntem, yeni modellerin tahmin hatalarını azaltarak, topluluk modeli olan F_M 'yi güçlendirerek daha doğru bir tahmin elde edilmesine olanak sağlamaktadır (Friedman, 2001).

$$F_{m+1} = F_m + h_{m+1}(x) \tag{1}$$

Burada, asıl amaç $h_{m+1}(x) = F_{m+1} - F_m$'nin nasıl bulunacağının hesaplanmasına dönüşmektedir. Genellikle, temel model $h_{m+1}(x)$'i öğrenmek için artık değer olarak, amaç fonksiyonunun negatif gradyanı kullanılmaktadır. XGBoost, birden fazla zayıf sınıflandırıcıyı doğrusal bir şekilde güçlü bir sınıflandırıcıda birleştiren bir Gradient Boosting uygulamasıdır. XGBoost, temel sınıflandırıcılar olarak hem sınıflama ve regresyon ağaçları (CART) hem de doğrusal sınıflandırıcıları desteklemektedir. Maliyet fonksiyonu üzerinde ikinci dereceden Taylor genişletmesi gerçekleştirerek daha bol bilgi ifade etmektedir. Çalışma hızı açısından, XGBoost bölünme noktalarının paralel seçimini desteklemektedir. Bu sayede model eğitimi çok daha az zamana mal olmaktadır. XGBoost'un ana fikri, farklı ağırlıklara sahip zayıf ağaçları sürekli olarak kümeye eklemektir. Kümedeki ağaçlar bir önceki tahminin artıklarına mümkün olduğunca yaklaşmalıdır, bu da (2) numaralı eşitlikteki gibi ifade edilmektedir:

$$\hat{y}_i = \sum_{k=1}^{K} f_k(x_i) \qquad f_k \in F \tag{2}$$

Burada $\hat{y}_i$ tahmin edilen değer, F tüm regresyon ağaçlarını içeren küme, f_k regresyon ağaçlarından biri ve K regresyon ağacı sayısıdır. Tahmin edilen değer $\hat{y}_i$'nin gerçek değer y_i'ye mümkün olduğunca yakın olması ve bu arada genelleme yeteneğini kaybetmemesi

beklenmektedir. Amaç fonksiyonu (*Obj)*'yi hesaplamak için kullanılan formül (3) numaralı eşitlikte verilmiştir:

$$Obj^{(t)} = \sum_{i=1}^{n} l\left(y_i, \hat{y}_i^{(t)}\right) + \sum_{i=1}^{t} \Omega(f_t) + \text{ sabit} \tag{3}$$

Burada, $l\left(y_i, \hat{y}_i^{(t)}\right)$ tahmin edilen değer ile gerçek değer arasındaki farkı temsil eden kayıp fonksiyonudur. İkinci dereceden türetilebilen herhangi bir kayıp fonksiyonu olabilir. $\Omega(f_t)$, modelin karmaşıklığını tanımlayan düzenlileştirme terimidir. $\Omega(f_t)$ değeri ne kadar küçük olursa, karmaşıklık o kadar düşük ve genelleme yeteneği o kadar güçlü olmaktadır.

$$\Omega(f) = \gamma T + \frac{1}{2}\lambda \parallel w \parallel^2 \tag{4}$$

Burada T yaprak düğümlerinin sayısı ve W yaprak düğümleri tarafından temsil edilen skordur. XGBoost yöntemi, gradyan artırma sürecinde kayıp fonksiyonunu genişletmek için ikinci dereceden Taylor açılımını kullanmaktadır. Nihai amaç fonksiyonu (5)-(12) numaraları denklemlerde verilmiştir:

$$Obj^{(t)} \simeq \sum_{i=1}^{n} \left[g_i f_t(x_i) + \frac{1}{2} h_i f_t^2(x_i)\right] + \Omega(f_t) \tag{5}$$

$$= \sum_{i=1}^{n} \left[g_i w_{q(x_i)} + \frac{1}{2} h_i w_{q(x_i)}^2\right] + \gamma T + \lambda \frac{1}{2} \sum_{j=1}^{T} w_j^2 \tag{6}$$

$$= \sum_{j=1}^{T} \left[\left(\sum_{i \in I_j} g_i\right) w_j + \frac{1}{2}\left(\sum_{i \in I_j} h_i + \lambda\right) w_j^2\right] + \gamma T \tag{7}$$

$$g_i = \partial_{\hat{y}^{(t-1)}} l\left(y_i, \hat{y}_i^{(t-1)}\right), h_i = \partial^2_{\hat{y}^{(t-1)}} l\left(y_i, \hat{y}_i^{(t-1)}\right) \tag{8}$$

$$Obj^{(t)} \simeq \sum_{i=1}^{n} \left[g_i f_t(x_i) + \frac{1}{2} h_i f_t^2(x_i)\right] + \Omega(f_t) \tag{9}$$

$$= \sum_{i=1}^{n} \left[g_i w_{q(x_i)} + \frac{1}{2} h_i w_{q(x_i)}^2\right] + \gamma T + \lambda \frac{1}{2} \sum_{j=1}^{T} w_j^2 \tag{10}$$

$$= \sum_{j=1}^{T} \left[\left(\sum_{i \in I_j} g_i\right) w_j + \frac{1}{2}\left(\sum_{i \in I_j} h_i + \lambda\right) w_j^2\right] + \gamma T \tag{11}$$

$$g_i = \partial_{\hat{y}^{(t-1)}} l\left(y_i, \hat{y}_i^{(t-1)}\right), h_i = \partial^2_{\hat{y}^{(t-1)}} l\left(y_i, \hat{y}_i^{(t-1)}\right) \tag{12}$$

Burada g_i ve h_i hata fonksiyonundaki her bir veri noktasının birinci dereceden türevi ve ikinci dereceden türevidir ve I_j her bir j yaprak düğümündeki örneklerin indeks kümesidir.

$$I_j = \{i \mid q(x_i) = j\} \tag{13}$$

Verilen $q(x_i)$ için w_j'nin türevini 0'a eşit alarak j yaprak düğümünün en iyi ağırlığı w_j^* elde edilebilir.

$$w_j^* = -\frac{\sum_{i\in I_j} g_i}{\sum_{i\in I_j} h_i + \lambda} \tag{14}$$

Optimum değer (15) numaralı eşitlikte hesaplanmaktadır:

$$\tilde{L}^{(t)}(q) = -\frac{1}{2}\sum_{j=1}^{T} \frac{\left(\sum_{i\in I_R} g_i\right)^2}{\sum_{i\in I_R} h_i + \lambda} - \frac{(\sum_{i\in I} g_i)^2}{\sum_{i\in I} h_i + \lambda} - \gamma \tag{15}$$

4. Bulgular

Öngörü çalışmalarında tahmin edilen modelin aşırı öğrenme (overfitting) yapmaması için genellikle veri setleri öğrenme ve test verisi olarak iki parçaya ayrılır. Bu çalışmada tüm veri setinin %75'i (310 gözlem) model tahmini için, kalan %25'i (103 gözlem) ise tahmin edilen modelin uyumu için test verisi olarak kullanılmaktadır. 1990:02- 2015:11 arası eğitim veri seti, 2015:12 - 2024:06 arası ise test veri setidir. Bununla birlikte çalışmada XGBoost yönteminin kriz dönemlerindeki başarısını belirlemek amacıyla farklı alt dönemler ele alınmıştır. Bu alt dönemler Tablo 2'de verilmiştir. Öngörü performansının değerlendirilmesinde literatürde farklı ölçütler kullanılmaktadır. Ortalama Hatanın Karekökü (RMSE) yaygın ancak ölçeğe bağlı bir ölçüttür ancak farklı değişkenlere veya frekanslara sahip modelleri karşılaştırmak için uygun değildir. Bu çalışmada, farklı veri kümeleri için daha iyi olan Simetrik Ortalama Mutlak Yüzde Hata (sMAPE) ve Ortalama Mutlak Ölçekli Hata (MASE) ölçütleri kullanılmıştır. sMAPE, ölçekten bağımsızlığı ve yorumlanabilirliği nedeniyle sıklıkla kullanılırken, MASE, sMAPE kullanımından kaynaklanan potansiyel sorunları azaltmaktadır. İlgili formüller denklem (16) ve (17)'de yer almaktadır.

$$\text{SMAPE} = \frac{2}{h}\sum_{t=1}^{h} \frac{2\left|Y_t - \hat{Y}_t\right|}{|Y_t| + \left|\hat{Y}_t\right|} \times 100 \tag{16}$$

$$MASE = \frac{1}{g}\frac{\sum_{t=1}^{h} \left|Y_t - \hat{Y}_t\right|}{\frac{1}{n-m}\sum_{t=m+1}^{n} |Y_t - Y_{t-m}|} \tag{17}$$

Burada, g dönem dışı tahminlerin miktarını, m veri sıklığını ve n toplam gözlem sayısını ifade etmektedir. Çok sayıda araştırmacı, sadece sMAPE ve MASE kullanmak yerine Göreceli MASE (RelMASE) ve Göreceli sMAPE (RelMAPE) gibi 'göreceli' ölçütlerin kullanılmasını tavsiye etmiştir (Ahlburg, 1992; Fildes, 1992; Hyndman ve Koehler, 2006). Literatürde performans ölçütü olarak genellikle rastgele yürüyüş süreci kullanılmaktadır (Pesaran vd., 2009; Makridakis vd., 2020). Performans ölçütü olarak Rastgele Yürüyüş Modeli seçildikten sonra göreli ölçütler, $RelsMAPE = sMAPE/sMAPE_{RW}$ ve $RelMASE = MASE/MASE_{RW}$ formülüyle hesaplanmaktadır. Göreceli metriklerin hesaplanmasının ardından ağırlıklı ortalama alınarak Genel Ağırlıklı Ortalama (OWA) kriteri elde edilmektedir.

Çalışmanın temel amacı XGBoost yönteminin enflasyon öngörüsündeki performansını incelemektir. XGBoost yöntemi, temelinde bir karar ağaçları algoritması kullanarak, enflasyon öngörüsünde etkin bir yöntem olarak uygulanmıştır. Bu çalışmada, para arzı (M2), sanayi üretim endeksi (2015=100), döviz kuru ve faiz oranı gibi makroekonomik göstergeler, modelin girdi değişkenleri olarak entegre edilmiştir. XGBoost, bu değişkenler arasında karmaşık ilişkileri

öğrenip, her bir karar ağacını sırayla oluşturarak hataları minimize etmek amacıyla modellemeyi optimize etmektedir. Her yeni karar ağacı, önceki ağaçların hatalarını düzeltmek için eğitilmiş ve modelin doğruluğu bu şekilde arttırılmıştır. Bununla birlikte XGBoost yönteminin başarısını karşılaştırmak amacıyla ARMA modeli kullanılmıştır. ARMA modelleri zaman serileri analizinde kullanılan en temel modellerden birisidir. Enflasyon için en uygun model ARMA(1,1) çıkmıştır. Son olarak XGBoost yöntemine farklı bir bakış açısı ile ARMA modelinden gelen 1 gecikme bilgisi eklenmiştir. Diğer bir ifadeyle girdi değişkenleri olarak sanayi üretim endeksi (2015=100), döviz kuru, para arzı (M2) ve faiz oranının anlık değerlerine ek olarak bunların ve enflasyonun 1 gecikmeli değerleri de model dahil edilmiştir. Bu model XGBoost (Gecikmeli) olarak adlandırılmıştır. Tablo 2'de farklı dönemler için bahsedilen modellerin öngörü performanslarına ilişkin sonuçlar verilmiştir. Faiz hariç tüm değişkenlerin logaritmik farkı kullanılmıştır. Faiz serisinin ise yalnızca farkı alınmıştır.

Tablo 2. Farklı Dönemler İçin Modellerin Öngörü Performanslarına İlişkin Sonuçlar

Dönemler		**ARMA(1,1)**	**XGBoost**	**XGBoost Gecikmeli**	**RW**
1990:01-1994:10 (n=57)	MAPE	0.60	0.54	0.80	0.78
	RealMAPE	0.77	0.70	1.03	1.00
	sMAPE	61.15	71.65	73.67	63.73
	RealsMAPE	0.96	1.12	1.16	1.00
	OWA	0.87	0.91	1.09	1.00
	Başarı Yüzdesi	**13.30**	8.87	-9.28	0.00
1990:01-2001:10 (n=141)	MAPE	0.43	0.72	0.30	0.45
	RealMAPE	0.95	1.59	0.66	1.00
	sMAPE	38.04	51.80	26.60	61.45
	RealsMAPE	0.62	0.84	0.43	1.00
	OWA	0.79	1.22	0.55	1.00
	Başarı Yüzdesi	21.47	-21.78	**45.31**	0.00
1990:01-2010:07 (n=246)	MAPE	3.82	2.11	1.64	2.10
	RealMAPE	1.82	1.00	0.78	1.00
	sMAPE	125.87	121.39	126.23	164.05
	RealsMAPE	0.77	0.74	0.77	1.00
	OWA	1.29	0.87	0.78	1.00
	Başarı Yüzdesi	-29.49	12.79	**22.31**	0.00
1990:01-2019:03 (n=350)	MAPE	2.38	1.53	1.42	3.59
	RealMAPE	0.66	0.43	0.40	1.00
	sMAPE	127.98	96.51	111.76	133.86
	RealsMAPE	0.96	0.72	0.83	1.00
	OWA	0.81	0.57	0.62	1.00
	Başarı Yüzdesi	19.06	**42.59**	**38.49**	0.00
1990:01-2022:06 (n=389)	MAPE	0.39	0.72	0.43	0.66
	RealMAPE	0.60	1.10	0.66	1.00
	sMAPE	94.65	121.16	43.90	98.97
	RealsMAPE	0.96	1.22	0.44	1.00
	OWA	0.78	1.16	0.55	1.00
	Başarı Yüzdesi	22.24	-16.00	**45.07**	0.00
1990:01-2024:06 (Tüm veri dönemi n=413)	MAPE	2.13	3.59	2.25	2.02
	RealMAPE	1.06	1.78	1.12	1.00
	sMAPE	70.57	78.86	60.95	120.93
	RealsMAPE	0.58	0.65	0.50	1.00
	OWA	0.82	1.22	0.81	1.00
	Başarı Yüzdesi	17.94	-21.76	**18.97**	0.00

Tablo 2 incelendiğinde, 1990:01-1994:10 döneminde ARMA(1,1) yöntemi %13.3 başarı oranıyla en yüksek performansı gösterirken, XGBoost %8.87 ile onun gerisinde kalmıştır. Gecikmeli XGBoost ise negatif bir başarı oranıyla (-%9.28) en düşük performansı sergilemiştir. Bu bulgu, Stock ve Watson (2007) tarafından basit tek değişkenli modellerin, bazı dönemlerde çok değişkenli modellere kıyasla daha yüksek doğruluk sağlayabileceği bulgularıyla uyumludur. XGBoost'un performans düşüklüğü, sınırlı veri gözlemlerine sahip bu dönemde karmaşık yapısının etkin çalışamamasından kaynaklanmış olabilir. 1990:01- 2001:10 döneminde ise Gecikmeli XGBoost %45.31 ile açık ara en başarılı yöntem olmuştur. ARMA(1,1) %21.47 ile daha makul bir başarı gösterirken, XGBoost negatif bir başarı oranıyla (-%21.78) en kötü performansı göstermiştir. 1990:01- 2010:07 döneminde, Gecikmeli XGBoost %22.31 ile yine en başarılı yöntem olurken, XGBoost %12.79 ile ortalama bir başarı göstermiştir. ARMA(1,1) ise bu dönemde negatif bir başarı oranı (-%29.49) ile en düşük performansı sergilemiştir. 1990:01-2019:03 dönemine bakıldığında, XGBoost %42.59 başarı oranıyla en yüksek performansa sahiptir. Ancak, Gecikmeli XGBoost %38.49 ile ona çok yakın bir başarı göstermiştir. ARMA(1,1) ise %19.06 başarı oranıyla daha düşük bir performans sergilemiştir. 1990:01-2022:06 döneminde yine Gecikmeli XGBoost %45.07 ile en yüksek başarı oranına sahipken, ARMA(1,1) %22.24 ile orta seviyede bir başarı göstermiştir. XGBoost ise -%16 başarı oranıyla en düşük performansı göstermiştir. Tüm veri dönemi olan 1990:01- 2024:06 döneminde Gecikmeli XGBoost %18.97 başarı oranı ile en başarılı yöntem olmuştur. ARMA(1,1) %17.94 ile çok yakın bir performans göstermiştir. Ancak XGBoost yine negatif bir başarı oranı (-%21.76) ile en düşük performansı göstermiştir. Gecikmeli XGBoost'un üstün performansı, özellikle büyük veri setlerinde ve kriz dönemlerinde zaman serisi içindeki içsel bağımlılıkları yakalama kabiliyetinden kaynaklanmaktadır. Bu bulgu, Koop (2013) ve Faust ve Wright (2013) çalışmalarında ileri sürülen, doğrusal olmayan modellerin daha karmaşık veri setlerinde daha başarılı sonuçlar verdiği bulgularıyla uyumludur. Ayrıca Nakamura (2005) ve McAdam ve McNelis (2005) çalışmaları, doğrusal olmayan modellerin doğrusal modellere kıyasla daha iyi sonuçlar verdiğini gösterirken, Özgür ve Akkoç (2022) çalışmasında, yüksek oynaklık dönemlerinde makine öğrenimi modellerinin üstün performans gösterdiğini belirtmiştir.

Kriz dönemlerinde genel olarak Gecikmeli XGBoost, özellikle uzun veri dönemine sahip kriz dönemlerinde (%45.31 ile 1990:01- 2001:10 ve %45.07 ile 1990:01- 2022:06) en yüksek başarı oranlarına ulaşarak oldukça başarılı sonuçlar vermiştir. XGBoost ise bazı dönemlerde (%42.59 ile 1990:01- 2019:03) başarılı olsa da, diğer dönemlerde düşük ve hatta negatif başarı oranları ile etkisiz kalmıştır. Bu nedenle kriz dönemlerinde Gecikmeli XGBoost yöntemi, genel olarak daha istikrarlı ve başarılı bir öngörü aracı olarak öne çıkmaktadır. Bu bulgu, Ogunc vd. (2013) çalışmasındaki tahmin modellerinin kriz dönemlerinde daha iyi sonuçlar verdiği bulgularıyla uyumlu görünmektedir. Ancak, yalnızca 1990:01-1994:10 döneminde ARMA modelinin performansı XGBoost ve Gecikmeli XGBoost'a göre daha iyi çıkmıştır. XGBoost, büyük ve karmaşık veri setleri üzerinde güçlü performans gösteren bir makine öğrenme algoritmasıdır. Ancak, bu dönemde kullanılan gözlem sayısının sınırlı olması, XGBoost'un potansiyel performansını ortaya koymasını zorlaştırmıştır. Ivaşcu (2023) verinin az olduğu ortamlarda makine öğrenmesi algoritmalarının basit otoregresif modelleri geçemediğini belirtmiştir. Nitekim genel olarak elde edilen sonuçlar bu bulguyla paralellik göstermektedir.

5. Sonuç

Bu çalışma, 1990-2024 tarihleri arasında Türkiye'deki enflasyon öngörüsünde XGBoost ve ARMA modellerinin performansını karşılaştırarak, kriz dönemlerinde bu yöntemlerin etkinliğini değerlendirmeyi amaçlamaktadır. Özellikle Türkiye'nin yaşadığı ekonomik kriz ve şok dönemlerinde (1994 krizi, 2001 finansal krizi, 2008 küresel finansal kriz, 2018 döviz krizi) her iki yöntemin tahmin doğruluğu incelenmiştir. Çalışmada XGBoost, karar ağaçları algoritmasına dayalı bir makine öğrenme yöntemi olarak, sanayi üretim endeksi, döviz kuru, para arzı (M2) ve faiz oranı gibi makroekonomik göstergeleri kullanarak enflasyon öngörüsünde uygulanmıştır. Ayrıca, gecikmeli verilerin modele dahil edildiği "Gecikmeli XGBoost" yöntemi de performans değerlendirmelerine eklenmiştir.

Bulgular, Gecikmeli XGBoost yönteminin gözlem sayısının fazla olduğu kriz dönemlerinde yüksek başarı oranları ile öne çıktığını göstermektedir. Özellikle 1990:01- 2001:10 ve 1990:01 - 2022:06 dönemlerinde Gecikmeli XGBoost, diğer yöntemlere kıyasla daha yüksek doğrulukta sonuçlar üretmiştir. Bununla birlikte, az sayıda gözleme sahip 1990:01 -1994:10 döneminde ARMA modeli, XGBoost ve Gecikmeli XGBoost’a göre daha iyi performans sergilemiştir. Bu durum, XGBoost’un küçük veri setlerinde potansiyel performansını tam olarak ortaya koyamadığını, ancak büyük veri setleri üzerinde daha etkin olduğunu işaret etmektedir. Ayrıca, çalışmada Gecikmeli XGBoost modelinin XGBoost’tan daha iyi performans göstermesi, enflasyon öngörüsünde gecikmeli değerlerin eklenmesinin önemli olduğunu ortaya koymaktadır. ARMA modelinden elde edilen gecikme bilgisinin XGBoost’a dahil edilmesi, XGBoost’un performansını önemli ölçüde artırmıştır. Bu bulgu, enflasyon tahminlerinde XGBoost yöntemi kullanılmasında sadece bağımsız değişkenlerin anlık değerlerinin değil, aynı zamanda gecikmeli değerlerinin de önemli bir açıklayıcı unsur olduğunu vurgulamaktadır. Gecikmeli XGBoost modelinin bu kadar başarılı olmasının nedeni, zaman serisi verilerindeki bu içsel bağımlılıkların dikkate alınmasıdır.

Genel olarak, çalışmada kriz dönemlerinde doğru enflasyon öngörüsü yapılabilmesi için kullanılan modelin veri seti büyüklüğü ve yapısına duyarlılığını göstermektedir. Gecikmeli XGBoost, uzun vadeli ve büyük veri setlerinde üstün performans sergilerken, ARMA modeli daha sınırlı veri setlerinde öne çıkmaktadır. Bu bulgular, gelecekte yapılacak enflasyon tahmin çalışmalarında model seçiminde dikkat edilmesi gereken noktalar üzerine önemli ipuçları sunmaktadır. Özellikle, zaman serisi dinamiklerinin dikkate alındığı modellerin daha güvenilir tahminler sunduğu, bu çalışmayla ortaya koyulmuştur. Elde edilen bulgular ışığında, enflasyon öngörülerinin daha etkin yapılabilmesi için politika yapıcıların kriz ve şok dönemlerinde makine öğrenmesi tekniklerinden faydalanmaları önerilmektedir. Özellikle Gecikmeli XGBoost gibi zaman serisi dinamiklerini dikkate alan modellerin, merkez bankaları ve ekonomik karar alıcılar tarafından enflasyon öngörüsü ve para politikalarının şekillendirilmesinde kullanılmasının, ekonomik istikrarı sağlama noktasında faydalı olacağı düşünülmektedir.

Araştırmacıların Katkı Oranı Beyanı
Yazarlar makaleye eşit oranda katkı sağlamış olduklarını beyan eder.

Araştırma ve Yayın Etiği Beyanı
Etik kurul izni ve/veya yasal/özel izin alınmasına gerek olmayan bu çalışmada araştırma ve yayın etiğine uyulmuştur.

Araştırmacıların Çıkar Çatışması Beyanı
Bu çalışmada herhangi bir potansiyel çıkar çatışması bulunmamaktadır.

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INFLATION FORECASTING IN THE CONTEXT OF ECONOMIC SHOCKS AND CRISES IN TÜRKİYE: COMPARISON OF XGBOOST AND ARMA METHODS

EXTENDED SUMMARY

Objective

This study examines the performance of XGBoost, a machine learning algorithm, and the traditional ARMA (AutoRegressive Moving Average) model in forecasting inflation in Türkiye during periods of economic shocks and crises. Given Türkiye’s frequent exposure to economic crises (e.g., the 1994 economic crisis, the 2001 financial crisis, the 2008 global financial crisis, and the 2018 currency crisis), accurate inflation forecasting is critical for economic stability and policy formulation.

Literature Review

Existing literature extensively covers the use of traditional econometric models like ARMA and advanced machine learning techniques such as XGBoost for inflation forecasting. Time-series models, especially ARMA, have been widely used for forecasting macroeconomic indicators due to their ability to model linear patterns. However, recent studies show that machine learning models, particularly XGBoost, offer superior predictive capabilities in complex datasets, especially for nonlinear relationships. Furthermore, hybrid models combining machine learning algorithms with traditional methods are increasingly being employed to enhance forecasting accuracy during volatile periods (Akbulut, 2022; Aras and Lisboa, 2022).

Methodology

The dataset spans the period from January 1990 to June 2024. It includes macroeconomic indicators such as the Consumer Price Index (CPI), exchange rates, money supply (M2), and interest rates, all used as explanatory variables. The XGBoost model was applied to forecast inflation, using these variables as input. Additionally, a variant of the XGBoost model with lagged variables ("Lagged XGBoost") was implemented to assess its predictive strength. As a traditional econometric approach, the ARMA model was also applied for comparison. The study focuses on crisis periods and the entire sample period to evaluate model performance across different time horizons.

Findings

The results indicate that XGBoost outperforms ARMA during crisis periods, particularly when the dataset is large. Including lagged variables in the XGBoost model further improves predictive accuracy, demonstrating that the inflation forecast benefits significantly from incorporating time-series dynamics. For example, between 1990-2001 and 1990-2022, Lagged XGBoost showed superior forecasting accuracy compared to ARMA and the standard XGBoost

model. However, ARMA proved more effective in shorter time spans or when the dataset is smaller, suggesting that XGBoost's potential is best realized with larger, more complex datasets.

Conclusion

This study demonstrates that XGBoost, particularly when augmented with lagged variables, is highly effective in forecasting inflation during periods of economic volatility in Türkiye. However, traditional models like ARMA remain relevant for smaller datasets and shorter forecasting horizons. These findings highlight the importance of considering both traditional econometric models and modern machine learning techniques for inflation forecasting, particularly in economies like Türkiye, which experience frequent economic shocks.

Policy Implications

From a policy perspective, it is recommended that decision-makers, including central banks, utilize machine learning models like XGBoost, especially during periods of economic uncertainty. Given their ability to capture complex patterns and dynamics, these models can support more accurate inflation forecasts, thus aiding in formulating more effective monetary policies. Policymakers should also consider hybrid models that integrate traditional time-series features to improve the robustness of economic forecasts.

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DİJİTALLEŞME VE DOĞAL KAYNAK LANETİ YAKLAŞIMI İLİŞKİSİ: OAPEC ÜLKELERİ*

The Relationship Between Digitalization and The Natural Resource Curse Approach: OAPEC Countries

Sena BAŞAR** & **Nurgün TOPALLI*****

Öz

Günümüzde dijitalleşmenin yaşam kalitesini artırarak toplumların refahını yükselttiği kabul edilmektedir. Ancak dijitalleşme ve kalkınma ilişkisinin tüm ülkeler için benzer olup olmadığı tartışılmaktadır. Özellikle doğal kaynak bakımından zengin olan ülkeler açısından doğal kaynak lanetinin geçerli olup olmadığı, dijitalleşme ve kalkınma kapsamında, önemini korumaktadır. Çalışmada ülkeler ikiye ayrılarak incelenmiştir. Grup 1 ülkeleri Katar, Suudi Arabistan, Kuveyt, Bahreyn ve Birleşik Arap Emirlikleri'nden oluşmaktadır. Bu ülkeler petrol açısından göreceli zengin ülkelerdir. Grup 2 ülkeleri arasında ise yüksek kalkınma oranlarına sahip Norveç, Güney Kore, Japonya, İsviçre, Amerika Birleşik Devletleri ve Almanya yer almaktadır. Çalışmada ilgili ülkelerin 2000-2021 dönemi için dijitalleşme ve kalkınma ilişkisi Konya (2006) nedensellik testi kullanılarak analiz edilmiştir. Çalışma sonucunda dijitalleşme ve kalkınma arasında tespit edilen nedensellik ilişkisinin Grup 1 ülkelerinde Grup 2 ülkelerine göre göreceli olarak düşük düzeyde olduğu sonucuna ulaşılmıştır. Doğal kaynak bakımından zengin olan Grup 1 ülkelerinde doğal kaynak laneti yaklaşımı geçerli iken dijitalleşme sürecinden kalkınmış ülkelerin daha çok olumlu etkilendiği tespit edilmiştir.

Anahtar Kelimeler: Dijitaleşme, Kalkınma, OAPEC Ülkeleri, Konya (2006) Nedensellik.

JEL Kodları: O33, 011, 057, C23.

Abstract

Today, it is accepted that digitalization increases the welfare of societies by improving the quality of life. However, it is debated whether the relationship between digitalization and development is similar for all countries. Whether the natural resource curse is valid, especially for countries rich in natural resources, remains important within the scope of digitalization and development. In the study, countries were divided into two groups. Group 1 countries include Qatar, Saudi Arabia, Kuwait, Bahrain, and the United Arab Emirates. These countries are relatively rich in terms of oil. Group 2 countries include Norway, South Korea, Japan, Switzerland, the United States, and Germany, which have high development rates. In the study, the relationship between digitalization and development of the relevant countries for the period 2000-2021 was analyzed using the Konya (2006) causality test. As a result of the study, it was concluded that the causality relationship between digitalization and development was at a relatively lower level in Group 1 countries than in Group 2 countries. While the natural resource curse approach is valid in Group 1 countries, which are rich in natural resources, it has been determined that developed countries are more positively affected by the digitalization process.

Keywords: Digitalization, Development, OAPEC Countries, Konya (2006) Causality

JEL Codes: O33, 011, 057, C23.

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** Yüksek Lisans Mezunu, Nevşehir Hacı Bektaş Veli Üniversitesi, Sosyal Bilimler Enstitüsü, İktisat Anabilim Dalı, Türkiye, shbasar8688@gmail.com

*** Prof, Dr., Nevşehir Hacı Bektaş Veli Üniversitesi, İİBF, Uluslararası Ticaret ve Lojistik Bölümü, Türkiye, nurguntopalli@nevsehir.edu.tr

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1. Giriş

Bilgi ve bilgi teknolojilerinde yaşanan gelişmeler ekonomileri ve toplumları etkilemekte ve değiştirmektedir. Toplumlar ilkel toplumdan tarım toplumuna, tarım toplumundan sanayi toplumuna doğru bir dönüşüm yaşamışlardır. Günümüzdeki toplum bilgi toplumu, ekonomi ise bilgi ekonomisi olarak adlandırılmaktadır (Ünal, 2009). Bilgi ekonomisinin temel özelliği temel üretim faktörü olarak toprağın ve sermayenin yerini bilginin almasıdır (Altay Topçu, 2021). Bilgi ekonomisinde ekonomilerin rekabetçi bir yapıya kavuşabilmesi ve rekabetçiliklerini sürdürebilmesinde hız, esneklik, yenilik, çeşitlilik, dijitalleşme anahtar kavramlar haline gelmiştir. Bu ekonomide bilgi ve iletişim teknolojilerinde yaşanan hızlı gelişim üretim yapısını, tüketim yapısını, hizmet yapısını, istihdam yapısını ve sosyal yaşamı etkilemektedir (UNCTAD, 2021; Mahmood, 2023). Dijitalleşmenin ekonomi üzerindeki önemli bir etkisinin verimliliği yükseltmesi ve maliyetleri azaltması sonucu ekonomik büyümeyi artıracağı yönündedir (Kurt, 2020; Khan vd., 2015; Yılmaz, 2021). Dijital teknolojilerin kullanımı ile birlikte bireysel tüketici zevk ve tercihlerine yönelik üretim gerçekleştirilebilmektedir. Tüketici çok sayıda ve çeşitli kalitede mal ve hizmetlere uygun fiyatla ulaşabilmektedir. İnternet ortamında daha hızlı bir şekilde gerçekleşen işlemler hem üretici hem de tüketici açısından zaman tasarrufu sağlamaktadır (Erbay vd., 2018). Dijitalleşmenin sağladı kolaylıklar insanların yaşam kalitesini iyileştirmektedir **(**Davutoğlu, 2020; Küçükvardar ve Aslan, 2021). Yaşam kalitesindeki yükselme ise ekonomik kalkınma ile yakından ilişkilidir.

Ülkelerin ekonomik kalkınmalarında sahip oldukları üretim faktörlerinin niceliği ve niteliği etkili olmaktadır. Üretim sürecinde emek ve sermaye kadar doğal kaynak faktörü de önemini korumaktadır. Çünkü doğal kaynak zenginliği ekonomiyi doğrudan ve dolaylı olarak etkilemektedir. Ancak doğal kaynakların ekonomi üzerinde olumlu etkileri olduğu gibi bazı durumlarda zengin doğal kaynağa sahip olmak ülkeler açısından dezavantajlar oluşturabilmektedir. Zengin doğal kaynağa sahip ülkelerde sermaye birikiminin diğer sektörlere kanalize edilememesi toplumun sosyo-ekonomik açıdan gerilemesine neden olabilmektedir (Ross, 2015; Kartal, 2022). Bu durum literatürde "doğal kaynak laneti" kavramı ile açıklanmaktadır (Şahin, 2021). Zengin doğal kaynaklara sahip olmanın ülke refahını ve zenginliğini artırıp artırmadığı konusu günümüzde tartışılan bir konudur. Literatürde dijitalleşme konusu ile ilgili yapılan çalışmaların büyük bir bölümünde dijitalleşme ve ekonomik büyüme ilişkisi incelenmiştir. Dijitalleşme ve ekonomik kalkınma ilişkisinin incelendiği çalışma ise sınırlı sayıdadır (Torun vd., 2009; David, 2019; Zhang vd., 2021). Bu çalışmanın ilk amacı seçilmiş ülke örneklerini dikkate alarak dijitalleşme ve kalkınma ilişkisini test etmektir. Bu çalışmanın ikinci amacı ise zengin doğal kaynağa (petrol kaynakları) sahip olmanın dijitalleşme ve kalkınma üzerinde etkili olup olmadığının incelenmesidir. Doğal kaynak laneti yaklaşımı dijitalleşme ve kalkınma ilişkisi kapsamında ele alınarak literatüre katkı sağlamak amaçlanmıştır.

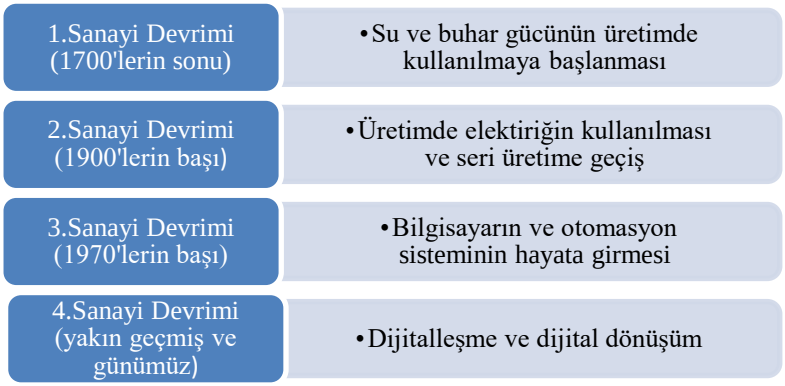
Çalışma yeni bölümden oluşmaktadır. İkinci bölümde dijitalleşme ve kalkınma ile ilgili kavramsal çerçeveye yer verilmiştir. Üçüncü bölümde kalkınmasız büyüme, doğal kaynak laneti ve ampirik literatür özetlenmiştir. Dördüncü bölüm veri ve yöntem, beşinci bölüm bulgulardan oluşmaktadır. Politika tartışmalarının yer aldığı altıncı bölümü takiben sonuç bölümünde elde edilen bulgular kapsamında genel bir değerlendirme yapılmıştır. Çalışmada ekonomik kalkınma göstergesi olarak insani gelişme endeksi, dijitalleşme göstergesi olarak sabit telefon abonelikleri (100 kişi başına), mobil hücresel abonelikler (100 kişi başına), internet kullanan bireyler (nüfusun %), sabit geniş bant abonelikleri (100 kişi başına) değişkenleri kullanılmıştır. Ülkeler iki gruba ayrılarak analiz edilmiştir. Grup 1 ülkeleri Katar, Suudi Arabistan, Kuveyt, Bahreyn Birleşik,

Arap Emirlikleri'nden oluşmaktadır. Bu ülkeler Petrol İhraç Eden Arap Ülkeleri Örgütüne (OAPEC) üye olan 11 ülkeden 5'idir. Bu ülkeler doğal kaynak bakımından zengin olup kalkınma düzeyi göreceli olarak Grup 2 ülkelerine göre düşük olan ülkeleri içermektedir. Grup 2 ülkeleri Norveç, Güney Kore, Japonya, İsviçre, Amerika Birleşik Devletleri (ABD), Almanya'yı içermektedir. Bu ülkeler kalkınma düzeyi bakımından yüksek olan ülkelerdir. Norveç ve ABD doğal kaynak bakımından zengin ülkeler olmakla birlikte OAPEC'e üye olmadıkları ve kalkınma düzeyleri Grup 1 ülkelerine göre daha yüksek olduğu için Grup 2 ülkeleri içinde ele alınmıştır. Çalışmada verilerin elde edilebilirlikleri dikkate alınarak ilgili ülkelerin 2000-2021 dönemi için değişkenler arasındaki ilişki Konya (2006) nedensellik testi kullanılarak analiz edilmiştir.

2. Dijitalleşmenin Kavramsal Çerçevesi

Teknolojide yaşanan gelişmelerin geldiği son aşama dijitalleşme kavramı ile özdeşleştirilmektedir (UNCTAD, 2021). Dijital kelimesi "sayısal", dijitalleşme "sayısallaştırma" olarak ifade edilmektedir (Bozkurt vd., 2021). Dijitalleşme bilgi ve iletişim teknolojilerinde yaşanan ileri düzey ilerleme olarak kabul edilmektedir (Alptekin, 2020). Kazan tarafından dijitalleşme "bilgisayar dili" olarak tanımlamaktadır (Kazan, 2017). Dijitalleşmenin temelini veri analitiği, yapay zekâ, nesnelerin interneti, bulut bilgi işlem gibi veriler oluşturmaktadır (UNCTAD, 2021). İnternet, dijital dönüşümün önemli bir aracı ve sonucu olmaktadır. İletişim alanında yaşanan gelişmeler, interneti yaşamın merkezi haline getirmiştir (Goldfarb vd., 2015). Dijital teknolojiler ekonomileri dönüştürerek, ekonomi ve topluma yayılarak yeni bir ekonomi oluşturmaktadır. Bu ekonominin temel özellikleri arasında akıllı, veriye dayalı ve öğrenen ekonomi yer almaktadır (Szeles ve Simionescu, 2020).

Ekonomide dijitalleşme kavramı ekonomik faaliyetlerin dijitalleşmesi olarak ifade edilmektedir. Ekonomik faaliyetlerin dijitalleşmesi geniş anlamda veri ve internetin üretim süreçlerine ve ürünlere, hane halkı ve devlet tüketim biçimlerine, sabit sermaye oluşumuna, sınır ötesi sermaye akımlarına ve finansal sisteme dâhil edilmesidir (IMF, 2018). Dijitalleşmenin önemli bir etkisi olarak insanın yaşam kalitesini artırdığı kabul edilmektedir. Özellikle dördüncü endüstri devrimi sürecinde dijitalleşme kavramı, ekonomik büyümeden daha çok ekonomik kalkınmaya doğru kaymıştır (Davutoğlu, 2020). Şekil 1'de sanayi devrimleri ve ilgili dönemlerde yaşanan gelişmelere yer verilmiştir.



Şekil 1. Sanayi Devrimleri ve Buluşlar (Şekil tarafımızca oluşturulmuştur)
Kaynak: Çalapkulu, 2021.

Dördüncü endüstri devriminin sunmuş olduğu dijital dönüşümün ve dijitalleşmenin yeni pazarlama tekniklerinde, enerji sağlamada, üretimde akıllı robot kullanma gibi tekniklerde, üretim kapasitesinde ve verimlilikte ülke ekonomisine önemli katkılar sağlayacağı ve milli geliri artıracağı beklenmektedir (Karakaya, 2021). Dördüncü sanayi devriminde dijitalleşmenin ekonomik boyutlarının yanı sıra sosyal boyutları da dikkate alınmaya başlanmıştır. Dijitalleşmenin sağlık, eğitim, çevre, enerji gibi alanlarda insan yaşam kalitesini geliştiren konular ile ilişkilendirilmesi dördüncü endüstri devriminin önemli adımlarından biridir. Diğer bir ifadeyle bu dönemde dijital dönüşüm ekonomik kalkınma için bir araç olmuştur (Sağbaş ve Gülseren, 2019).

2.1. Dijitalleşmenin Ekonomi Üzerine Etkileri

Dijital ekonomi kavramı ilk kez Negroponte'de 1995'te kullanılmıştır (Stavytskyy vd., 2019). Genel olarak dijital ekonomi, "internet üzerinden elektronik ticaret yoluyla mal ve hizmet ticaretinin sağlandığı ve yürütüldüğü ekonomi" olarak tanımlanmaktadır (OECD, 2012). Bilgi ve iletişim teknoloji temelli kaynağını dijitalleşmeden alan her türlü ekonomik faaliyet dijital ekonomi olarak kabul edilmektedir. OECD'ye (2015) göre dijital ekonomi "teknolojiyi daha ucuz ve güçlü yapan, iş süreçlerinin geliştirilmesi ve aynı zamanda ekonomideki tüm sektörlerin yeniliğini destekleyen bilgi ve iletişim teknolojisi ile gelişen değişim süreçlerinin bir sonucudur" (OECD, 2015). Dijital ekonomi kavramı yerine, "bilgi ekonomisi", "enformasyon ekonomisi", "yeni ekonomi", "ağ ekonomisi", "tekonomi", "entelektüel sermaye ekonomisi" gibi kavramlar da kullanılabilmektedir (Kevük, 2006). Dijital ekonomide emek, sermaye, doğal kaynak, müteşebbis gibi klasik üretim faktörlerinin yerini bilgi faktörü almaktadır (Altay Topçu, 2021). Dijital ekonominin özellikleri arasında küresel olması, maliyetleri azaltıcı özelliğe sahip olması, girdilerin entelektüel birikim ve beceriye dayalı olması, ağlara bağlı olması, bilginin toplumun merkezi olması, piyasaların dijitalleşmesi, alıcı ve satıcı arasındaki farkın azalması gibi unsurlar yer almaktadır (Odabaşı ve Erdal, 2018). Dijital ekonomide telekomünikasyon, yazılım ve bilgi teknolojileri, kapsamlı dijital servis, platform ekonomisi, paylaşım ekonomisi, iş ekonomisi, e-ticaret, 4. endüstri devrimi, hassas tarım, algoritmik ekonomi gibi kavramlar önem göstermektedir (Altay Topçu, 2021).

Dijitalleşmenin ekonomi üzerinde maliyetleri azaltma, toplam üretimi artırma, işsizliği düşürme, dış ticareti geliştirme, rekabet üstünlüğü sağlama gibi etkileri mevcuttur (Kurt, 2020). Üretim yöntemlerindeki gelişmeler üretimde etkinlik ve verimliliği yükselterek üretim yapan işletmelerin kârını artırmaktadır. Üretimde etkinliğinin artması ise üretim artışına yol açarak ekonomik büyümeyi sağlamaktadır. Aynı zamanda dijitalleşme mal ve hizmetlerin internet üzerinden pazarlanması ve satılması gibi imkânlar sunarak toplam üretimi artırmakta ve ekonomik büyümeyi olumlu etkilemektedir. Ülke içerisinde üretilen mal ve hizmetlerin internet sayesinde dış pazarlara açılması dış ticaret hacmini genişletmektedir (Yılmaz, 2021). Dijitalleşmenin etkileri en yoğun olarak bankacılık, finans hizmetleri, e- ticaret, e-ihracat, eğitim, sağlık, iletişim, bilgi ve veriye ulaşım gibi alanlarda gözlemlenmektedir (Dikkaya ve Aytekin, 2019; Pakdemirli, 2019). Günümüzün dijitalleşen dünyasında ülkeler arasındaki rekabet üstünlüğü, geleneksel ekonomi anlayışındaki gibi karşılaştırmalı veya mutlak üstünlüğe değil ülkelerin bilgi üretimi ve teknolojik ilerlemesine bağlı olmaktadır. Bu nedenle dijitalleşme ve dijital dönüşüm ülkelerin rekabet gücünü artırarak ekonomik büyümeyi ve kalkınmayı teşvik etmektedir (Yüksel ve Artar Kibritçi, 2022). Ekonomideki dijitalleşme düzeyi ne kadar yüksek

ise toplumdaki modernleşmenin o kadar fazla olacağı görüşü birçok kesim tarafından kabul edilmektedir. Bu nedenle ekonomik birimler çağa ayak uydurmak ve modernleşme çabası içerisinde dijitalleşme yolunda adımlar atmaktadır (Küçükvardar ve Aslan, 2021). Dijitalleşme ile tüketim alışkanlıklarında, çalışma ve iş yapılarında meydana gelen değişimler sonucu özellikle gelişmiş ülkelerde yeniliğe uyum, bir prestij kaynağı olarak görülmektedir (Baloğlu, 2023). Dijitalleşmenin hız kazanması ile birlikte sosyal ve ekonomik yaşamın kalitesinin arttığı gözlemlenmiştir. Dijital yaşamın insan yaşamına olumlu katkı sağlayabilmesi için dijitalleşme sürecine uyum sağlamak ve bireylerin yaşam kalitesini teknoloji aracılığı ile iyileştirmek önemli hale gelmiştir (Bozkurt vd., 2021).

3. Teorik ve Ampirik Literatür

3.1. Kalkınma Kavramı

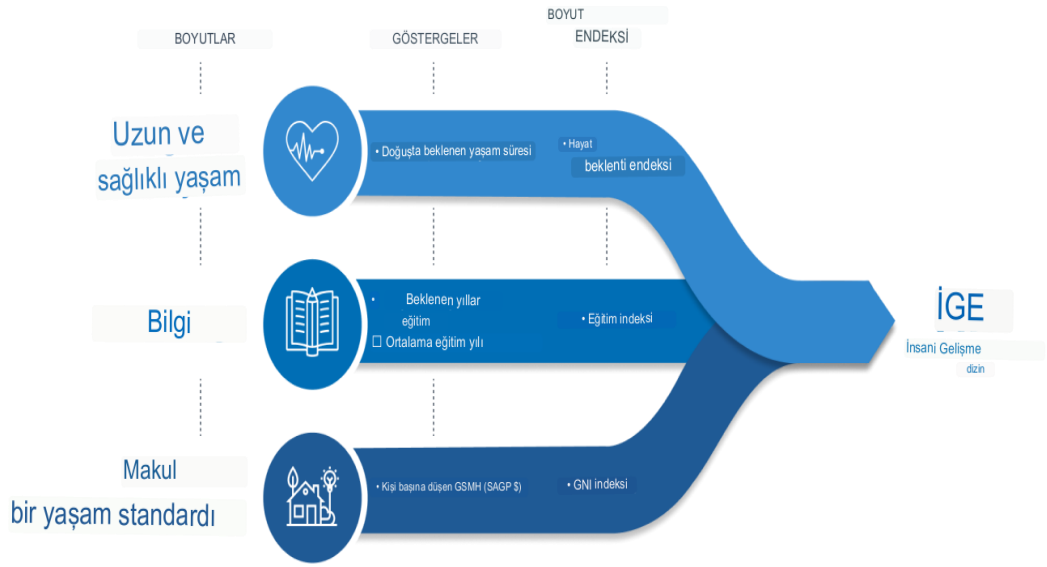
Türk Dil Kurumu'nda kalkınma kavramı "durumu düzeltmek, aşamalı bir biçimde gelişmek, ilerlemek ve zengin olmak" olarak ifade edilmektedir. Sosyal bilimciler tarafından kalkınmanın ortak bir tanımında uzlaşılamamıştır. Kalkınma kavramı en genel olarak "insan refahını temel alan teorik ve pratik uygulamaların bütünü olarak" ifade edilmektedir (Turhan, 2020). Kalkınma "üretim ve kişi başına gelirin artmasıyla birlikte, ekonomik ve sosyo-kültürel yapının da değişmesi" anlamına gelmektedir (Tolunay ve Akyol, 2006). Geray (1991) tarafından kalkınma, "bir ülkenin yapısal niteliklerinin olumlu yönde değişimi" şeklinde ifade edilmiştir (aktaran Tolunay ve Akyol, 2006). Kalkınmanın en güncel ve genel tanımlaması, ekonomik koşullarla birlikte yaşam kalitesindeki ilerlemeye bağlı refah artışı olarak değerlendirilmektedir. Ekonomik kalkınmanın konusunu üretim kapasitesi, toplumsal dönüşüm, yaşam kalitesi ve gelişmişlik farkları oluşturmaktadır. Kalkınma kavramı teorik olarak kullanılmaya başlandığı ilk dönemlerde sadece ekonomiye dayalı bir olgu olarak tanımlanırken, zamanla ilgili kavram ekonomi ile birlikte sosyal, siyasal ve kültürel tanımları ve olguları açıklamada da kullanılmaya başlanmıştır (Doğan, 2011).

3.1.1. Kalkınmasız Büyüme Kavramı

Kalkınmasız büyüme özellikle petrol zenginliğine sahip ülkelerde görülen bir durumdur. Dünyada en önemli doğal kaynak petrol olarak bilinmektedir. Petrolün en fazla bulunduğu yer Orta Doğu ve OPEC ülkeleridir. Bu ülkelerin ekonomik büyüme oranı diğer birçok ülkeden daha yüksektir. Ülkeler arasında ekonomik büyüme oranı bakımından ilk 10 arasında çoğunlukla OPEC ülkeleri gelmektedir. Ancak bu ülkelerde siyasal, yönetimsel, gelir, demokrasi, vergi gibi konularda yaşanan olumsuzluklardan dolayı refah ve kaliteli yaşamda sorunlar gözlemlenmektedir (Kartal, 2022). Petrol bakımından zenginlik ilk başlarda önemli bir avantaj gibi değerlendirilse de bu durum günümüzde ülkelerin kalkınmasının önünde büyük bir engel olabilmektedir. Bu ülkelerde ciddi bir otorite boşluğunun mevcut olması, ortak bir rejim anlayışının varlığı ve bu rejim anlayışının yayılma mekanizması, demokrasinin önünde büyük bir engel olarak kalkınmayı önleyici bir özellik gösterebilmektedir (Brooks ve Marcus, 2016).

Doğal kaynak bakımından zengin olan bu ülkelerde özellikle kalkınmada yaşanan sorunlar bu ülkelerin kalkınmasız büyüyen ülkeler olarak nitelendirilmesine neden olmaktadır. Ekonomik büyümenin bu ülkelerin yaşam kalitesini artırmadığı, artırsa bile diğer ülkelere kıyasla daha gecikmeli bir şekilde artırdığı gözlemlenmektedir. Birçok petrol zengini ülke ekonomik büyüme

oranı bakımından dünyada ilk sıralarda yer almaktadır. Fakat bu petrol zengini ülkelerinin insani gelişme endeksi gelişmiş ülkelerin insani gelişme endeksi ile karşılaştırıldığında bu ülkelerdeki değerin düşük bir düzeyde olduğu dikkat çekmektedir. Kalkınmasız büyüme ile ilgili ülkeler genellikle doğal kaynak laneti ile ilişkilendirilmiş ülkeler olarak bilinmektedir (Kartal, 2022). Kalkınmanın boyutunu ölçmek için en yaygın kullanılan endeks Birleşmiş Milletler Kalkınma Programının (UNDP) geliştirmiş olduğu "İnsani Gelişme Endeksi"'dir. İnsani Gelişme Endeksinin boyut ve göstergeleri Şekilde 2'de özetlenmiştir.



Şekil 2. İnsani Gelişme Endeksinin Boyut ve Göstergeleri
Kaynak: UNDP, 2023.

Çalışmada analize dâhil edilen ülkelerin 2022 yılı verilerine göre insani gelişme endeksi sıralamasında İsviçre birinci, Norveç ikinci, Almanya yedinci, Birleşik Arap Emirlikleri on yedinci, Güney Kore on dokuzuncu, ABD yirminci, Japonya yirmi dördüncü, Bahreyn otuz dördüncü, Katar ve Suudi Arabistan kırkıncı, Kuveyt kırk dokuzuncu sırada gelmektedir (UNDP, 2024).

Sanayi devrimleri ile yaşanan gelişmeler üretimin büyük bir bölümünde teknoloji faktörünün önem kazanmasına neden olmuştur. Yeni teknolojilerin ve yeni üretim yöntemlerinin kullanılması ülkelerin ekonomik, sosyal ve siyasal yapılarını etkilemektedir (Günay, 2002). Tekonolik gelişme sürecinde ülkelerin araştırma ve geliştirmeye (Ar-Ge) yapmış oldukları harcamalar önemli bir gösterge olarak kabul edilmektedir. Analize dâhil edilen Grup 1 ülkelerinin 2021 yılı verilerine göre Ar-ge harcamalarının GSYİH içindeki payları sırasıyla Katar %0,68, Suudi Arabistan %0,44, Birleşik Arap Emirlikleri %1,49, Kuveyt'in 2022 yılı verisi ise %0,07'dir. Grup 2 ülkelerinin 2021 yılı Ar-ge harcamalarının GSYİH içindeki payları ise sırasıyla Norveç için %1,93, Güney Kore için %4,93, Japonya için %3,29, İsviçre için %3,35, ABD için %3,45 ve Almanya için %3,14 olarak gerçekleşmiştir (World Bank, 2024). Grup 1 ve Grup 2 ülkelerinin Ar-ge harcamalarına ayırdıkları paylar dikkate alındığında kalkınma düzeyi yüksek olan Grup 2 ülkelerinin payının daha yüksek olduğu gözlemlenmiştir. Bir ülkenin rekabet üstünlüğünde etkili olan faktörlerden bir diğer ise katma değeri yüksek ürün ihracatıdır. Yüksek teknoloji endüstri ihracatının faktör verimliliğini yükselterek, bilgi yayılımını teşvik ederek,

firmaların dış rekabet gücünü artırarak tüm sektörlerde ekonomik büyümeye yol açabileceği vurgulanmaktadır (Sojoodi ve Baghbanpour, 2024). Tablo 1'de Grup 1 ülkelerinin 2011-2022 dönemi yüksek teknoloji ihracat değerlerine yer verilmiştir.

Tablo 1. Grup 1 Ülkelerinde 2011-2022 Dönemi Yüksek Teknoloji İhracatının İmalat İhracatı İçindeki Payı (%)

Yıl	Katar	Suudi Arabistan	Kuveyt	Bahreyn	B.A.E.
2011	0,005	0,59	2,77	0,15	-
2012	0,60	0,66	-	0,38	3,76
2013	0,54	0,71	1,66	0,59	3,60
2014	0,04	0,59	0,13	1,49	10,16
2015	1,10	0,78	0,12	0,93	5,30
2016	0,001	1,30	0,14	1,05	2,61
2017	0,005	0,73	0,20	0,62	2,84
2018	1,80	0,54	4,11	0,44	2,90
2019	0,002	0,64	0,90	4,44	2,99
2020	7,11	0,60	1,34	8,97	5,37
2021	1,71	0,30	1,19	0,59	8,95
2022	2,85	-	0,71	0,56	9,28

Kaynak: World Bank, 2024.

Grup 1 ülkeleri içerisinde imalat sanayi içerisinde yüksek teknoloji ihracat payı en yüksek olan ülke Birleşik Arap Emirlikleri'dir. Diğer ülke payları ise yaklaşık %1 ila %2 arasında düşük düzeyde gerçekleşmiştir. Tablo 2'de Grup 2 ülkelerinin 2011-2022 dönemi yüksek teknoloji ihracat değerlerine yer verilmiştir.

Tablo 2. Grup 2 Ülkelerinde 2011-2022 Dönemi Yüksek Teknoloji İhracatının İmalat İhracatı İçindeki Payı (%)

Yıl	Norveç	G. Kore	Japonya	İsviçre	ABD	Almanya
2011	21,54	28,21	18,39	25,27	20,62	16,34
2012	21,12	28,22	18,23	26,05	20,17	17,22
2013	21,02	29,81	17,75	26,75	20,18	17,29
2014	22,31	30,06	17,78	26,65	20,48	17,20
2015	22,26	31,21	18,04	27,05	21,39	17,82
2016	20,95	30,52	17,62	27,33	22,41	18,08
2017	21,59	32,54	17,59	14,02	19,26	15,85
2018	21,11	36,39	17,29	13,31	18,48	15,74
2019	22,49	32,40	17,03	12,90	18,68	16,38
2020	22,06	35,60	18,63	12,84	19,49	15,50
2021	20,58	36,01	18,00	14,23	19,90	15,38
2022	23,95	36,11	18,25	29,98	20,57	17,48

Kaynak: World Bank, 2024.

Grup 2 ülkeleri içerinde imalat sanayi içerisinde yüksek teknoloji ihracat payı yüksek olan ülkelerin başında G. Kore ve Norveç gelmektedir. Genel olarak Grup 1 ve Grup 2 ülkeleri karşılaştırıldığında Grup 2 ülkelerinin imalat sanayi içerisinde yüksek teknoloji ihracat payının Grup 1 ülkelerine göre çok yüksek düzeyde gerçekleştiği söylenebilir. Bu ise bu ülkelerin üretimlerinde teknoljik gelişimi ve teknolojik gelişimin ileri boyutu olan dijitalleşmeyi daha fazla kullandıklarını göstermektedir.

3.1.2. Doğal Kaynak Laneti Yaklaşımı

Kaynak laneti terimi ilk kez ekonomik coğrafyacı Richard Auty (1993) tarafından kullanılmıştır. İlgili kavram kaynak zengini ülkelerde özellikle Afrika, Orta Doğu, Latin Amerika ve Eski Sovyetler Birliği'nde gözlemlenen sorunları açıklamak için kullanılmıştır (Ross, 2015). Doğal Kaynak Laneti Auty'de (2001) "yeni bulgular gösteriyor ki doğal kaynak zengini ülkeler bu nimetten faydalanma konusunda başarısız olmak bir yana, aslında kaynak bahşedilmemiş ülkelerden daha kötü performans sergileyebiliyorlar" şeklinde ifade edilmiştir (aktaran Şahin, 2021). Ekonomi literatüründe ise kaynak laneti "doğal kaynaklar bakımından zengin olan ülkelerin ekonomik performanslarının, kaynak yoksulu ülkelere kıyasla nispeten düşük olması" olarak adlandırılmaktadır (Akçura, 2019). Geniş kapsamlı olarak kavram, "bir ülkenin doğal kaynak zenginliğinin ekonomik, sosyal veya politik refahı üzerindeki olumsuz etkileri" şeklinde kabul edilmektedir (Ulucak, 2016).

Doğal kaynak zenginliğinin ekonomik yapı üzerinde doğrudan ve olumlu etkileri mevcuttur. Yaygın olarak OPEC ülkeleri için kullanılan bu kavram aslında yüksek bir milli geliri ifade etmektedir (Şahin, 2021). Ülkeler açısından doğal kaynakların bol olması ekonomik büyüme ve gelişme için önemli bir faktör olarak kabul edilmektedir (Akçura, 2019). Ancak sermaye birikiminin ülkelerde başka sektörlere aktarılmaması toplumun sosyo-ekonomik açıdan gerilemesine neden olmaktadır (Şahin, 2021). Özellikle bu kaynakların planlı ve bilinçli bir şekilde kullanılmaması sonucu bu ülkelerde "Hollanda Hastalığı, yolsuzluk, otoriter rejim, zayıf yönetişim, gelir dağılımı eşitsizliği, iç savaş ve çatışma riski ile rant arayışı" gibi birçok sorunla karşı karşıya kalınabilmektedir (Akçura, 2019). Kaynak bolluğunun bir ülkenin ekonomik büyümesini artırarak yaşam kalitesini artırması beklenmektedir. Ancak araştırmalar bu durumun olumsuz sonuçlarına dikkat çekmektedir (Alexeev ve Conrad, 2011).

Bu olumsuz etkileri açıklamada kullanılan yaklaşımlardan biri "Hollanda Hastalığı"'dır. Hollanda Hastalığı, petrol veya diğer mineral ve tarımsal emtialardaki bir yükselmenin olumsuz yan etkilerini ifade etmek için kullanılmıştır. Bu olgu, ihraç edilen emtianın dünya fiyatında güçlü, ancak geçici bir yükseliş dalgasının etkileri sonucu ortaya çıkmaktadır. İhraç edilen emtiya fiyatlarındaki artış beraberinde para biriminde büyük bir değer artışına, harcamalarda artışa, ticaret dışı malların fiyatında artışa, çari açıkta artışa neden olmaktadır (Frankel, 2010). Petrol ve doğal gaz fiyatlarının yükselmesi ülkeye giren döviz miktarını artırmakta, ulusal parayı aşırı değerlendirmekte, ülke mallarını pahalılaştırmakta ve ülkenin dış rekabet gücünü azaltmaktadır. Sanayisi tek bir kaynağa bağlı olan bu ülkelerdeki petrol fiyatlarındaki azalma ise işsizliğe ve ülkenin fakirleşmesine neden olmaktadır (Yardımcıoğlu ve Gülmez, 2013). Bu ülkelerde üretim sektöründeki yoğunlaşma tek bir sektörde olduğunda bunun etkisi sanayisizleşme şeklinde kendini göstermektedir (Frankel, 2010).

Zengin doğal kaynağa sahip ülkelerin bu durumdan olumsuz etkilenebileceğini açıklamada kullanılan diğer bir yaklaşım Singer-Prebish tezidir. Tarım ve sanayi ürünleri arasındaki ticaret hadlerinin uzun dönemde tarım ürünleri aleyhine değişeceği görüşü Singer-Prebish tezi olarak adlandırılmaktadır (Seyidoğlu, 2015). Maden ve tarım ürünlerinin fiyatlarının, imalat ve diğer ürünlerin fiyatlarına kıyasla uzun vadede aşağı yönlü bir seyir izleyeceği hipotezi, Raul Prebisch (1950) ve Hans Singer (1950) ile ilişkilendirilmiştir. Bu hipotezin temelinde birincil ürünlere yönelik dünya talebinin dünya gelirine göre esnek olmaması yer almaktadır (Frankel, 2010). Bu nedenle Singer'e (1950) ve Prebisch'e (1950) göre doğal kaynak zenginliği ticaret hadlerindeki yaşanan bozulma aracılığıyla ekonomik büyümeyi olumsuz etkileyebilecektir. Özellikle ihracatı

ağırlıklı olarak doğal kaynaklara bağlı gelişmekte olan ülkeler emtiya piyasalarındaki dalgalanmalardan ve emtiya fiyatlarındaki yüksek volatiliteden daha çok etkilenmektedir. Aynı zamanda Auty'e (1993) göre doğal kaynak bakımından zengin olan ülkeler bu kaynaklardan elde ettikleri gelirleri verimli alanlara yönlendirememekte bu ise kaynak lanetinin ortaya çıkmasına neden olmaktadır (Bal ve Palandökenlier, 2021).

Gelişmiş ülkelerle gelişmekte olan ülkelerde toplanan vergiler karşılaştırıldığında, özellikle doğal kaynak zengini ülkelerde, bu oran daha düşük düzeyde olmaktadır. Çünkü hükümet doğal kaynak ihracatından daha fazla gelir elde ettiği için diğer alanlardan vergi geliri elde etme çabasında bulunmamaktadır. Bu ise bu ülkelerde vergi sistemini olumsuz etkilemektedir. Doğal kaynak zengini ülkelerin çoğunda otoriter rejimler demokratikleşmeye izin vermemekte ve kurumsal zayıflıklar gözlemlenmektedir. Literatürde bazı yazarlar, kurumsal zayıflığın doğal kaynak laneti yoluyla düşük ekonomik büyüme performansına neden olduğunu, diğer bir grup yazar ise doğal kaynak rantının kurumları zayıflattığını ifade etmektedir. Bu ülkelerde kaynakların dağıtımı yetkisi siyasi otoritelerin elindedir. Kamu sektörü ise gerekli kaynakları tahsis edememektedir. Ekonomileri büyük ölçüde doğal kaynak çıkarımına bağımlı olan ülkelerde yüksek vasıflı işgücüne veya eğitime ihtiyaç duyulmamaktadır. Üretim sektörüyle karşılaştırıldığında, kaynak temelli sektörler zayıf teknolojiye ve daha az nitelikli insan sermayesine ihtiyaç duymaktadır. Kaynak temelli çalışanlar daha az kalifiye olsalar dahi, doğal kaynak sektörünün daha yüksek kar oranlarına sahip olması nedeniyle imalat sanayi işçilerinden daha fazla ücret almaktadırlar. Bu nedenle, doğal kaynak bakımından zengin ülkelerde yüksek vasıflı işgücüne olan talep ve eğitim yatırımları azalmaktadır (Gedikli, 2020).

Bununla birlikte bu durum her doğal kaynak zengini ülkeler için geçerli değildir. Doğal kaynaktan elde ettiği geliri diğer sektörlere aktaran ve insani yaşam kalitesini yükselten ülkeler doğal kaynak zenginliğini avantaja dönüştürmektedir. Ancak doğal kaynakları plansız ve bilinçsiz kullanan ülkeler çok kısa bir dönem için zenginleşirken uzun dönemde fakirleşmektedir. Doğal kaynak zengini ülkede doğal kaynaktan elde edilecek gelir o ülkeyi kısa dönemde zenginleştirmektedir. Uzun dönemde ise ülkede hukuki ve siyasi boşluğun varlığı sonucu büyümenin kalkınmayı desteklememesi kalkınmaya engel olmaktadır (Ulucak, 2016). Diğer bir ifadeyle doğal kaynağın varlığı bu ekonomilerde ekonomik büyümeyi kısa vadede olumlu etkilemektedir. Ancak yatırımların sadece doğal kaynak yönünde olması diğer sektörleri ve beşeri sermaye yatırımlarının ihmal edilmesi zaman içerisinde ekonomik daralma ile sonuçlanmaktadır (Alexeev ve Conrad, 2011). Bu ülkelerde doğal kaynak dışındaki diğer sektörlerin ihmal edildiği ve genellikle yerli üretici bulunmadığı kanısı hâkimdir. Yerli üreticinin yetersizliği ve ithalat mallarına olan talep inovasyonun gelişimini kısıtlamaktadır. Yerli üretim olmadığı için nitelikli işgücüne ihtiyaç duyulmamakta ve kalkınmadaki önemli bir faktör olan eğitim ihmal edilmektedir. Eğitim yetersizliği nedeniyle bu ülkelerde teknolojik buluşlar, inovasyon ve Ar-ge faaliyetleri de kısıtlı düzeyde kalmaktadır (Ulucak, 2016).

3.2. Dijitalleşme ve Kalkınma İlişkisi

Dijitalleşmenin temelini oluşturan teknik ilerleme ekonomik kalkınmanın bir gerekliliği olarak ilk kez 1950'lerde ortaya çıkmıştır (Kaynak, 2003). Dördüncü endüstri devrimi ile başlayan ve içinde bulunduğumuz dönem dijital çağ olarak adlandırılmaktadır. Bu çağda gelişmiş ve gelişmekte olan ülke ayrımının en büyük belirleyicilerinden biri ülkelerin sahip olduğu teknoloji faktörü olarak değerlendirilmektedir (Bakırtaş ve Ustaömer, 2019). Yeni ekonomik

düzen olarak adlandırılan dijital ekonominin temeli bilgi ve teknolojiye dayanmakta olup bilgi ve teknoloji ekonomik kalkınmanın temel aracılarından biri olma rolünü üstlenmektedir (Kevük, 2006). Dijital dönüşüm süreci içerisinde dijitalleşmeyi sağlamak ekonomik kalkınma için önemli bir faktör haline gelmektedir (UNCTAD, 2021). Dijitalleşme bireylerin yaşam biçimini, devletlerin stratejilerini, işletmelerin üretim yöntemini ve ekonominin yönünü belirlemektedir. Dijitalleşme kaliteli yaşam belirleyicisi olması yönüyle kalkınma ile doğrudan ilişkili hale gelmektedir (Demirkıran vd., 2022). Dijital çağın en büyük gerekliliği olan dijital teknolojiler ekonomik kalkınma, refah seviyesi ve insani yaşam kalitesini artırma gibi konularda rol oynamaktadır (Pakdemirli, 2019).

Günümüzde teknolojik ilerlemenin ekonomik kalkınmanın önemli faktörlerinden biri olduğu kabul edilmektedir (Ersungur, 1994). Teknoloji üretimi ve kullanımının artması dijitalleşme sürecini hızlandırmakta ve insani yaşam kalitesinin yükselmesine neden olmaktadır (Şad ve Arıbaş, 2010). Teknolojik gelişim ülkedeki üretim kapasitesini artırarak toplumun temel ihtiyaçlarına, eğitim ve sağlık imkânlarına daha kolay ulaşılmasına, haberleşmenin ve ulaşımın kolaylaşmasına sebep olmaktadır (Ersungur, 1994). Dijitalleşmenin hızla ilerlemesi, bilgi akışı, iletişim, alışveriş, çalışma hayatı, hizmet alma gibi gündelik rutini hızlı bir şekilde değiştirmektedir (UNCTAD, 2021). Bilgi ve iletişim teknolojilerine yapılan yatırımlar sonucu inovasyonlar ülkelerin rekabet gücünü artırarak ekonomik büyüme ve kalkınmaya neden olmaktadır. Aynı zamanda ülkelerin sürdürülebilir ekonomik kalkınmayı sağlamak için dijitalleşme yönündeki bilgi ve iletişim teknolojilerine yapılan yatırımların artışı da inovasyon çalışmalarını artırmaktadır (Pakdemirli, 2019). Dijitalleşmenin yüksek olduğu ülkelerde insanlar işlerini internet üzerinden yapmakta ve zaman tasarrufu sağlamaktadır. Gelişmiş ülkelerde mal üretiminden daha çok bilgi üretimi önemli hale gelmiştir. Bilgi üretimi ise entelektüel sermayeye bağlı olup entelektüel sermaye ülkelerin refah seviyesini artırmaktadır **(**Kaynak, 2014).

Yeni ekonomik düzende uluslararası ekonomik işlemlerin dijital ekonomiye entegre olması ile birlikte ekonomik kalkınmaya da yeni bir bakış açısı gelmiştir. Bu bakış açısı dijitalleşmeyle ilerleyen kalkınmadır. Dijitalleşme ile birlikte yeni bir düzen olarak karşılaşılan ve geleneksel ekonomiden dayanakları farklı olan dijital ekonomi, ekonomik kalkınma için anahtar olmaktadır. Ancak kalkınması yüksek düzeyde olan ülkeler dijitalleşme olanaklarından ileri düzeyde faydalanırken az gelişmiş ülkelerde dijitalleşme olanaklarından istenildiği gibi fayda sağlanamadığı gözlemlenmektedir (UNCTAD, 2021).

3.3 Ampirik Literatür

Dijitalleşme konusu ile ilgili yapılan çalışmaların büyük çoğunluğunda dijitalleşme ve ekonomik büyüme ilişkisi incelenmiştir. Örneğin dijitalleşme ve ekonomik büyüme arasındaki ilişkiyi dikkate alarak inceleyen Türedi (2012), Işık ve Kılınç (2013), Köse ve Şentürk (2017), Niebel (2018), Aykırı ve Bulut (2018), Lazanyuk ve Revinova (2019), David (2019), Solomon ve Klyton (2020), Myovella vd. (2020), Kasa (2020), Lazovic vd. (2022), Gomes vd. (2022), Akyol vd. (2023) çalışmalarında değişkenler arasında pozitif yönlü ilişki tespit edilmiştir.

Diğer bir grup çalışmada ise doğal kaynak laneti yaklaşımı incelenmiştir. Örneğin Kara Acar ve Topdağ (2020) OPEC ve Mena ülkelerinin 2006-2018 yılları arasındaki doğal kaynak bağımlılığı ve kurumsal gelişmenin ekonomik kalkınma üzerine etkisi incelemiştir. Çalışma sonucunda doğal kaynak gelirlerinin ekonomik kalkınmayı olumsuz yönde etkilediği ve doğal

kaynak laneti yaklaşımının geçerli olduğu sonucuna ulaşılmıştır. BRICS ülkelerinin dikkate alındığı Hacıimamoğlu (2021) ise doğal kaynak ve finansal gelişim arasındaki ilişki ele alınmıştır. Çalışmanın sonucunda Brezilya ve Rusya'da doğal kaynak geliri ve finansal kalkınma arasındaki ilişkinin olumlu, Güney Afrika'da ise bu ilişkinin olumsuz olduğu yönündedir. Çin ve Hindistan'da ise değişkenler arasında anlamlı bir ilişki tespit edilememiştir. Çamkaya'da (2023) doğal kaynak laneti yaklaşımı MINT ülkelerinin 1990-2019 yılları dikkate alınarak analiz edilmiştir. Çalışmada doğal kaynak, beşeri sermaye ve ekonomik büyüme ilişkisi test edilmiştir. Elde edilen bulgular MINT ülkeleri için doğal kaynak laneti yaklaşımını destekler niteliktedir. Ayrıca incelenen ülkelerde beşeri sermaye ve sabit sermaye stoğu artışının ekonomik büyümeyi artırdığı tespit edilmiştir.

Son dönemlerde yapılan çalışmalar ise dijitalleşme ve ekonomik kalkınma konularına doğru kaymıştır. Konu ile ilgili yapılan ilk çalışmalardan biri Hardy'dir (1980). Bu çalışmada dijitalleşme ve kalkınma ilişkisi 60 ülkenin 13 yıllık verileri dikkate alınarak incelenmiştir. Elde edilen bulgulara göre telefon kullanımı ekonomik kalkınmayı olumlu yönde etkilemektedir. 69 ülke ve 28 OECD üyesi ülkedeki 2000-2004 dönemine ait bilgi ve iletişim teknolojileri (BİT) ile kalkınma arasındaki ilişkiyi inceleyen Torun ve diğerleri de (2009) BİT ve inovasyon yatırımlarının kalkınmayı pozitif etkilediği sonucuna ulaşılmıştır. David'de (2019) dijitalleşme, ekonomik büyüme, ekonomik kalkınma ilişkisi 46 Afrika ülkesi için analiz edilmiştir. Çalışmada reel Gayrisafi Yurtiçi Hasıla (GSYİH), İnsani Gelişme Endeksi, Telekomünikasyon Endeksi kullanılmıştır. Çalışma sonucunda değişkenler arasında uzun dönemli bir ilişki ve çift yönlü nedensellik ilişkisi tespit edilmiştir. Mamedov'da (2019) bilgi ekonomisi ve ekonomik kalkınma arasındaki ilişki nedensellik testi ve eşbütünleşme testi kullanılarak analiz edilmiştir. Çalışmadan elde edilen sonuca göre bilgi ekonomisi politikada tam olarak uygulandığı durumda kalkınmayı olumlu bir şekilde etkilemektedir. Aly (2022) ise yapay zekanın gelişmiş ve gelişmekte olan ülkelerde sosyal ve ekonomik etkileri araştırılmıştır. Elde edilen bulgular, yapay zekanın ekonomik kalkınma, istihdam ve işgücünün verimliliği üzerinde hem olumlu hem de olumsuz etkileri olduğunu göstermiştir. İnovasyon ve ekonomik kalkınma arasındaki ilişkiyi inceleyen diğer bir çalışma Özer ve Ünlü'dür (2020). Çalışmada üst orta gelirli 24 ülkenin 2000-2017 yıllarına ait İnsani Gelişme Endeksi, AR-GE harcamaları, yerleşik patent başvuruları, bilimsel araştırma ve teknik makale sayısı, bilgi ve iletişim teknolojileri hizmet ihracatı verileri kullanılmıştır. İlgili çalışmada inovasyonun ekonomik kalkınmayı pozitif etkilediği bulgusu elde edilmiştir

Dijitalleşme ve sürdürülebilir kalkınma ilişkisinin incelendiği Altay Topçu'da (2021) 28 AB üyesi ülke analize dâhil edilmiştir. Çalışmada Uluslararası Dijital Ekonomi İndeksi, Toplum İndeksi, Sürdürülebilir Kalkınma İndeksleri kullanılmıştır. Çalışma sonucunda dijital ekonominin sürdürülebilir kalkınma üzerinde anlamlı ve pozitif etkisi olduğu bulgusu elde edilmiştir. İyigüngör (2002) tarafından Endüstiri 4.0 sonucu Japonya'da uygulanan dijitallesme politikalarına toplumun uyum etkileri incelenmiştir. Çalışmadan elde edilen bulgular Japonya'nın uyguladığı politikalar sonucu dijitalleşmeye ayak uyduran ve yaşam kalitesini artıran toplumsal bir yapının oluştuğu şeklindedir. Zhang vd. (2021) Çin'in 30 kenti için 2015-2019 döneminde dijital ekonominin ekonomik kalkınma üzerindeki etkileri test edilmiştir. Çalışma sonucunda dijitalleşmenin bölgesel faktör verimliliği üzerine olumlu etkisi olduğu bulgusu elde edilmiştir. Behera ve Sahoo (2022) Hindistan'ın BİT, küreselleşme ve insani gelişme değişkenleri arasındaki ilişki test edilmiştir. Elde edilen bulgular küreselleşme ile internet ve mobil yoğunluğunun

artmasının uzun dönemde insani gelişime olumlu katkı sağlayacağı ve insani yaşam kalitesini artacağı şeklindedir.

4. Veri ve Yöntem

Çalışmada dijitalleşme ve kalkınma ilişkisi Petrol İhraç Eden Arap Ülkeleri Örgütü (OAPEC) üyelerinden 5 ülke (Katar, Suudi Arabistan, Kuveyt, Bahreyn ve Birleşik Arap Emirlikleri) ile kalkınma düzeyi yüksek olan Norveç, Güney Kore, Japonya, İsviçre, ABD, Almanya analize dâhil edilerek incelenmiştir. Çalışmada verilerin elde edilebilirliğine göre 2000-2021, 2000-2020 ve 2002-2021 dönemleri dikkate alınmış ve değişkenler arasındaki nedensellik ilişkisi Konya (2006) nedensellik testi ile sınanmıştır.

UNDP tarafından geliştirilen "İnsanı Gelişmişlik Endeksi" kalkınma boyutunu ölçmek için en yaygın kullanılan indekslerden biridir (UNDP, 2023). Dijitalleşme göstergeleri ise Shahbaz ve diğerlerinde (2022) kullanılan dijital ekonomi endeksi verileri dikkate alınarak belirlenmiştir. Dijitalleşme göstergesi olarak sabit telefon abonelikleri, mobil hücresel abonelikler, internet kullanan bireyler, sabit geniş bant abonelikleri, kalkınma göstergesi olarak insani gelişme endeksi kullanılmıştır. Çalışmada kullanılan veriler Uluslararası Telekomünikasyon Birliği (ITU) ve Dünya Bankası Kalkınma Göstergeleri (WDI) veri tabanından temin edilmiştir. Değişkenlerin logaritmaları analize dâhil edilmiştir. Çalışmada Gauss 6.0 programı kullanılmıştır.

$$LNHD_{i,t} = \alpha_0 + \alpha_1 LNFTS + U_{i,t} \quad (1)$$

$$LNHD_{i,t} = \theta_0 + \theta_1 LNMCS + \upsilon_{i,t} \quad (2)$$

$$LNHD_{i,t} = \Omega_0 + \Omega_1 LNINT + \omega_{i,t} \quad (3)$$

$$LNHD_{i,t} = \Phi_0 + \Phi_1 LNFBS + \hat{w}_{i,t} \quad (4)$$

Modellerde LNHD insani gelişme endeksini, LNFTS sabit telefon abonelikleri (100 kişi başına), LNMCS mobil hücresel aboneliklerini (100 kişi başına), LNINT internet kullanan bireylerin payını (nüfusun %), LNFBS sabit geniş bant aboneliklerini (100 kişi başına), $U_{i,t}, \upsilon_{i,t}, \omega_{i,t}, \hat{w}_{i,t}$ hata terimlerini temsil etmektedir.

Çalışmada kurulan modeller kapsamında aşağıdaki hipotezler sınanmıştır:

H_0: Dijitalleşme ekonomik kalkınmanın Granger nedeni değildir

H_a: Dijitalleşme ekonomik kalkınmanın Granger nedenidir.

H_0: Ekonomik kalkınma dijitalleşmenin Granger nedeni değildir

H_a: Ekonomik kalkınma dijitalleşmenin Granger nedenidir.

5. Bulgular

Konya (2006) nedensellik testi yatay kesit bağımlılığını ve heterojeniteyi dikkate alan bir test olup, bu testi uygulamak için öncesinde panel birim kök testi ya da panel eş-bütünleşme testi uygulanmasına gerek duyulmamaktadır (Kar vd., 2011). Çalışmadan elde edilen bulgular Grup 1 ve Grup 2 ülkeleri için ayrı ayrı başlıklar halinde sunulmuştur.

5.1. Grup 1 Ülkeleri İçin Yapılan Analiz Sonuçları

Çalışmada ilk olarak, OAPEC üyelerinden Katar, Suudi Arabistan, Kuveyt, Bahreyn ve Birleşik Arap Emirlikleri'nin yer aldığı Grup 1 ülkeleri için yatay kesit bağımlılığı testi yapılmıştır. Yatay kesit bağımlılığı testinden elde edilen bulgular Tablo 3'te sunulmuştur. LNFTS1, LNMCS1, LNINT1 için 2000-2021 dönemi, LNFBS1 için 2002-2021 dönemi dikkate alınmıştır. LNHD1, LNFTS1, LNMCS1, LNINT1, LNFBS1 değişkenleri için %5 anlamlılık düzeyinde H_0 boş hipotezi reddedilmektedir. Diğer bir ifadeyle modelde ilgili değişkenler için yatay kesit bağımlılığı söz konusudur.

Tablo 3. Yatay Kesit Bağımlılığı Test Sonuçları

H_0: Yatay kesit bağımlılığı yoktur.	H_a: Yatay kesit bağımlılığı vardır.	
LNHD1=F(LNFTS1)	**İstatistik Değeri**	**Olasılık Değeri (p-değeri)**
LM (Breusch, Pagan 1980)	28.59**	0.001
CDlm (Pesaran 2004)	4.16**	0.000
CD (Pesaran 2004)	4.19 **	0.000
LMadj (PUY, 2008)	19.89 **	0.000
LNFTS1=F(LNHD1)		
LM (Breusch, Pagan 1980)	13.52	0.196
CDlm (Pesaran 2004)	0.79	0.216
CD (Pesaran 2004)	0.59	0.275
LMadj (PUY, 2008)	19.85**	0.000
LNHD1=F(LNMCS1)		
LM (Breusch, Pagan 1980)	59.32**	0.000
CDlm (Pesaran 2004)	11.03 **	0.000
CD (Pesaran 2004)	6.69 **	0.000
LMadj (PUY, 2008)	37.39 **	0.000
LNMCS1=F(LNHD1)		
LM (Breusch, Pagan 1980)	59.10 **	0.000
CDlm (Pesaran 2004)	10.97 **	0.000
CD (Pesaran 2004)	6.77**	0.000
LMadj (PUY,2008)	37.78**	0.000
LNHD1=F(LNINT1)		
LM (Breusch, Pagan 1980)	43.87**	0.000
CDlm (Pesaran 2004)	7.57**	0.000
CD (Pesaran 2004)	4.60 **	0.000
LMadj (PUY,2008)	40.56 **	0.000
LNINT1=F(LNHD1)		
LM (Breusch, Pagan 1980)	50.77**	0.000
CDlm (Pesaran 2004)	9.11**	0.000
CD (Pesaran 2004)	5.88 **	0.000
LMadj (PUY,2008)	41.26**	0.000
LNHD1=F(LNFBS1)		
LM (Breusch, Pagan 1980)	36.72**	0.000
CDlm (Pesaran 2004)	5.97**	0.000
CD (Pesaran 2004)	3.45 **	0.000
LMadj (PUY,2008)	33.41 **	0.000
LNFBS1=F(LNHD1)		
LM (Breusch, Pagan 1980)	31.23**	0.000
CDlm (Pesaran 2004)	4.74**	0.000
CD (Pesaran 2004)	4.10**	0.000
LMadj (PUY,2008)	33.17**	0.000

Not: *, **, *** sırasıyla %1, %5 ve %10 anlamlılık düzeyini göstermektedir.

Tablo 4'te, Grup 1 ülkelerinin homojenlik testi sonuçlarına yer verilmiştir. LNFTS1, LNMCS1, LNINT1 için 2000-2021 dönemi, LNFBS1 için 2002-2021 dönemi dikkate alınmıştır. Sonuçlara göre LNFTS1, LNMCS1, LNINT1, LNFBS1 değişkenleri için %5 anlamlılık düzeyinde eğim katsayıları homojendir Ho hipotezi reddedilmektedir. İlgili değişkenlerin heterojen olduğu sonucuna ulaşılmıştır.

Tablo 4. Homojenlik Testi Sonuçları

H_0: Eğim katsayıları homojendir.	H_a: Eğim katsayıları heterojendir.	
LNFTS1	**İstatistik Değeri**	**Olasılık Değ. (p-değeri)**
Delta_tilde	4.371**	0.000
Delta_tilde_adj	4.687**	0.000
LNMCS1		
Delta_tilde	2.007**	0.022
Delta_tilde_adj	2.152**	0.016
LNINT1		
Delta_tilde	11.722**	0.000
Delta_tilde_adj	12.570**	0.000
LNFBS1		
Delta_tilde	5.123**	0.000
Delta_tilde_adj	5.557**	0.000

Not: *, **, *** sırasıyla %1, %5 ve %10 anlamlılık düzeyini göstermektedir.

Tablo 5'te LNFTS1 ve LNHD1 değişkenleri arasındaki nedensellik ilişkisi sonuçları yer almaktadır. Tablo 5'e göre LNFTS1 ve LNHD1 arasında; Katar, Kuveyt, Bahreyn, Birleşik Arap Emirlikleri için değişkenler arasında nedensellik ilişkisi olmadığı, Suudi Arabistan için %5 anlamlılık düzeyinde LNFTS1'den LNHD1'e doğru tek yönlü nedensellik ilişkisi olduğu tespit edilmiştir.

Tablo 5. İnsani Gelişmişlik ve Sabit Telefon Abonelikleri Arasındaki Konya Nedensellik Testi Sonuçları (2000-2021 dönemi)

Ülke	**H_0: LNFTS1, LNHD1'in nedeni değildir**				
	Wald İst.	**Bootstrap Kritik Değ.**			**Sonuç**
		%1	**%5**	**%10**	
Katar	0.001	21.7	14.3	11.2	lnfts⇏lnhd
Suudi Arabis.	3.414**	6.30	3.26	2.211	lnfts→lnhd
Kuveyt	6.57	43.42	30.10	23.35	lnfts⇏lnhd
Bahrey.	1.55	11.95	8.006	6.141	lnfts⇏lnhd
B.A.E.	1.19	26.78	17.55	13.72	lnfts⇏lnhd
Panel Fisher	8.151 [0.614]				
Ülke	**H_0: LNHD1, LNFTS1'in nedeni değildir**				
	Wald İst.	**Bootstrap Kritik Değ.**			**Sonuç**
		%1	**%5**	**%10**	
Katar	0.38	33.2	23.5	19.8	lnhd⇏lnfts
Suudi Arabis.	0.019	5.362	2.98	2.11	lnhd⇏lnfts
Kuveyt	2.518	25.476	17.38	14.8	lnhd⇏lnfts
Bahrey.	11.41	31.52	20.57	17.1	lnhd⇏lnfts
B.A.E.	0.959	15.95	11.22	9.50	lnhd⇏lnfts
Panel Fisher	3.181[0.977]				

Not: *, **, *** sırasıyla %1, %5 ve %10 anlamlılık düzeyini göstermektedir.

Tablo 6'ya göre LNMCS1ve LNHD1 arasında; Katar, Kuveyt için değişkenler arasında nedensellik ilişkisi olmadığı, Suudi Arabistan için %5 anlamlılık düzeyinde ve Bahreyn için %5 ve %10 anlamlılık düzeylerinde LNHD1 ve LNMCS1 arasında çift yönlü, Birleşik Arap Emirlikleri için %5 anlamlılık düzeyinde LNHD1'den LNMCS1'e doğru tek yönlü nedensellik ilişkisi olduğu bulgusu elde edilmiştir.

Tablo 6. İnsani Gelişmişlik ve Mobil Hücresel Abonelikleri Arasındaki Konya Nedensellik Testi Sonuçları (2000-2021 Dönemi)

Ülke	H_0: LNMCS1, LNHD1'in nedeni değildir				
	Wald İst.	Bootstrap Kritik Değ.			Sonuç
		%1	%5	%10	
Katar	1.88	18.6	11.6	10.0	lnmcs⇏lnhd
Suudi Arabis.	8.1**	10.1	7.57	6.17	lnmcs→lnhd
Kuveyt	12.15	22.7	15.0	12.2	lnmcs⇏lnhd
Bahrey.	3.8***	5.96	4.49	3.73	lnmcs→lnhd
B.A.E.	1.704	9.97	4.91	3.40	lnmcs⇏lnhd
Panel Fisher		18.447[0.048]			
Ülke	**H_0: LNHD1, LNMCS1'in nedeni değildir**				
	Wald İst.	**Bootstrap Kritik Değ.**			**Sonuç**
		%1	**%5**	**%10**	
Katar	0.030	4.86	2.72	1.88	lnhd⇏lnmcs
Suudi Arabis.	10.8**	6.45	4.43	3.36	lnhd→lnmcs
Kuveyt	1.61	16.2	10.6	8.49	lnhd⇏lnmcs
Bahrey.	7.67**	8.66	5.52	4.26	lnhd→lnmcs
B.A.E.	23.2**	27.1	14.5	11.3	lnhd→lnmcs
Panel Fisher		28.429[0.002]			

Not: *,**,*** sırasıyla %1, %5 ve %10 anlamlılık düzeyini göstermektedir.

Tablo 7. İnsani Gelişmişlik ve İnternet Kullanan Bireylerin Nüfus İçindeki Payı Arasındaki Konya Nedensellik Testi Sonuçları (2000-2021 Dönemi)

Ülke	H_0: LNINT1, LNHD1'in nedeni değildir				
	Wald İst.	Boot. Kri. Değ.			Sonuç
		%1	%5	%10	
Katar	4.18	29.7	22.4	18.7	lnint⇏lnhd
Suudi Arabis.	9.9***	14.8	11.1	9.11	lnint→lnhd
Kuveyt	14.490	43.2	31.4	25.7	lnint⇏lnhd
Bahrey.	2.813	12.7	8.82	7.70	lnint⇏lnhd
B.A.E.	0.986	12.3	6.42	4.9	lnint⇏lnhd
Panel Fisher		8.172 [0.612]			
Ülke	**H_0: LNHD1, LNINT1'in nedeni değildir**				
	Wald İst.	**Boot. Kri. Değ.**			**Sonuç**
		%1	**%5**	**%10**	
Katar	1.689	7.11	3.90	2.30	lnhd⇏lnint
Suudi Arabis.	4.928	10.6	6.52	5.16	lnhd⇏lnint
Kuveyt	0.007	24.2	13.9	9.87	lnhd⇏lnint
Bahrey.	0.075	4.94	3.43	2.53	lnhd⇏lnint
B.A.E.	0.328	4.57	2.02	1.52	lnhd⇏lnint
Panel Fisher		9.770 [0.461]			

Not: *, **, *** sırasıyla %1, %5 ve %10 anlamlılık düzeyini göstermektedir.

Tablo 7'de yer alan sonuçlara göre LNINT1 ve LNHD1 arasında; Katar, Kuveyt, Bahreyn, Birleşik Arap Emirlikleri için değişkenler arasında nedensellik ilişkisi olmadığı, Suudi Arabistan

için %10 anlamlılık düzeyinde LNINT1'den LNHD1'e doğru tek yönlü nedensellik ilişkisi olduğu sonucuna ulaşılmıştır.

Tablo 8'e göre LNHD1 ve LNFBS1 arasında; Suudi Arabistan, Kuveyt, Birleşik Arap Emirlikleri için değişkenler arasında nedensellik ilişkisi olmadığı, Bahreyn için %5 anlamlılık düzeyinde LNFBS1'den LNHD1'e doğru, Katar için %10 anlamlılık düzeyinde LNHD1'den LNFBS1'e doğru tek yönlü nedensellik ilişkisi olduğu bulgusu elde edilmiştir.

Tablo 8. İnsani Gelişmişlik ve Sabit Geniş Bant Aboneliklerini Arasındaki Konya Nedensellik Testi Sonuçları (2002-2021 Dönemi)

Ülke	H_0: LNFBS1, LNHD1'in nedeni değildir				
	Wald İst.	Bootstrap Krit. Değ.			Sonuç
		%1	%5	%10	
Katar	0.063	19.9	9.36	6.47	lnfbs⇏lnhd
Suudi Arabis.	2.717	11.0	6.80	5.35	lnfbs⇏lnhd
Kuveyt	1.458	23.6	14.8	11.5	lnfbs⇏lnhd
Bahrey.	4.912**	4.39	2.97	2.35	lnfbs→lnhd
B.A.E.	1.452	14.5	6.97	5.00	lnfbs⇏lnhd
Panel Fisher	14.676[0.144]				
Ülke	**H_0: LNHD1, LNFBS1'in nedeni değildir**				
	Wald İst.	**Bootstrap Krit. Değ.**			**Sonuç**
		%1	**%5**	**%10**	
Katar	2.9***	7.06	3.72	2.57	lnhd→lnfbs
Suudi Arabis.	3.450	20.2	13.6	10.2	lnhd⇏lnfbs
Kuveyt	1.282	15.2	9.50	7.75	lnhd⇏lnfbs
Bahrey.	1.226	8.16	4.86	3.65	lnhd⇏lnfbs
B.A.E.	1.136	6.66	2.94	1.90	lnhd⇏lnfbs
Panel Fisher	11.775[0.300]				

Not: *, **, *** sırasıyla %1, %5 ve %10 anlamlılık düzeyini göstermektedir.

Genel olarak Grup 1 ülkelerinde i) Suudi Arabistan için LNFTS1'den LNHD1'e doğru tek yönlü nedensellik, ii) Suudi Arabistan ve Bahreyn için LNMCS1 ve LNHD1 arasında çift yönlü nedensellik, iii) Birleşik Arap Emirlikleri için LNHD1'den LNMCS1'e doğru tek yönlü nedensellik, iv) Suudi Arabistan için LNINT1'den LNHD1'e doğru tek yönlü nedensellik, v) Bahreyn için LNFBS1'den LNHD1'e doğru tek yönlü nedensellik, vi) Katar için LNHD1'den LNFBS1'e doğru tek yönlü nedensellik ilişkisi tespit edilmiştir.

5.2. Grup 2 Ülkeleri İçin Yapılan Analiz Sonuçları

Kalkınma düzeyi yüksek olan Grup 2 ülkeleri (Norveç, Güney Kore, Japonya, İsviçre, Amerika Birleşik Devletleri ve Almanya) için yapılan yatay kesit bağımlılığı testi sonuçları Tablo 9'da yer almaktadır. H_0 hipotezi yatay kesit bağımlılığı yoktur; H_a hipotezi yatay kesit bağımlılığı vardır şeklindedir. LNFTS2, LNMCS2 için 2000-2021 dönemi, LNINT2, LNFBS2 için 2000-2020 dönemi dikkate alınmıştır. Tablo 9'da özetlenenen test sonuçlarına göre %5 anlamlılık düzeyinde Ho hipotezi reddedilmektedir. Diğer bir ifadeyle modelde LNHD2, LNFTS2, LNMCS2 LNINT2, LNFBS2, değişkenleri için yatay kesit bağımlılığı mevcuttur.

Tablo 9. Yatay Kesit Bağımlılığı Test Sonuçları

LNHD2=F(LNFTS2)	**İstatistik Değeri**	**Olasılık Değ. (p-değeri)**
LM (Breusch, Pagan 1980)	91.303 **	0.000
CDlm (Pesaran 2004)	13.931**	0.000
CD (Pesaran 2004)	7.672 **	0.000
LMadj (PUY, 2008)	30.083**	0.000
LNFTS2=F(LNHD2)		
LM (Breusch, Pagan 1980)	108.593**	0.000
CDlm (Pesaran 2004)	17.088 **	0.000
CD (Pesaran 2004)	8.215 **	0.000
LMadj (PUY, 2008)	29.710 **	0.000
LNHD2=F(LNMCS2)		
LM (Breusch, Pagan 1980)	126.132**	0.000
CDlm (Pesaran 2004)	20.290**	0.000
CD (Pesaran 2004)	10.891**	0.000
LMadj (PUY, 2008)	42.793**	0.000
LNMCS2=F(LNHD2)		
LM (Breusch, Pagan 1980)	105.984 **	0.000
CDlm (Pesaran 2004)	16.611 **	0.000
CD (Pesaran 2004)	9.534 **	0.000
LMadj (PUY, 2008)	43.256**	0.000
LNHD2=F(LNINT2)		
LM (Breusch, Pagan 1980)	141.936**	0.000
CDlm (Pesaran 2004)	23.175**	0.000
CD (Pesaran 2004)	11.579**	0.000
LMadj (PUY, 2008)	40.604 **	0.000
LNINT2=F(LNHD2)		
LM (Breusch, Pagan 1980)	278.276**	0.000
CDlm (Pesaran 2004)	48.067 **	0.000
CD (Pesaran 2004)	16.661 **	0.000
LMadj (PUY, 2008)	9.442 **	0.000
LNHD2=F(LNFBS2)		
LM (Breusch, Pagan 1980)	205.030**	0.000
CDlm (Pesaran 2004)	34.694**	0.000
CD (Pesaran 2004)	14.054**	0.000
LMadj (PUY, 2008)	5.518 **	0.000
LNFBS2=F(LNHD2)		
LM (Breusch, Pagan 1980)	163.054**	0.000
CDlm (Pesaran 2004)	27.031**	0.000
CD (Pesaran 2004)	10.654**	0.000
LMadj (PUY, 2008)	5.816 **	0.000

Not: *, **, *** sırasıyla %1, %5, %10 anlamlılık düzeyini göstermektedir

Tablo 10'da Grup 2 ülkeleri için homojenlik testi sonuçlarına yer verilmiştir. Hipotezler H_0: Eğim katsayıları homojendir. H_a: Eğim katsayıları heterojendir şeklindedir. LNFTS2, LNMCS2 için 2000-2021 dönemi, LNINT2, LNFBS2 için 2000-2020 dönemi dikkate alınmıştır. Tablo 10 homojenlik testi sonuçlarına göre tüm değişkenler için %5 anlamlılık düzeyinde eğim katsayıları homojendir olan Ho boş hipotezi reddedilmektedir. LNFTS2, LNMCS2, LNINT2, LNFBS2 değişkenlerinin eğim katsayılarının heterojen olduğu bulgusu elde edilmiştir.

Tablo 10. Homojenlik Testi Sonuçları

LNFTS2	**İstatistik Değeri**	**Olasılık Değ.(p-değeri)**
Delta_tilde	7.969**	0.000
Delta_tilde_adj	8.545**	0.000
LNMCS2		
Delta_tilde	12.572**	0.000
Delta_tilde_adj	13.482**	0.000
LNINT2		
Delta_tilde	8.456**	0.000
Delta_tilde_adj	9.099**	0.000
LNFBS2		
Delta_tilde	3.974**	0.000
Delta_tilde_adj	4.276**	0.000

Not: *, **,*** sırasıyla %1 , %5, %10 anlamlılık düzeyini göstermektedir.

Tablo 11, Tablo 12, Tablo 13 ve Tablo 14'te Grup 2 ülkeleri için yapılan Konya (2006) nedensellik testi sonuçları verilmiştir. Tablo 11'de sunulan Konya (2006) nedensellik testi sonuçlarına göre, Norveç, İsviçre ve Almanya için %5 anlamlılık düzeyinde LNHD2'den LNFTS2'e doğru tek yönlü nedensellik ilişkisi olduğu, Güney Kore için %10 anlamlılık düzeyinde ve Japonya için %5 ve %10 anlamlılık düzeylerinde LNHD2 ve LNFTS2 değişkenleri arasında çift yönlü nedensellik olduğu, ABD için değişkenler arasında nedensellik ilişkisi olmadığı tespit edilmiştir.

Tablo 11. İnsani Gelişmişlik ve Sabit Telefon Abonelikleri Arasındaki Konya Nedensellik Testi Sonuçları (2000-2021 Dönemi)

Ülke	**H_0: LNFTS2, LNHD2'nin nedeni değildir**				
	Wald İst.	**Boot. Kritik Değ.**			**Sonuç**
		%1	**%5**	**%10**	
Norv.	0.293	6.15	4.61	3.584	lnfts⇏lnhd
G.Kore	0.96***	2.40	1.40	0.937	lnfts→lnhd
Japon.	69.15**	40.0	25.9	20.40	lnfts→lnhd
İsviç.	0.376	18.2	12.1	9.607	lnfts⇏lnhd
ABD	0.162	53.3	36.9	28.45	lnfts⇏lnhd
Alman.	0.502	8.48	6.28	4.928	lnfts⇏lnhd
Panel	19.473[0.078]				Panel
Ülke	**H_0: LNHD2, LNFTS2'nin nedeni değildir**				
	Wald İst.	**Boot. Kritik Değ.**			**Sonuç**
		%1	**%5**	**%10**	
Norv.	11.54**	4.669	2.965	2.217	lnhd→lnfts
G.Kore	0.44***	1.190	0.622	0.420	lnhd→lnfts
Japon.	7.34***	14.98	8.430	5.877	lnhd→lnfts
İsviç.	20.51**	17.28	12.92	11.11	lnhd→lnfts
ABD	1.802	26.71	15.58	10.39	lnhd⇏lnfts
Alman.	71.72**	16.38	12.96	11.22	lnhd→lnfts
Panel	24.727 [0.016]				Panel

Not: *, **, *** sırasıyla %1, %5, %10 anlamlılık düzeyini göstermektedir.

Tablo 12'de yer alan nedensellik testi sonuçlarına göre Norveç ve İsviçre için %5 anlamlılık düzeyinde LNHD2'den LNMCS2'e doğru tek yönlü nedensellik ilişkisi olduğu, Almanya için %10 anlamlılık düzeyinde LNMCS2'den LNHD2'ye doğru tek yönlü nedensellik

ilişkisi olduğu, Güney Kore, Japonya ve ABD için LNHD2 ve LNMCS2 değişkenleri arasında nedensellik ilişkisi olmadığı görülmektedir.

Tablo 12. İnsani Gelişmişlik ve Mobil Hücresel Abonelikleri Arasındaki Konya Nedensellik Testi Sonuçları (2000-2021 Dönemi)

Ülke	H_0: LNMCS2, LNHD2'nin nedeni değildir				
	Wald İst.	Boot. Kr. Değ.			Sonuç
		%1	%5	%10	
Norv.	6.454	14.1	10.5	8.48	lnmcs⇏lnhd
G.Kore	6.727	41.5	30.0	24.6	lnmcs⇏lnhd
Japon.	0.047	4.69	2.95	2.29	lnmcs⇏lnhd
İsviç.	8.649	38.7	31.4	27.9	lnmcs⇏lnhd
ABD	7.961	22.9	18.5	16.0	lnmcs⇏lnhd
Alman.	8.2***	16.3	9.27	7.21	lnmcs→lnhd
Panel	9.821 [0.632]				
Ülke	**H_0: LNHD2, LNMCS2'nin nedeni değildir**				
	Wald İst.	**Boot. Kr. Değ.**			**Sonuç**
		%1	**%5**	**%10**	
Norv.	7.9 **	3.13	1.87	1.30	lnhd→lnmcs
G.Kore	0.429	25.4	17.7	14.6	lnhd⇏lnmcs
Japon.	0.074	8.50	5.78	4.58	lnhd⇏lnmcs
İsviç.	3.41**	4.48	2.39	1.73	lnhd→lnmcs
ABD	2.014	6.70	3.83	2.91	lnhd⇏lnmcs
Alman.	2.079	14.7	8.02	6.43	lnhd⇏lnmcs
Panel	12.632[0.396]				

Not: *,**,*** sırasıyla %1, %5, %10 anlamlılık düzeyini göstermektedir.

İnsani gelişmişlik ve internet kullanan bireylerin nüfus içindeki payı arasındaki Konya nedensellik testi sonuçları Tablo 13'te görülmektedir.

Tablo 13. İnsani Gelişmişlik ve İnternet Kullanan Bireylerin Nüfus İçindeki Payı Arasındaki Konya Nedensellik Testi Sonuçları (2000-2020 Dönemi)

Ülke	H_0: LNINT2, LNHD2'nin nedeni değildir				
	Wald İst.	Boot. Kritik Değ.			Sonuç
		%1	%5	%10	
Norv.	14.4**	14.1	9.68	7.81	lnint→lnhd
G. Kore	5.334	12.8	8.14	6.04	lnint⇏lnhd
Japon.	0.266	3.19	1.79	1.17	lnint⇏lnhd
İsviç.	7.906	14.1	10.5	8.99	lnint⇏lnhd
ABD	2.818	13.8	8.97	7.05	lnint⇏lnhd
Alman.	1.453	18.0	8.94	6.65	lnint⇏lnhd
Panel	21.798[0.040]				Panel
Ülke	**H_0: LNHD2, LNINT2'nin nedeni değildir**				
	Wald İst.	**Boot. Kritik Değ.**			**Sonuç**
		%1	**%5**	**%10**	
Norv.	14.3**	6.98	3.95	3.10	lnhd→lnint
G. Kore	13.2**	13.7	8.24	6.78	lnhd→lnint
Japon.	0.256	6.51	3.32	2.38	lnhd⇏lnint
İsviç.	3.913	8.31	5.43	4.47	lnhd⇏lnint
ABD	6.857	15.3	9.76	8.37	lnhd⇏lnint
Alman.	0.004	15.4	7.98	5.64	lnhd⇏lnint
Panel	30.617[0.002]				Panel

Not: *, **, *** sırasıyla %1, %5, %10 anlamlılık düzeyini göstermektedir.

Tablo 13'te yer alan bulgulara göre Norveç için %5 anlamlılık düzeyinde LNHD2 ve LNINT2 değişkenleri arasında çift yönlü nedensellik ilişkisi bulunmaktadır. G. Kore için %5 anlamlılık düzeyinde LNHD2'den LNINT2'ye doğru tek yönlü nedensellik ilişkisi olduğu bulunmaktadır. Japonya, İsviçre, ABD ve Almanya için LNHD2 ve LNINT2 değişkenleri arasında nedensellik ilişkisi olmadığı tespit edilmiştir.

Tablo 14'te verilen sonuçlara göre; Norveç ve ABD için %10 anlamlılık düzeyinde LNFBS2'den LNHD2'ye tek yönlü nedensellik ilişkisi olduğu, G. Kore için %5 anlamlılık düzeyinde ve Almanya için %10 anlamlılık düzeylerinde LNHD2'den LNFBS2'ye doğru tek yönlü nedensellik ilişkisi olduğu, Japonya için %5 ve %10 anlamlılık düzeylerine göre LNHD2 ve LNFBS2 değişkenleri arasında çift yönlü nedensellik ilişkisi olduğu, İsviçre için değişkenler arasında nedensellik ilişkisi olmadığı bulgusu elde edilmiştir.

Tablo 14. İnsani Gelişmişlik ve Sabit Geniş Bant Aboneliklerini Arasındaki Konya Nedensellik Testi Sonuçları (2000-2020 dönemi)

Ülke	H_0: LNFBS2, LNHD2'nin nedeni değildir				
	Wald İst.	Bootstrap Krit. Değ.			Sonuç
		%1	%5	%10	
Norv.	9.7***	14.9	10.9	9.20	lnfbs→lnhd
G. Kore	1.211	8.64	6.42	5.0	lnfbs⇏lnhd
Japon.	62.71**	34.5	21.8	16.1	lnfbs→lnhd
İsviç.	1.581	10.5	8.35	7.02	lnfbs⇏lnhd
ABD	4.9***	7.5	5.27	4.28	lnfbs→lnhd
Alman.	1.329	18.2	12.2	9.26	lnfbs⇏lnhd
Panel	24.775 [0.016]				
Ülke	H_0: LNHD2, LNFBS2'nin nedeni değildir				
	Wald İst.	Bootstrap Krit. Değ.			Sonuç
		%1	%5	%10	
Norv.	0.278	7.51	3.28	2.41	lnhd⇏lnfbs
G. Kore	126.7**	15.0	9.46	7.10	lnhd→lnfbs
Japon.	4.5***	14.2	7.45	4.48	lnhd→lnfbs
İsviç.	1.423	3.67	1.84	1.44	lnhd⇏lnfbs
ABD	2.739	6.84	3.91	3.06	lnhd⇏lnfbs
Alman.	11.5***	17.0	11.9	8.78	lnhd→lnfbs
Panel	20.311 [0.061]				

Not: *,**,*** sırasıyla%1, %5, %10 anlamlılık düzeyini göstermektedir.

Çalışmadan elde edilen bulgulara göre Grup 2 ülkeleri için; i) Güney Kore ve Japonya'da LNHD2 ve LNFTS2 arasında çift yönlü, ii) Norveç, İsviçre ve Almanya için LNHD2'den LNFTS2'e doğru tek yönlü, iii) Almanya'da LNMCS2'den LNHD2'ye doğru tek yönlü, vi) Norveç ve İsviçre'de LNHD2'den LNMCS2'e doğru tek yönlü, v) Norveç'te LNHD2 ve LNINT2 arasında çift yönlü, vi) G. Kore için LNHD2'den LNINT2'ye doğru tek yönlü, vii) Norveç ve ABD'de LNFBS2'den LNHD2'ye tek yönlü, viii) G. Kore ve Almanya için LNHD2'den LNFBS2'ye doğru tek yönlü, ix) Japonya için LNHD2 ve LNFBS2 değişkenleri arasında çift yönlü nedensellik ilişkisi olduğu sonucuna ulaşılmıştır.

6. Politika Tartışmaları

Bu çalışmada dijitalleşme ve kalkınma ilişkisi incelenmiştir. Çalışmada ülkeler doğal kaynak bakımından zengin ülkeler ile kalkınma düzeyi yüksek olan ülkeler olmak üzere iki gruba ayrılarak incelenmiştir. Analizde ülkelerin 2000-2021 dönemi dijitalleşme ve kalkınma verileri

kullanılmıştır. Değişkenler arasındaki ilişki yatay kesit bağımlılığı testleri, homojenlik testleri ve Konya (2006) nedensellik testi kullanılarak analiz edilmiştir. Çalışmada kalkınma göstergesi olarak insani gelişme endeksi, dijitalleşme göstergesi olarak sabit telefon abonelikleri (100 kişi başına), mobil hücresel abonelikleri (100 kişi başına), internet kullanan bireylerin payı (nüfusun %), sabit geniş bant abonelikleri (100 kişi başına) kullanılmıştır. Literatürde yapılan çalışmaların büyük bir bölümünde ekonomik büyüme ve teknolojik gelişme arasındaki ilişki üzerine odaklanılmıştır. Bu çalışmada ise dijitalleşme ve kalkınma ilişkisi ele alınarak literatüre katkı sağlamak amaçlanmıştır.

Çalışmadan elde edilen bulgular doğrultusunda analize dâhil edilen ülkelerdeki dijitalleşme ve kalkınma arasındaki nedensellik ilişkisi değerlendirildiğinde; i) Dijitalleşme ve kalkınma arasındaki nedensellik ilişkisi Grup 1 ülkelerinde Grup 2 ülkelerine göre göreceli olarak düşüktür. Diğer bir ifadeyle doğal kaynak bakımından zengin olan Grup 1 ülkelerinde dijitalleşme ve kalkınma arasındaki nedensellik ilişkisi Grup 2 ülkelerine göre daha az sayıdadır. ii) Grup 2 ülkelerinde ülke bazında dijitalleşme göstergeleri ve kalkınma göstergesi arasında daha çok nedensellik ilişkisi tespit edilmiştir. Grup 1 ülkelerinde dijitalleşmenin kalkınmayı, kalkınmanın da dijitalleşmeyi, Grup 2 ülkelerine göre daha az etkilemesi bu ülkelerdeki petrol zenginliğinin refahı beklenilen boyutta artırmadığını göstermektedir. Diğer bir ifadeyle doğal kaynak bakımından zengin olan Grup 1 ülkeleri açısından bu doğal kaynak üstünlüğünün dijitalleşme ve kalkınma ilişkisi üzerinde çok etkili olmadığı yönündedir. Elde edilen bu bulgu Grup 1 ülkeler için kaynak laneti hipotezini destekler niteliktedir. Kalkınma düzeyi yüksek olan Grup 2 ülkeleri için ise dijitalleşme ve kalkınma ilişkisinin daha kuvvetli olduğu tespit edilmiştir. Grup 2 ülkeleri içinde yer alan Norveç ve ABD hem kalkınma düzeyi yüksek hem de doğal kaynak bakımından zengin olan ülkelerdir. Bu ülkelerin bulguları dikkate alındığında Norveç için doğal kaynak lanetinin geçerli olmadığı söylenebilir. Norveç'in zengin doğal kaynakları yanında, ekonomik dönüşümünde iyi eğitimli insan sermayesi etkili olmaktadır. Aynı zamanda Norveç kaliteli siyasi ve hukuki kurumlara sahip olan bir ülkedir. iii) Grup 2 ülkelerinden elde edilen nedensellik bulguları nedensellik yönünün ağırlıklı olarak kalkınmadan dijitalleşmeye doğru olduğu yönündedir. Diğer bir ifadeyle bu ülkelerde kalkınmanın dijitalleşmeyi olumlu yönde etkilediği sonucuna ulaşılmıştır. Bu sonucun elde edilmesinde bu ülkelerde dijitalleşme için gerekli altyapıların sağlanmış olması, ar-ge için yapılan harcamaların yüksek olması, kalkınma düzeyi yükseldikçe hanehalkının dijital teknolojilere yönelik taleplerinin artması gibi faktörlerin etkiliği olduğu söylenebilir. Çalışmadan elde edilen bulgular literatürde dijitalleşme ve kalkınma ilişki ile ilgili olarak daha önce yapılmış olan Hardy (1980), David (2019), Altay Topçu (2021), Zhang vd. (2021), UNCTAD (2021), Akyol vd. (2023) çalışmaların sonuçları ile benzerlik göstermektedir. Dijitalleşme ve ekonomik kalkınma ilişkisinin ortaya konulması politika yapıcılar açısından önem göstermektedir. Dijitalleşme konusunun ekonomik kalkınma kapsamında kalkınma politikalarında yer alması toplum refahının artırılmasında etkili olacaktır.

7. Sonuç

Endüstri 4.0 ile başlayan teknolojideki hızlı dönüşüm dijitalleşme kavramını önemli hale getirmiştir. Günümüzde dijitalleşmenin ekonomiler ve sosyal yaşam üzerindeki etkileri hem gözlemlenmekte hem de hissedilmektedir. Dijitalleşmenin ekonomi üzerinde üretimi, ticareti ve istihdamı artırma, maliyetleri düşürme, hizmet kolaylığı sağlayarak zaman tasarrufu sağlama gibi olumlu etkileri olduğu kabul edilmektedir. Teknolojik gelişmenin sağlamış olduğu dijitalleşme

ekonomik büyüme ve ekonomik kalkınmanın önemli unsurları arasında yer almaktadır. Dijitalleşmenin ve dijitalleşme sürecinin insan yaşamını daha kolay ve daha kaliteli hale getirmesi dijitalleşme kavramını kalkınma ile yakından ilişkilendirmektedir.

Ülkelerin ekonomik kalkınma düzeylerinin yükselmesi insanların yaşam standartlarını iyileştirmektedir. Özellikle ekonomik büyüme tarafından desteklenen ekonomik kalkınmanın ülke refahını artırdığı gözlemlenmektedir. Bununla birlikte ekonomik kalkınmayı desteklemeyen ekonomik büyüme ise gerilemeye neden olabilmektedir. Bu durum literatürde "Kalkınmasız Büyüme" kavramı ile açıklanmaktadır. Kalkınmasız büyüme genellikle doğal kaynak bakımından, özellikle petrol bakımından, zengin olan ülkelerde karşılaşılan bir durumdur. Zengin doğal kaynağa sahip olmak başlangıçta avantaj gibi görülse de bu ülkelerde kaynakların doğru alanlara aktarılmaması, yerli üretimin düşük olması, siyasi boşluklar, gelir dağılımındaki adaletsizlik, eğitim düzeyindeki düşüklük, ekonomik ve politik şeffaflığın az olması gibi faktörler bu avantajı dezavantaja dönüştürmektedir. Ülkede gerekli koşulların sağlanamaması ise kalkınmanın önünde engel oluşturmaktadır. Kalkınmasız büyümenin gözlemlendiği ülkeler ağırlıklı olarak doğal kaynak laneti ile ilişkilendirilmekte ve doğal kaynak laneti doğal kaynak zenginliğinin ekonomi, politika ve sosyal yaşam üzerindeki refahı azaltan olumsuz etkileri ile açıklanmaktadır.

Doğal kaynak bakımından zenginliğin ve bu kaynak üstünlüğünün belirli ekonomiler için ekonomik büyüme üzerinde olumlu etkisi olduğu söylenebilir. Örneğin, Norveç ve ABD büyük doğal kaynak rezervlerine sahip olup birçok doğal kaynak zengini gelişmekte olan ülkeden farklı olarak dikkate değer bir ekonomik büyüme performansı göstermiştir. Özellikle Norveç'in ekonomik dönüşümünde zengin doğal kaynakları yanında, iyi eğitimli insan sermayesi, kaliteli siyasi ve hukuki kurumlara sahip olması etkili olmuştur. Çalışmadan elde edilen bulgulara göre doğal kaynak bakımından zengin Grup 1 ülkelerinde dijitalleşme ve kalkınma boyutu dikkate alındığında bu doğal kaynak zenginliğinin kalkınma üzerinde olumlu etkisinin sınırlı düzeyde kaldığı gözlemlenmiştir. Genel olarak çalışmanın sonuçları UNCTAD (2021) tarafından belirtildiği gibi kalkınması yüksek düzeyde olan ülkelerin dijitalleşme olanaklarından ileri düzeyde faydalanırken az gelişmiş ülkelerin dijitalleşme olanaklarından istenildiği gibi fayda sağlayamadığı görüşünü desteklemektedir. Bu ülkelerde doğal kaynaklardan elde edilen gelirlerin, beşeri sermaye yatırımlarında, dijitalleşme alt yapısı ve dijital dönüşümde, araştırma ve geliştirme yatırımlarında kullanılması, kurumsal faktörlerin iyileştirilmesi kalkınmayı olumlu yönde etkileyerek refah düzeyini yükseltecektir. Refahta yaşanan artış ise dijitalleşme sürecini olumlu yönde etkileyecektir. Bu çalışmanın kısıtı dijitalleşme ve kalkınma ilişkisi analiz edilirken sınırlı sayıdaki ülkenin bilgi ve iletişim alt yapısı göstergeleri dikkate alınmıştır. Diğer çalışmalarda beşeri sermaye yatırımları, sağlık harcamaları, demokrasi, yolsuzluk, kurumsallık gibi değişkenlerin analize dâhil edilmesi ve ülke grubunun genişletilmesi faydalı olacaktır.

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 RELATIONSHIP BETWEEN DIGITALIZATION AND THE NATURAL RESOURCE CURSE APPROACH: OAPEC COUNTRIES

EXTENDED SUMMARY

Purpose of the Study

Technology is one of the important tools in the transformation of societies, and it is considered that one of the main differences between developed and underdeveloped countries is the difference in technology level. The production and use of technology accelerate the digitalization process and increase the quality of human life. The increase in the quality of life is closely related to economic development. This has made the concept of digitalization an important issue for all countries. However, the effects of digitalization on the economy and society may differ according to country. The effects of digitalization on development are among the issues discussed today

Natural resource wealth affects the economy directly and indirectly. It is generally accepted that natural resources have positive effects on the economy. However, in some cases, having rich natural resources may create disadvantages for countries. In these countries, failure to transfer capital accumulation to other sectors leads to a socio-economic decrease in society. In the literature, this situation is referred to as the 'natural resource curse'. Whether having rich natural resources increases the welfare and wealth of a country is a controversial issue. In particular, whether this resource advantage of countries rich in natural resources is effective on the digitalisation and development process.

The number of studies examining the relationship between digitalization and development by considering the natural resource factor is limited. This study aims to contribute to the literature. The first objective of this study is to analyze the relationship between digitalization and economic development. The other aim of the study is to determine the relationship between digitalization and development in countries with relatively abundant oil (relatively low development levels) and countries with relatively high development levels. In other words, it is to determine whether natural resource superiority is effective in the digitalization and development process.

Literature

The determination of digitalization and economic growth is important for the literature. Most of the studies in the economics literature have examined the issue within the scope of digitalization and economic growth (Türedi, 2012; Işık and Kılınç, 2013; Köse and Şentürk, 2017; Niebel, 2018; Aykırı and Bulut, 2018; Lazanyuk and Revinova, 2019; David, 2019; Solomon and Klyton, 2020; Myovella et al., 2020; Kasa, 2020, Lazovic et al., 2022; Gomes et al., 2022; Akyol et al., 2023). In these studies, a positive relationship was found between the variables. In another group of studies (Topdağ, 2021; Hacıimamoğlu, 2021; Çamkaya, 2023), the natural resource curse approach was examined for various countries. One of the first studies on digitalization and economic development is Hardy (1980) and there are studies on the subject in the literature (Torun et al., 2009; Özer and Ünlü 2010; David, 2019; Mamedov et al. 2019; Aly, 2020; Altay Topçu, 2021; İyigüngör, 2002; Zhang et al., 2021; Behera and Sahoo, 2022).

Methodology of the Study

The relationship between the variables in the study was analyzed using the Konya (2006) causality test. In the study, countries are analysed by dividing them into two groups Group 1 and Group 2. In the study, the 2000-2021, 2000-2020, and 2002-2021 periods of the relevant countries were taken into consideration according to the availability of data. In the study, the Human Development Index (LNHD) was used as a development indicator. Digitalization indicators include fixed telephone subscriptions (per 100 people) (LNFTS), mobile cellular subscriptions (per 100 people) (LNMCS), fixed broadband subscriptions (per 100 people) (LNFBS), number of people using the Internet (% population) (LNINT) variables.

Main Findings of the Study

Group 1 countries i) Unidirectional causality from LNFTS1 to LNHD1 for Saudi Arabia, ii) Bidirectional causality between LNMCS1 and LNHD1 for Saudi Arabia and Bahrain, iii) Unidirectional causality from LNHD1 to LNMCS1 for the UAE, iv) Unidirectional causality from LNINT1 to LNHD1 for Saudi Arabia, v) Unidirectional causality from LNFBS1 to LNHD1 for Bahrain, vi) For Qatar, a unidirectional causality relationship was found from LNHD1 to LNFBS1. According to the findings of the study, for Group 2 countries; i) bidirectional relationship between LNHD2 and LNFTS2 in South Korea and Japan, ii) unidirectional from LNHD2 to LNFTS2 in Norway, Switzerland, and Germany, iii) unidirectional from LNMCS2 to LNHD2 in Germany, vi) Unidirectional from LNHD2 to LNMCS2 in Norway and Switzerland, v) Bidirectional between LNHD2 and LNINT2 in Norway, vi) LNHD2 to LNINT2 for S. Korea, vii) LNFBS2 to LNHD2 for Norway and USA, viii) LNHD2 to LNFBS2 for S. Korea and Germany, ix) It is concluded that there is a bidirectional causality relationship between LNHD2 and LNFBS2 variables for Japan.

Results

When the causality relationship between digitalization and development in the countries included in the analysis is evaluated: i) The causal relationship between digitalization and economic development is relatively lower in Group 1 countries than in Group 2 countries. ii) In Group 2 countries, a causality relationship was found between country-based digitalization indicators and development indicators. This shows that the resource curse hypothesis is valid for Group 1 countries. In other words, the fact that digitalization affects economic development and development affects digitalization less in Group 1 countries than in Group 2 countries shows that oil wealth in these countries does not increase welfare to the expected extent. The findings suggest that this natural resource superiority is not very effective on the relationship between digitalization and development for Group 1 countries, which are rich in natural resources, while the relationship between digitalization and development is stronger for Group 2 countries, which are not rich in natural resources. iii) The causality findings obtained in Group 2 countries suggest that the causality relationship from development to digitalization is relatively higher. In other words, it is concluded that development positively affects digitalization in these countries.

In resource-rich countries, the use of income from natural resources in human capital investments, digitalization infrastructure and digital transformation, research and development investments, and the improvement of institutional factors will positively affect development and increase the level of welfare.