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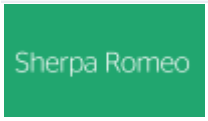

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Measuring the Financial Performance of Reinsurance Companies in Türkiye with LODECI, CRADIS and AROMAN MCDM Methods

LODECI, CRADIS ve AROMAN ÇKKV Yöntemleri ile Türkiye'de Reasürans Şirketlerinin Finansal Performansının Ölçülmesi

Arif ÇİLEK
Asst. Prof. Dr., Giresun University
arif.cilek@giresun.edu.tr
https://orcid.org/ 0000-0002-9277-3953

Onur ŞEYRANLIOĞLU
Asst. Prof. Dr., Giresun University
onurseyranlioglu@gmail.com
https://orcid.org/0000-0002-1105-4034

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ABSTRACT

This study aims to measure and evaluate the financial performance of four reinsurance companies operating in Türkiye between 2022 and 2023 using the LODECI, CRADIS, and AROMAN decision models. In the study, the LODECI procedure was used to calculate the objective weight coefficients of ten performance evaluation indicators considered. Subsequently, the financial performance of the reinsurance companies over the years was assessed using the CRADIS and AROMAN procedures. The results obtained from the weighting procedures indicate that the conservation ratio is the most influential criterion on financial performance, whereas the active profitability ratio has been found to have the least effect. The CRADIS and AROMAN ranking procedures show that the performance rankings for 2022 and 2023 are as follows; Türk Reasürans, Türk Katılım Reasürans, Milli Reasürans, and VHV Reasürans. Moreover, the sensitivity analysis, carried out using 100 different scenarios to test the consistency of the findings from the proposed model, confirms that the current models produce robust and consistent results.

Anahtar Kelimeler:
Sigorta, Reasürans, Finansal Performans, ÇKKV
Jel Kodları:
C61, E60, G22

ÖZET

Bu çalışmanın amacı, Türkiye'de faaliyet gösteren dört reasürans şirketinin 2022-2023 yılları arasındaki finansal performansının LODECI, CRADIS ve AROMAN karar modeli kullanılarak ölçülmesi ve değerlendirilmesidir. Çalışmada dikkate alınan on adet performans değerlendirme göstergelerinin objektif ağırlık katsayılarının hesaplanmasında LODECI prosedürü kullanılmıştır. Daha sonra, reasürans şirketlerinin yıllara ilişkin finansal performansları CRADIS ve AROMAN prosedürü vasıtasıyla değerlendirilmiştir. Ağırlıklandırma prosedürlerinin uygulanmasından elde edilen sonuçlar göstermektedir ki konservasyon oranı finansal performans üzerinde etkili olan en önemli kriterdir. Bununla beraber aktif kârlılık oranı ise performans üzerinde en az etkiye sahip kriter olduğu tespit edilmiştir. CRADIS ve AROMAN sıralama prosedürleri, 2022 ve 2023 yıllarında performans sıralamalarının Türk Reasürans, Türk Katılım Reasürans, Milli Reasürans ve VHV Reasürans şeklinde olduğunu göstermektedir. Ayrıca, önerilen modelden elde edilen bulguların tutarlılığını test etmek amacıyla 100 farklı senaryo kullanılarak gerçekleştirilen duyarlılık analizi sonuçları mevcut modellerin sağlam ve tutarlı sonuçlar ürettiğini teyit etmektedir.

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1. INTRODUCTION

The main function of insurance in an economy is to manage risks arising from nature or related to human life. To support this, the insurance system fulfils the functions of collecting resources and transferring these resources in various ways (Kartasheva, 2014: 1). Insurance companies, which undertake the carriage of various risks of individuals and institutions in return for a certain premium, face the risk that the risks they guarantee may occur simultaneously and widely. However, it is not possible for insurance companies to guarantee all kinds of risks in terms of their technical and financial obligations. The reinsurance function is one of the most important elements that make it possible to manage these fundamental risks, which are vital for the financial system and economic life. With this reinsurance support, insurance companies can provide coverage to policies far exceeding their risk acceptance capacity and realize rapid claim payments (Ayan, 2020: 1004; Özcan &Yıldırım, 2021: 2).

Reinsurance aims to transfer the risks carried by insurance companies to national or international reinsurance companies, thus increasing the total risk capacity they can undertake, protecting the financial balance of the company and increasing its financial strength (Özdemir, 2022: 264). In other words, it is the partial or complete transfer of the insurance amount remaining from the retention shares determined by the insurance companies according to the technical structure of the risk and their financial possibilities from the risks they have taken on by insuring them to one or more other insurers or to reinsurance companies established exclusively for this business (Özer, 2014: 304; Özkan, 2015: 210). As stated, the primary purpose of reinsurance is to spread the risk of loss. In this way, the risks of losses that may lead the insurance company to bankruptcy are spread to the reinsurance company. Secondly, the reinsurance system enables the insurance company to accept risks that may be beyond its capacity and to transfer part of the risk to the reinsurance company. Reinsurance frees up capital reserves by allowing them to be treated as an asset in the financial statements of the insurance company, which in turn reduces the statutory reserve requirement. Thus, the insurance company has more capital and can use this capital in investments or insure more and different types of risks. This system encourages small insurance companies to compete with larger insurers. As a result, reinsurance creates more underwriting opportunities for insurance companies, enabling them to accept a wider range of risks and to offer higher policy limits on the risks they accept (Thomas, 1992: 1549).

As of the end of 2023, a total of 72 companies were operating in the insurance and private pension sector in Türkiye, of which 50 were non-life insurance companies, 3 were exclusively life insurance companies, 15 were pension companies and 4 were reinsurance companies. The total assets of the insurance and private pension sector, which has a 5.3% share in the financial sector, increased by 88% to TL 1,471 billion as of the end of 2023 compared to the end of the previous year. The sector also stands out in premium production. In 2023, the premium production of the sector increased by 106% compared to the previous year and reached TL 483 billion. The share of premium production in GDP was 1.8%. TL 57 billion of the production was realized in the life branch and TL 426 billion in non-life branches. As of year-end 2023, reinsurance companies' premium production increased by 124% year-on-year to TL 22 billion (SEDDK, 2023: 5-16).

Table 1. Financial Indicators (TL Billion)

	2019	2020	2021	2022	2023	2022-2023 Change (%)
Panel 1: Asset Size						
HD insurance companies	77	96	125	248	507	104
H/E insurance companies	154	205	294	514	920	79
Insurance companies total	232	301	419	762	1,472	87
Reinsurance companies	5	7	10	19	44	132
Insurance sector total	237	308	429	781	1,471	88
Financial sector	5,028	6,795	10,271	16,540	27,752	68
Insurance sector share (%)	4.71	4.53	4.18	4.72	5.30	12
Panel 2: Financial Indicators Specific to Reinsurance Companies						
Asset size/Financial sector (% share)	0.099	0.103	0.097	0.114	0.158	38
Shareholders' Equity	2.4	3.2	4.1	8	14	75
Technical profit	0.1	0.2	0.5	1	1.6	60
Balance sheet profit	0.3	0.5	0.8	1.6	5	212.5

Source: (SEDDK, 2023: 13-16). **Note:** HD stands for non-life insurance companies; H/E stands for life insurance and pension companies. Some data in the table are based on the authors' calculations from the relevant source.

To summarize the information specific to the reinsurance system in the light of the information presented in Table 1, reinsurance companies, which have a small share in the Türkiye financial system, received a share of approximately 0.1% in 2019 in terms of asset size, while this ratio increased to 0.15% in 2023. It is seen that the sector increased its asset size by approximately 50% between 2019 and 2023. Although the share of the reinsurance system in the financial system is very low in Türkiye, the joint risk management practices established with insurance companies are of vital importance for a country's economy. Considering the progress made by the sector in terms of asset size, shareholders' equity, technical profit and balance sheet profit in the 2019-2023 period, it is thought that the state-owned companies Türk Reasürans and Türk Katılım Reasürans, which have entered the sector in recent years, have played an important role in this development. At the point where reinsurance companies have reached in terms of both company and financial indicators, the financial performance of these companies is of vital importance for the sustainability of the insurance sector and the overall economic system. The strong financial structure of these companies can support the resilience of the insurance sector to shocks, such as large-scale natural disasters or economic crises. In addition, strong financial performance increases the capacity of reinsurance companies to fulfil their obligations and may instill confidence in the market. Thus, the effectiveness of risk management in the country can be increased by contributing to the stability of both insurance companies and the economy in general.

In this framework, the aim of this study is to analyze the financial performance of four reinsurance companies operating in Türkiye with annual data for the period 2022-2023 using LODECI-based CRADIS and AROMAN hybrid MCDM (Multi Criteria Decision Making) methods.

The decision-making process used in the application of this research is a mentally complex process, but it is a problem-solving program that aims to reach a desired result by considering different aspects. This process may be rational or irrational, and on the other hand, it may contain implicit or explicit assumptions influenced by various factors such as physiological, biological, cultural and social. All these aspects can influence the levels of authority and risk and the level of complexity of the decision-making process. Nowadays, complex decision-making problems can be solved using mathematical equations, multiple statistics, mathematics, economic theories and computer devices that help to automatically calculate and predict the solutions to these problems (Taherdoost & Madanchian, 2023: 77). In this framework, in recent years, MCDM methods have enabled the measurement of financial performance in a sound manner. These methods make financial decision processes more objective and transparent by balancing between different alternatives and criteria. In this way, it is possible to analyze the financial position of companies more accurately and to make strategic decisions.

The following comments can be made about the originality of this research and the motivation for writing it. Firstly, with the entry of state-owned reinsurance companies into the reinsurance market in Türkiye in recent years, competition has moved to a different dimension and the number of companies has increased from two (Milli Reasürans and VHV Reasürans) to four (Türk Reasürans and Türk Katılım Reasürans). A review of the relevant literature reveals that there is no financial performance study based on four reinsurance companies and this study is written with this main motivation. Although there is a very limited number of studies on the financial performance of reinsurance companies in Türkiye (Yılmaz, 2021a; Yılmaz, 2021b; Taşcı, 2024a), there is a similar situation in the international literature (Bawa & Verma, 2017; Mukherjee et al., 2020). Secondly, it is the application of MCDM methods in this study, which contain the methods that are closest to producing objective and healthy results in revealing the financial performance of companies. Although financial performance has been analyzed with MCDM methods as in Yılmaz (2021a), Yılmaz (2021b) and Taşcı (2024b), in this study, the methods developed in recent years and up-to-date methods were used. LODECI (LOgarithmic DEcomposition of Criteria Importance) developed by Pala (2024a) was used to determine the importance level of the criteria; CRADIS (Compromise Ranking of Alternatives from Distance to Ideal Solution) developed by Puška et al. (2022a) and AROMAN (Alternative Ranking Order Method Accounting for Two-Step Normalization) developed by Bošković et al. (2023a) were used to rank the performance of alternatives. The LODECI-based CRADIS and AROMAN hybrid MCDM model has been applied for the first time in financial performance measurement. The LODECI method offers flexibility, efficiency and accuracy in solving nonlinear systems. This method is a powerful tool for numerical analysis, especially for complex problems that are difficult to solve analytically. CRADIS method offers advantages such as simplicity, flexibility, consistency and fast results in multi-criteria decision-making processes. This method has become popular especially because it produces balanced and reliable solutions in complex problems. The AROMAN method offers a systematic, flexible, transparent and objective approach to MCDM problems. These characteristics make the method an effective and reliable tool in complex decision problems. Finally, the criteria used to measure financial performance in the study are the most frequently used criteria by the practitioners in the sector, although they are sufficient and standardized criteria that can reveal

the financial health of a reinsurance company. All these reasons make this research different and unique from the previous ones and it is thought that it will enrich literature.

The other stages of the research are designed as follows. After the introduction, the relevant literature review, the methods used in the research and the application process are detailed. The research is completed with the conclusion and evaluation phase.

2. LITERATURE REVIEW

In the literature, there is a very limited number of studies addressing the financial performance of reinsurance companies with various methods. Ndirangu (2014), one of the examples of research on Kenya from African countries, analyzed the impact of exchange rate risk management practices on the financial performance of reinsurance companies. The research was conducted with primary data obtained through a questionnaire and secondary data obtained from the financial reports of the companies for the years 2008-2012. The data were analyzed by multiple regression methods. The research findings revealed that the ratio of foreign currency profits to total profits and the use of operational hedging are critical variables to improve financial performance for managers aiming at shareholder value maximization. Muchiri & Njoka (2021) examined how the financial performance of 7 reinsurance companies operating in Kenya is affected by the corporate governance practices of the companies using the regression analysis method with data for the period 2013-2017. The concept of corporate governance is measured in terms of board size, board composition, board independence and duality of the CEO. The research findings reveal that board size and composition have a positive and significant relationship with the financial performance of companies. In addition, the study also revealed that there is a positive and significant relationship between board independence and financial performance measures such as return on assets. Olarewaju & Msomi (2022) examined the profitability of 42 reinsurance companies operating in Sub-Saharan African countries using the generalized method of moments with data for the period 1991-2020. In the study, it is argued that reinsurance companies should expand their services and achieve premium growth to sustain their profitability, and it is determined that factors such as GDP, competition, premium growth, investment performance, underwriting risk and operational efficiency affect the profitability of companies.

Bawa & Verma (2017), one of the examples of research on the financial performance of General Insurance Corporation of India Reinsurance (GIC RE), which has a very prominent position in the Indian insurance market and dominates the Indian reinsurance market, conducted a financial performance analysis with the ratios obtained from the annual reports of the company with data for the period 2006-2015. CARAMELS (capital adequacy, asset quality, reinsurance and actuarial issues, management soundness, income/profitability, liquidity and sensitivity to market risk) model was used in the research. According to the findings of the research, the company has performed well over the years; however, improvements in the combined ratio and liquidity would be beneficial. In another study on GIC RE, Mukherjee et al. (2020) examined the financial performance of this company in four different ways with data for the period 2002-2018. Firstly, the financial performance is analyzed by using some financial ratios; secondly, the consistency of different financial performance indicators of the company; thirdly, the internal growth capacity of the company; and finally, the probability of financial distress of the company. The net loss ratio, the ratio of company expenses and underwriting commission to net premium earned, the return on assets ratio, the ratio of net premium to gross premium expressed as risk retention ratio, the ratio of incurred losses and expenses to earned premium expressed as combined ratio were used to measure financial performance. Kendall's Coefficient of Consistency was used to assess the consistency of the company's different financial performance indicators, and the growth rate was used to assess the internal growth capacity. Finally, the probability of financial distress is analyzed with the modified Altman Z-score model, which is a multivariate discriminant analysis method, and Ohlson's O-score model, which is a logit analysis technique. According to the results of the research, it has been determined that the financial performance by years is partially satisfactory and there is no significant consistency between different financial performance indicators. Moreover, while the results confirm that the company does not have the capacity to grow internally, there is a significant likelihood of financial distress soon.

Yılmaz (2021a), one of the rare studies on the financial performance of reinsurance companies in Türkiye, analyzed the financial performance of Milli Reasürans, Türk Reasürans and VHV Reasürans operating in Türkiye between 2018 and 2020 using the Weighted Product Method (WPM). In the study, equity/total assets representing capital adequacy, current assets/total assets and current ratio representing liquidity ratios, financial liabilities/equity and liabilities/equity representing financial structure ratios, return on assets and return on equity representing profitability, and the share of total assets in the insurance market as the sector share were used.

According to the performance results, Milli Reasürans was the most successful company between 2018 and 2020. This company was followed by Türk Reasürans and VHV Reasürans, respectively. The factors that are effective in Milli Re's high performance are high sector share, capital adequacy, profitability and low financial indebtedness. With the same company samples, Yılmaz (2021b) used AHP (Analytical Hierarchy Process) and ELECTRE MCDM methods to analyze financial performance with 2020 data in another study. In the study, equity/total assets, current ratio, return on assets and return on equity ratios were used to represent capital adequacy. According to the weighting findings obtained by the AHP method, the most important criterion affecting the performance of the companies is the return on equity, while the least effective criterion is the current ratio. In ELECTRE findings, Milli Reasürans was the highest performing company in 2020, while the performance of Türk Reasürans and VHV Reasürans was measured at the same level. Taşçı (2024b) analyzed the financial performance of Milli Reasürans, one of the leading companies in the reinsurance market in Türkiye, with the PSI-MEREC-ARAS decision model, which is one of the MCDM methods, using annual data for the period 2015-2022. Liquidity ratio, current ratio, return on equity, return on assets, loss ratio, expense ratio, combined ratio, technical profitability ratio, retention ratio and claim settlement ratio were used in the study. According to PSI and MEREC objective weighting methods, the conservation ratio is the most effective criterion on financial performance, while the technical profitability ratio is the criterion with the least effect on performance. In the ranking made by the ARAS method, the company showed the best performance in 2016 and the worst performance in 2015.

The fact that studies on the financial performance of reinsurance companies are rare shows that there is a lack of research in this field both in the world and in Türkiye. Therefore, it is necessary to analyze the reinsurance market, whose efficiency in the finance sector in Türkiye is increasing day by day, and to make it the subject of academic studies. In this framework, in this study, LODECI, CRADIS and AROMAN MCDM methods, which have been developed in recent years and have very limited use in the literature, have been used to evaluate the financial performance of four reinsurance companies (Milli Reasürans, VHV Reasürans, Türk Reasürans and Türk Katılım Reasürans) operating in 2022-2023.

As stated before, the methods used in this research are the most up-to-date methods used in the weighing of criteria and performance ranking of alternatives developed in recent years. Among these methods, LODECI was introduced by Pala (2024a). Pala (2024a), in the assessment of the social progress of the Member States of the European Union; Pala et al. (2024), in the evaluation of the financial performance of cement companies operating in Borsa Istanbul; Pala (2024b), in the evaluation of social discrimination in OECD countries; Yalçın et al. (2024), commercial insurance selection are some application areas where this method is used. CRADIS, developed by Puška et al. (2022a), has found application in the performance ranking of alternatives in recent years. Puška et al. (2022a), in the assessment and selection of waste incineration plants; Puška et al. (2022b), in the selection of green suppliers in the agricultural sector; Puška et al. (2023), in the selection of electric cars; Starčević et al. (2022), in assessing the impact of foreign direct investments on the sustainability of the economic system; Dordevic et al. (2022), in production optimization; Krishankumar & Ecer (2023), in the selection of IoT service provider for sustainable transportation; Ulutaş et al. (2023), in environmental impact and energy use in production; Keleş (2023), in the assessment of livable power center cities of the G7 countries and Türkiye; Xu et al. (2023), in the assessment of sustainable mountain tourism; Wang et al. (2023), in risk assessment in the energy sector; Altıntaş (2023), in the assessment of the welfare performance of the G7 countries; Taşçı (2024a) used the CRADIS method in the evaluation of the performance of the Doğal Afet Sigortaları Kurumu in Türkiye; Kanmaz & Ertuğrul (2024) used it in the selection of electric vehicles; Asker (2024) used it in the evaluation of the impact of the COVID-19 outbreak on the participation banking sector. Another method used in this study for measuring the performance of alternatives is the AROMAN method developed by Bošković et al. (2023a). It is observed that the AROMAN method is used in the selection of electric vehicles by Bošković et al. (2023a); in the cargo bicycle delivery problem by Bošković et al. (2023b); in the driver selection by Čubranić-Dobrodolac et al. (2023); in the determination of sustainable competitiveness levels by Kara et al. (2024); in the forest fire risk assessment by Pishahang et al. (2023); Şahin Macit (2023) in the evaluation of macroeconomic performances of selected European and Central Asian countries; Bakır & İnce (2024) in the evaluation of passenger satisfaction in airline companies; Özekenci (2024) in the evaluation of the financial and environmental performance of a logistics company; Dündar (2024) in the evaluation of the performances of provinces and some regions in Türkiye in terms of benefiting from entrepreneurship supports.

3. METHODOLOGY

In this section, LOCEDI, CRADIS and AROMAN methods used to evaluate the financial success of four reinsurance companies operating in Türkiye according to ten evaluation criteria with the data for the period 2022-2023 are introduced.

3.1. LODECI Method

LODECI as an objective criterion weighting method was proposed by Pala (2024a) to resolve the contradiction between Entropy and MEREC. While Entropy emphasizes a criterion where a few alternatives are significantly superior to others, MEREC focuses on a criterion where a few alternatives are significantly inferior to others. In order to fulfil these two aspects simultaneously, a maximum decomposition approach is applied and evaluated for each alternative according to each criterion. In addition, the use of the logarithmic function in LODECI balances the range of weights on an appropriate scale to avoid the problem of overvaluation of some criteria encountered when using Entropy and MEREC (Pala, 2024a: 3).

The maximum normalization approach proposed for the decision matrix $= \|x_{ij}\|_{(nxm)}$ in the MCDM problem can also be used for LODECI as in Equations 1 and 2 (Pala, 2024a):

$$a_{ij}=\frac{x_{ij}}{x_j^{max}} \text{ benefit criteria} \tag{1}$$

$$a_{ij}=1-\frac{x_{ij}}{x_j^{max}} \text{ cost criteria} \tag{2}$$

The Discrimination Value (AD) is calculated using a_{ij} as in Equation 3.

$$AD_{ij}=maks\{|a_{ij}-a_{rj}|\}\ r\neq i,\ r=1,2,\ldots,n \tag{3}$$

Logarithmic AD (LAD) for each criterion is calculated as in Equation 4.

$$LAD_j=ln\left(1+\frac{\sum_{i=1}^{n} AD_{ij}}{n}\right) \tag{4}$$

The importance levels of the criteria, w_j, are obtained according to Equation 5.

$$w_j=\frac{LAD_j}{\sum_{j=1}^{m} LAD_j} \tag{5}$$

3.2. CRADIS Method

The CRADIS (Compromise Ranking of Alternatives from Distance to Ideal Solution) method developed by Puška et al. (2022a) solves the decision problem based on ideal and non-ideal solutions (Starcevic et al., 2022). The process steps of the CRADIS method, which is expressed as a combination of TOPSIS, ARAS and MARCOS methods, are given below (Puška et al., 2022a).

The evaluation criteria in the decision matrix are normalized by Equation (6) and Equation (7) according to their benefit or cost orientation.

$$x_{ij}=\frac{c_{ij}}{c_j^{max}} \text{ for utility-oriented criteria} \tag{6}$$

$$x_{ij}=\frac{c_j^{min}}{c_{ij}} \text{ for cost-oriented criteria} \tag{7}$$

The normalized decision matrix is multiplied by the criteria weight values obtained because of the CRADIS method as shown in Equation (8) to obtain the weighted normalized decision matrix.

$$v_{ij}=x_{ij}\,.\,w_j \tag{8}$$

In order to find the ideal solution, the largest value in the weighted decision matrix is determined by Equation (9), while in order to find the non-ideal solution, the smallest value in the weighted decision matrix is determined by Equation (10).

$$t_i=max\left(v_{ij}\right) \tag{9}$$

$$t_{ai}=min\left(v_{ij}\right) \tag{10}$$

The deviations of the decision alternatives from the ideal and non-ideal solution are calculated using Equation (11) and Equation (12), respectively.

$$d^{+}=t_i\text{-}v_{ij} \tag{11}$$

$$d^{-}=v_{ij}\text{-}t_{ai} \tag{12}$$

Then, the ideal and non-ideal deviation degrees of each decision alternative are calculated by means of Equation (13) and Equation (14).

$$s_i^{+}=\sum_{j=1}^{m} d^{+} \tag{13}$$

$$s_i^{-}=\sum_{j=1}^{m} d^{-} \tag{14}$$

According to the amount of deviation in the optimum alternatives, the utility function for each alternative is calculated by Equation (15) and Equation (16).

$$K_i^{+}=\frac{s_0^{+}}{s_i^{+}} \tag{15}$$

$$K_i^{-}=\frac{s_i^{-}}{s_0^{-}} \tag{16}$$

In the last step of the method, the average deviation of the degree of utility of the decision alternatives $\left(Q_i\right)$ is calculated by means of Equation (17).

$$Q_i=\frac{K_i^{+}+K_i^{-}}{2} \tag{17}$$

The decision alternative with the highest value $\left(Q_i\right)$ among the decision alternatives is considered as the best alternative.

3.3. AROMAN Method

AROMAN is a new method developed by Bošković et al. (2023a) in order to solve MCDM problems. The main objective of the method is to provide a more accurate computational approach to decision-making problems by combining linear and vector normalization techniques (Čubranić-Dobrodolac et al., 2023: 11). In practice, the AROMAN method combines the values obtained as a result of two-step normalization with the help of a β parameter (Nikolić et al., 2023: 12). This method offers a practical and powerful alternative ranking opportunity by avoiding complex calculations (Kara et al., 2024: 2).

After the initial decision matrix is constructed, normalization is performed in order to standardize the matrix elements between 0 and 1. In this direction, linear normalization with the help of Equations (18) and (19) is applied for both benefit and cost criteria respectively (Bošković et al., 2023a).

$$t_{ij}=\frac{x_{ij}-\min x_{ij}}{\max x_{ij}-\min x_{ij}}\ (benefit) \tag{18}$$

$$t_{ij}=\frac{\max x_{ij}-x_{ij}}{\max x_{ij}-\min x_{ij}}\ (cost) \tag{19}$$

With the help of Equations (20) and (21), vector normalization is applied for both benefit and cost criteria respectively.

$$t_{ij}=\frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}\ (benefit) \tag{20}$$

$$t_{ij}=1-\frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}\ (cost) \tag{21}$$

In this step where the arithmetic mean is used, the matrices obtained as a result of linear and vector normalization are combined with the help of Equation (22).

$$t_{ij}^{norm}=\frac{\beta t_{ij}+(1-\beta)t_{ij}^{*}}{2},\ i=1,2,\ldots,m;\ j=1,2,\ldots,n. \tag{22}$$

Where t_{ij}^{norm} refers to the combined and averaged normalized matrix and the parameter β represents a weighting factor ranging between 0 and 1. Bošković et al. (2023a) suggested a threshold of 0.5 for the β parameter.

The combined normalized matrix elements are multiplied by the weight coefficient of the relevant criterion using Equation (23).

$$\hat{t}_{ij}=w_{ij}\ .\ t_{ij}^{norm},\ i=1,2,\ldots,m;\ j=1,2,\ldots,n. \tag{23}$$

The weighted normalized values for the cost type criteria are summed using equation (24) and the weighted normalized values for the benefit type criteria are summed using equation (25).

$$L_i=\sum_{j=1}^{n}\hat{t}_{ij}^{(min)},\ i=1,2,\ldots,m;\ j=1,2,\ldots,n. \tag{24}$$

$$A_i=\sum_{j=1}^{n}\hat{t}_{ij}^{(mak)},\ i=1,2,\ldots,m;\ j=1,2,\ldots,n. \tag{25}$$

In this step, the λ value represents the coefficient degree of the criterion type. In other words, the value of λ can vary according to the benefit-cost criterion ratio in the research. For example, if there are 2 cost and 1 benefit criteria in the decision problem, the value of λ can be used as 2/3 (Bošković et al., 2023b). The related operations are performed using Equations (26) and (27) respectively.

$$\hat{L_i}=L_i^{\lambda}=\left(\sum_{j=1}^{n}\hat{t}_{ij}^{(min)}\right)^{\lambda},\ i=1,2,\ldots,m;\ j=1,2,\ldots,n. \tag{26}$$

$$\hat{A_i}=A_i^{1-\lambda}=\left(\sum_{j=1}^{n}\hat{t}_{ij}^{(mak)}\right)^{1-\lambda},\ i=1,2,\ldots,m;\ j=1,2,\ldots,n. \tag{27}$$

Equation (28) is applied to obtain the final ranking (R_i) of the alternatives.

$$R_i=L_i^{\lambda}+A_i^{1-\lambda},\ i=1,2,\ldots,m. \tag{28}$$

The R_i value reflects the final utility score of the alternatives, with the largest R_i value indicating the most optimal alternative.

4. RESULTS

In the study, the financial performance analysis of four reinsurance companies listed in Table 2, which operate in the insurance sector in the period 2022-2023 and whose financial indicators can be accessed in this period range, has been carried out.

Table 2. Reinsurance Companies Operating in Türkiye

Symbol	Companies
MR	Milli Reasürans Türk A.Ş.
TKR	Türk Katılım Reasürans A.Ş.
TR	Türk Reasürans A.Ş.
VHV	VHV Reasürans A.Ş.

Financial ratios generally used in the insurance sector have been considered in analyzing the financial position of the companies. Financial ratios used in the study were determined in Table 3 because of researching the studies on the reinsurance sector in the literature. The liquidity ratios used assess a company's ability to pay its short-term debts and test whether its working capital is sufficient. The current ratio and acid-test ratio are important liquidity ratios (Akgüç, 2010: 23). The current ratio provides a broad perspective on liquidity and is calculated by dividing current assets by short-term liabilities. The acid-test ratio, on the other hand, examines liquidity in a more stringent manner by excluding certain current assets that take longer to convert to cash and is calculated by dividing liquid assets by short-term liabilities (Okay, 2019: 138). The best indicator of the effective use of equity invested in the company by shareholders is the return on equity ratio, which is also referred to as financial profitability. This ratio is calculated by dividing net income for the period by shareholders' equity. The return on assets ratio examines the profitability resulting from a company's investment in its assets and assesses the effective use of those assets. This ratio is obtained by dividing net income for the period by total assets (Elmas & Ardıç, 2018: 149). The technical profitability ratio, which is found by relating technical profit to earned premiums, measures the profitability obtained from a company's core activities. A high value for this ratio indicates that the company has high technical profitability (Kalaycı & Yılmaz, 2011: 93). The combined ratio expresses the ratio of losses and expenses incurred to earned premiums. This ratio is considered a key indicator of the overall financial performance of a reinsurance company, and a lower ratio indicates better financial performance for the company (Mukherjee et al., 2020: 188). The claim premium ratio is calculated as the ratio of incurred losses to earned premiums for the current period (Sarıaslan, 2007: 14). This ratio indicates how much loss has occurred for every 100 units of premium written. A lower claim premium ratio positively impacts the technical profitability of companies (Kalaycı & Yılmaz, 2011: 90). The conservation ratio, which is associated with the risk retention ratio, indicates the risk undertaken by the company, or its risk-bearing capacity. It is calculated as the ratio of Net Premium to Gross Premium. A higher ratio demonstrates that the company has a better risk retention capacity. This suggests that the company relies more on its own resources and is less dependent on external sources (Bawa & Verma, 2017: 49). The expense ratio is calculated by dividing the total expenses of the reinsurance company, including the net commissions paid, by the net premium. This ratio indicates what portion of the net premium is used by the reinsurance company to acquire, write, and service the business obtained from insurance companies. In other words, it is used to assess whether the expenses of the reinsurance company are reasonable (Bawa & Verma, 2017: 48). Finally, the claims payout ratio is a metric that shows the damages incurred and the extent to which the company has paid these claims (Kalaycı & Yılmaz, 2011: 89). The financial indicators presented in Table 3 and the selection of the benefit/cost aspects of these indicators are based on the research conducted by Taşçı (2024b).

Table 3. Evaluation Criteria for Reinsurance Companies

Financial Ratios	Symbol	Benefit/Cost
Return on assets ratio	ROA	Maximum
Combined ratio, net	CRNet	Minimum
Current ratio	CR	Maximum
Claim premium ratio, net	CPRNet	Minimum
Conservation ratio	CONR	Maximum
Liquidity ratio (acid-test ratio)	LR	Maximum
Expense ratio, net	ERNet	Minimum
Return on equity ratio	ROE	Maximum
Claims payment ratio	CPAR	Maximum
Technical profitability ratio (Technical department balance/Earned premiums)	TPR	Maximum

The financial ratios for Türk Reasürans, Türk Katılım Reasürans, and Milli Reasürans were obtained directly from the companies' activity reports, while the financial ratios for VHV Reasürans were calculated by the authors using

statistical data from the Türkiye Sigorta Birliği and the company's unconsolidated independent auditor's report. In the selection of the research period, it was important that the Türk Katılım Reasürans started its operations in 2021. The financial performances of the companies for the years 2022-2023, which are the most recent data of the companies during the study, have been evaluated and the results of the 2023 data are given in detail in the method stages. Table 4 shows the decision matrix consisting of financial ratios of reinsurance companies.

Table 4. 2022-2023 Decision Matrix

Company	Period	ROA	CRNet	CR	CPRNet	CONR	LR	ERNet	ROE	CPAR	TPR
MR	2022	7.16	160	101	114	85	131	25	17.58	37	6
	2023	16	155	87	275	79	90	26	35.83	51	2
TKR	2022	0.3	109	393	75	97	194	34	1	57	1
	2023	2.2	108	243	72	90	70	37	15	78	4
TR	2022	15.62	96	384	64	95	211	32	43	66	29
	2023	7.38	100	309	66	90	143	34	45	71	24
VHV	2022	1.82	861.01	138.59	710.6	9.84	128.79	150.41	3.28	30	-266.53
	2023	-0.22	298.11	109.47	272.6	15.13	104.09	25.51	-0.91	26	-40.25

Since it is not appropriate to use the negative values in the decision matrix in the LODECI method, which includes the logarithm process, the Z-score method proposed by Zhang et al. (2014) was used.

$$x_{ij}=\frac{X_{ij}-\overline{X}_{\dot{I}}}{S_i} \tag{29}$$

$$x'_{ij}=x_{ij}+A \qquad A>\left|minx_{ij}\right| \tag{30}$$

'x_{ij}' in Equation 29 The transformation of 'x_{ij}' is realized by subtracting the criterion means from the decision matrix x_{ij}' and dividing by the standard deviation of the criterion. In Equation 30, the process is completed by adding an A number that will make the values of x'_{ij} positive. Since there were negative values in all years in the study, all operations were carried out with Z-score-adjusted data. The adjusted decision matrix is presented in Table 5.

Table 5. Edited Decision Matrix for 2022-2023

Company	Period	ROA	CRNet	CR	CPRNet	CONR	LR	ERNet	ROE	CPAR	TPR
MR	2022	1.634	1.104	0.517	1.095	1.819	0.671	0.911	1.570	0.875	1.954
	2023	2.845	1.387	0.559	2.375	1.790	1.117	0.696	2.084	1.263	1.668
TKR	2022	0.643	0.966	2.389	0.970	2.107	2.153	1.061	0.711	2.064	1.918
	2023	0.922	0.875	2.024	0.659	2.096	0.469	2.605	1.077	2.421	1.742
TR	2022	2.857	0.931	2.332	0.935	2.059	2.553	1.028	2.886	2.599	2.119
	2023	1.644	0.788	2.643	0.608	2.096	2.836	2.084	2.528	2.120	2.482
VHV	2022	0.862	2.995	0.758	2.995	0.011	0.619	2.996	0.829	0.459	0.005
	2023	0.585	2.946	0.770	2.355	0.015	1.574	0.611	0.307	0.192	0.104

4.1. LODECI Analysis Findings

The normalized decision matrix obtained for LODECI with the help of Equations 1 and 2 is calculated as shown in Table 6.

Table 6. 2023 LODECI Normalized Decision Matrix

Company	ROA	CRNet	CR	CPRNet	CONR	LR	ERNet	ROE	CPAR	TPR
MR	1.000	0.529	0.211	0.000	0.854	0.394	0.733	0.825	0.522	0.672
TKR	0.324	0.703	0.766	0.723	1.000	0.165	0.000	0.426	1.000	0.702
TR	0.578	0.732	1.000	0.744	1.000	1.000	0.200	1.000	0.876	1.000
VHV	0.206	0.000	0.291	0.009	0.007	0.555	0.766	0.121	0.079	0.042

The DV matrix and LDV values calculated by Equations 3 and 4 are given in Table 7. Accordingly, CONR (Conservation Ratio) provided the highest decomposition. The lowest level of decomposition was obtained with ROA (Return on Assets Ratio).

Table 7. 2023 LODECI, DV Matrix and LDV Values

Company	ROA	CRNet	CR	CPRNet	CONR	LR	ERNet	ROE	CPAR	TPR
MR	0.794	0.529	0.789	0.744	0.847	0.606	0.733	0.703	0.478	0.630
TKR	0.676	0.703	0.554	0.723	0.993	0.835	0.766	0.574	0.921	0.660
TR	0.422	0.732	0.789	0.744	0.993	0.835	0.566	0.879	0.797	0.958
VHV	0.794	0.732	0.709	0.736	0.993	0.445	0.766	0.879	0.921	0.958
LDV	0.514	0.515	0.536	0.552	0.671	0.519	0.535	0.564	0.576	0.589

In Table 8, the criterion importance levels calculated using Equation 5 are given for the years 2022 and 2023.

Table 8. LODECI Criteria Importance Weights for 2022-2023

Period	ROA	CRNet	CR	CPRNet	CONR	LR	ERNet	ROE	CPAR	TPR
2022	0.0922	0.0925	0.1010	0.0925	0.1206	0.0969	0.0927	0.0922	0.0989	0.1206
2023	0.0922	0.0925	0.0963	0.0991	0.1205	0.0931	0.0960	0.1013	0.1034	0.1056

In 2022 and 2023, the prominent criterion is CONR (Conservation Ratio), while the importance of ROA (Return on Assets Ratio) is at the lowest level. In general, the importance levels of criteria in 2022 and 2023 are close to each other.

4.2. CRADIS Analysis Findings

In the study, firstly, the performance ranking of the companies was carried out based on the CRADIS method and using the data in Table 5, the CRADIS normalized decision matrix was obtained according to Equations 6 and 7 as shown in Table 9.

Table 9. 2023 CRADIS Normalized Decision Matrix

Company	ROA	CRNet	CR	CPRNet	CONR	LR	ERNet	ROE	CPAR	TPR
MR	1.000	0.568	0.211	0.256	0.854	0.394	0.878	0.825	0.522	0.672
TKR	0.324	0.900	0.766	0.923	1.000	0.165	0.234	0.426	1.000	0.702
TR	0.578	1.000	1.000	1.000	1.000	1.000	0.293	1.000	0.876	1.000
VHV	0.206	0.268	0.291	0.258	0.007	0.555	1.000	0.121	0.079	0.042

The weighted decision matrix is given in Table 10.

Table 10. 2023 CRADIS Weighted Decision Matrix

Company	ROA	CRNet	CR	CPRNet	CONR	LR	ERNet	ROE	CPAR	TPR
MR	0.092	0.053	0.020	0.025	0.103	0.037	0.084	0.084	0.054	0.071
TKR	0.030	0.083	0.074	0.091	0.120	0.015	0.023	0.043	0.103	0.074
TR	0.053	0.092	0.096	0.099	0.120	0.093	0.028	0.101	0.091	0.106
VHV	0.019	0.025	0.028	0.026	0.001	0.052	0.096	0.012	0.008	0.004

Deviations from ideal and anti-ideal solutions and utility values obtained by CRADIS are calculated as shown in Table 11. Türk Reasürans, which is in a relatively good position in terms of deviations from anti-ideal and ideal solutions, outperformed the other companies in terms of both K_i^- and K_i^+ values. VHV Reasürans, on the other hand, lagged with the worst performance in terms of both parameters.

Table 11. CRADIS 2023 Deviations and Benefit Values from Ideal and Anti-Ideal Solutions

Company	S_i^+	S_i^-	K_i^+	K_i^-
MR	0.582	0.614	0.352	0.620
TKR	0.547	0.649	0.374	0.654
TR	0.324	0.872	0.631	0.879
VHV	0.934	0.262	0.219	0.265

The final CRADIS rankings and scores for all years are as shown in Table 12.

Table 12. CRADIS Scores of Reinsurance Companies for the Period 2022-2023

	2022		2023	
Company	Score	Rank	Score	Rank
MR	0.509	3	0.486	3
TKR	0.645	2	0.514	2
TR	0.957	1	0.755	1
VHV	0.210	4	0.242	4

According to Table 12, TR stands out as the reinsurance company with the best performance in all years, while TKR stands out as the reinsurance company with the second-best performance. In all years, MR performs in third place, while VHV ranks last. In 2023, it was determined that the CRADIS scores of TR, TKR and MR decreased, while the CRADIS score of VHV increased. The reason for this situation may be the decrease in the value of benefit-oriented criteria and the increase in the value of cost-oriented criteria in 2023 compared to 2022 for TR, TKR and MR. On the contrary, it can be suggested that the value of benefit-oriented criteria increased, and the value of cost-oriented criteria decreased in 2023 for VHV. In 2023, although TR ranked first, its CRADIS score decreased the most compared to 2022.

4.3. AROMAN Analysis Findings

AROMAN method uses linear and vector normalization techniques together to provide a more powerful solution in decision problems. Secondly, the performance ranking of the companies was carried out based on the AROMAN method and using the data in Table 5, the decision matrix was obtained as shown in Table 13 according to Equations 18 and 19 with AROMAN linear normalization technique.

Table 13. 2023 Linear Normalized Decision Matrix

Company	ROA	CRNet	CR	CPRNet	CONR	LR	ERNet	ROE	CPAR	TPR
MR	1.000	0.722	0.000	0.000	0.853	0.274	0.957	0.800	0.481	0.658
TKR	0.149	0.960	0.703	0.971	1.000	0.000	0.000	0.347	1.000	0.689
TR	0.469	1.000	1.000	1.000	1.000	1.000	0.261	1.000	0.865	1.000
VHV	0.000	0.000	0.101	0.011	0.000	0.467	1.000	0.000	0.000	0.000

The normalized decision matrix obtained because of vector normalization using Equations (21) and (22) is given in Table 14.

Table 14. 2023 Vector Normalized Decision Matrix

Company	ROA	CRNet	CR	CPRNet	CONR	LR	ERNet	ROE	CPAR	TPR
MR	0.822	0.599	0.161	0.314	0.517	0.323	0.799	0.602	0.365	0.482
TKR	0.266	0.747	0.584	0.810	0.605	0.135	0.248	0.311	0.699	0.503
TR	0.475	0.772	0.763	0.824	0.605	0.819	0.398	0.730	0.612	0.717
VHV	0.169	0.149	0.222	0.320	0.004	0.455	0.824	0.089	0.055	0.030

After the normalization process, the AROMAN method combines the matrix elements obtained because of different normalization techniques using the arithmetic mean technique (Bošković et al., 2023a: 39501). In this step, the normalized matrix elements in Table 13 and Table 14 are combined using Equation (22). The combined and averaged normalized decision matrix is given in Table 15. The parameter β was taken as 0.5 during the merging.

Table 15. 2023 Combined Normalized Decision Matrix

Company	ROA	CRNet	CR	CPRNet	CONR	LR	ERNet	ROE	CPAR	TPR
MR	0.455	0.330	0.040	0.079	0.343	0.149	0.439	0.351	0.211	0.285
TKR	0.104	0.427	0.322	0.445	0.401	0.034	0.062	0.164	0.425	0.298
TR	0.236	0.443	0.441	0.456	0.401	0.455	0.165	0.433	0.369	0.429
VHV	0.042	0.037	0.081	0.083	0.001	0.230	0.456	0.022	0.014	0.008

The criteria weights obtained by the CRADIS method are included in the AROMAN application using Equation (23). The weighted normalized decision matrix is given in Table 16.

Table 16. 2023 Weighted Normalized Decision Matrix

Company	ROA	CRNet	CR	CPRNet	CONR	LR	ERNet	ROE	CPAR	TPR
MR	0.042	0.031	0.004	0.008	0.041	0.014	0.042	0.036	0.022	0.030
TKR	0.010	0.039	0.031	0.044	0.048	0.003	0.006	0.017	0.044	0.031
TR	0.022	0.041	0.042	0.045	0.048	0.042	0.016	0.044	0.038	0.045
VHV	0.004	0.003	0.008	0.008	0.000	0.021	0.044	0.002	0.001	0.001

L_i, A_i,and R_i values were calculated by utilising Table 16 and Equations (26)-(28) and the ranking of the alternatives was obtained. Information on these variables is given in Table 17. Here, while calculating the R_i value, the coefficient λ is taken as 3/10 since there are minimum type 3 criteria and maximum type 7 criteria.

Table 17. 2022-2023 Period Reinsurance Companies AROMAN Scores

	2022				2023			
Company	L_i	A_i	R_i	**Rank**	L_i	A_i	R_i	**Rank**
MR	0.114	0.148	0.784	3	0.081	0.188	0.781	3
TKR	0.116	0.212	0.862	2	0.090	0.184	0.791	2
TR	0.118	0.307	0.965	1	0.102	0.282	0.917	1
VHV	0.009	0.031	0.335	4	0.055	0.038	0.521	4

Table 17 shows the financial performance rankings of reinsurance companies for the period 2022-2023 according to the AROMAN method. Accordingly, Türk Reasürans is the most successful reinsurance company in terms of financial performance in 2022 and 2023. Türk Katılım Reasürans and Milli Reaüsürans ranked second and third, respectively, while VHV Reasürans ranked last.

4.4. Sensitivity Analysis Findings

In order to observe the effect of the change in the importance weights of the criteria on the ranking of the decision alternatives, 100 different scenarios were created. The method developed by Božanić et al. (2021) and Pamucar et al. (2022) was preferred for the testing of MCDM methods. According to this sensitivity analysis, the weight of the criterion with the highest importance level was reduced by 2% each time and the weights of the other criteria were increased proportionally. In this method, the sum of the importance levels of all criteria considered in the same way was calculated to be equal to 1. The criteria weights obtained for 100 scenarios are visualized in Figure 1.

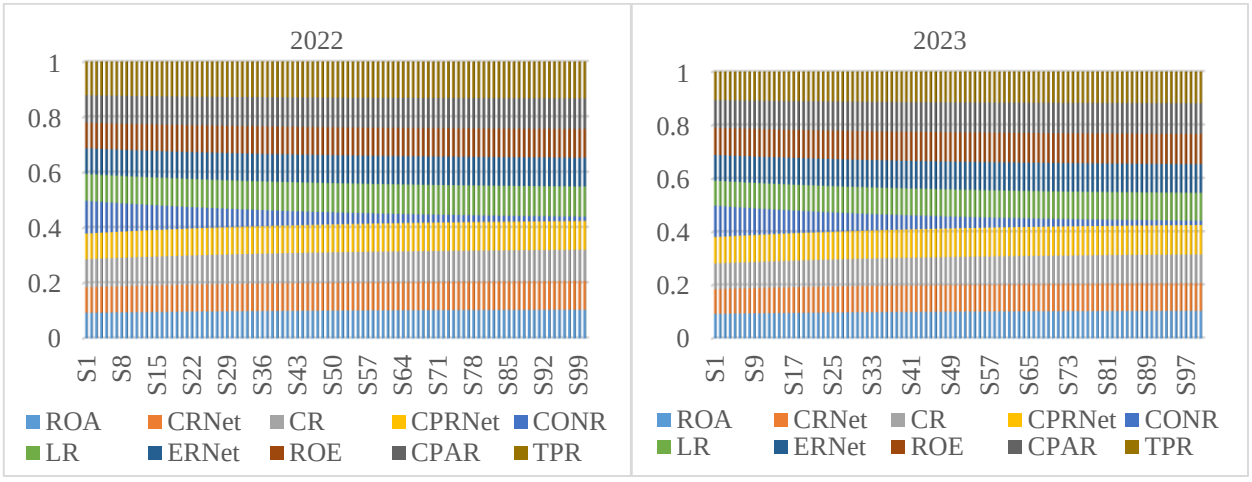
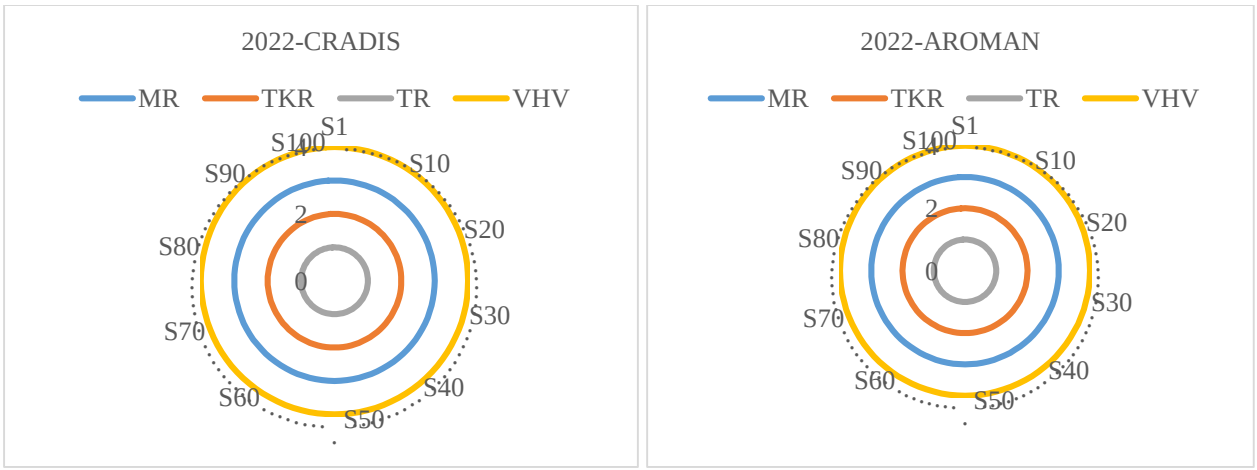


Figure 1. Scenario Based Criteria Weights (2022-2023)

The sensitivity analysis ranking results of the repeated CRADIS and AROMAN application using the criteria weights in Figure 1 are given in Figure 2.



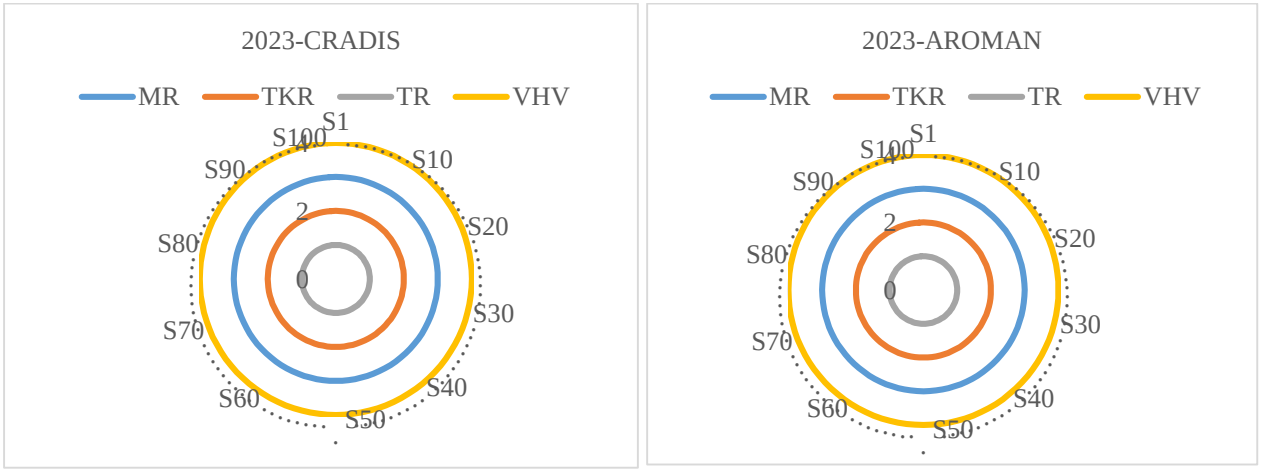


Figure 2. Ranking Results of Reinsurance Companies According to 100 Different Scenarios

According to Figure 2, the ranking suggested by the LODECI-CRADIS and LODECI-AROMAN model was not affected by the change in the criteria weights and a very strong implementation was obtained. When the results are analyzed, it is found that the ranking of the best alternative, Türk Reasürans, is not significantly affected by different criteria weight scenarios for 100 scenarios. According to the reported results, it is seen that there are no changes in the performance rankings of other decision alternatives in different scenarios. As a result, the ranking results obtained from the applied sensitivity analysis confirm that the MCDM performance evaluation models proposed in this study are consistent, robust and applicable.

5. CONCLUSION

The increase in the assets of the insurance sector, which is included in the finance sector, is extremely important for the entire national economy due to its function of transferring resources to the economy. The financial performance of reinsurance companies, which have the function of contributing to the financing of insurance companies, taking over their risks and transferring some of these risks to other reinsurance companies abroad, affects other insurance companies. The reinsurance function is of vital importance for the insurance sector to operate effectively and create economic benefits. With the contribution of reinsurance activities, the risks of insurance companies are spread over a larger geography. In this way, large risks are homogenized in a more diversified and balanced portfolio structure. Thus, large risks can be managed more easily, increasing the capacities and flexibility of insurance companies.

The aim of this study is to evaluate the financial performance of four Reinsurance Companies operating in the Türkiye reinsurance sector for the period 2022- 2023 with a MCDM approach including LODECI, CRADIS and AROMAN methods. For this purpose, the performance of four reinsurance companies was evaluated using 10 performance indicators. With the application of the LODECI method, it was determined that the most effective criterion on the performance of these reinsurance companies during the analysis period was the conservation rate criterion, while the variable with the least effect on the performance of these companies was the return on assets ratio. According to the results of CRADIS and AROMAN ranking methods, in both 2022 and 2023, Türk Reasürans ranked first, Türk Katılım Reasürans ranked second, Milli Reasürans ranked third and VHV Reasürans ranked last.

In the literature, studies analysing the financial performance of reinsurance companies are limited and are generally specific to certain countries or regions. For example, Ndirangu (2014) analysed the financial performance of reinsurance companies in Kenya in the context of exchange rate risk management, while Muchiri & Njoka (2021) examined the impact of corporate governance practices on financial performance. Olarewaju & Msomi (2022) analysed the determinants of profitability of reinsurance companies in Sub-Saharan African countries. The common point of these studies is that they reveal the determinants of financial performance by using regression analyses and time series methods. On the other hand, the studies focusing on reinsurance companies in India and Türkiye were mostly conducted with financial ratio analyses and multi-criteria decision-making (MCDM) methods. While Bawa & Verma (2017) and Mukherjee et al. (2020) evaluate the financial performance of GIC RE in India using ratio analyses and statistical methods, studies in Türkiye focus on MCDM

methods. For example, Yılmaz (2021a, 2021b) and Taşçı (2024b) analysed reinsurance companies operating in Türkiye with different MCDM methods and created performance rankings. Unlike these studies, this study evaluates the financial performance of four reinsurance companies operating in Türkiye in 2022-2023 with LODECI, CRADIS and AROMAN decision models. While similar analyses in the literature generally use methods such as AHP, ELECTRE and PSI-MEREC-ARAS, in this study, the LODECI procedure is preferred for objective weight calculations and CRADIS and AROMAN procedures are applied for ranking purposes. The findings of Yılmaz (2021a; 2021b), which is the closest study to this study in terms of sample and period, differ from the results of this study. It can be thought that the reason for this situation may be due to the fact that the financial performance of reinsurance companies may vary periodically, and different analysis methods and evaluation criteria are used.

This study evaluates the financial performance of four reinsurance companies operating in Türkiye between 2022 and 2023 using LODECI, CRADIS, and AROMAN decision models, offering significant insights for the sector. The results indicate that the conservation ratio is the most decisive factor affecting financial performance, whereas the return on assets has a relatively lower impact. Based on these findings, it is recommended that reinsurance companies strengthen their capital structures and improve risk management strategies to achieve higher conservation ratios. Notably, the financial leadership of Türk Reasürans highlights the necessity of increasing local capacity and exploring opportunities for integration into international markets. The growth of participation-based reinsurance also underscores the need for alternative financing models. Additionally, the sensitivity analysis results confirming the robustness of the model encourage the use of advanced analytical techniques in the industry. Regulatory bodies should implement stricter policies regarding capital adequacy and liquidity management to ensure financial stability. Investments in digitalization and data analytics can enhance operational efficiency and strengthen risk assessment processes. The study's findings are expected to serve as a guide for insurance and reinsurance sector stakeholders, company executives, and policymakers. Company managers can plan future strategies and take preventive measures based on the results, while insurance companies may consider these findings when selecting reinsurance partners. The performance evaluation decision model used in this study can also be applied at the firm or sector level for performance assessment across various financial and non-financial industries. In this context, industry stakeholders are expected to make more informed decisions regarding risk management, investment strategies, and regulatory policies based on the study’s findings.

The inclusion of all reinsurance companies in the study, the use of ten evaluation criteria and the fact that the data set covers the 2022-2023 period can be considered as limitations of the study. In future studies, the time interval of reinsurance companies to be included in the analysis can be increased if the data is accessible. In addition, the scope of the study can be expanded by conducting analyses based on grey numbers, fuzzy numbers or intuitionistic fuzzy numbers. In addition, it is thought that it would be useful to compare the results obtained from this analysis of the reinsurance sector operating in Türkiye with other multi-criteria decision-making techniques and other analyses using different criteria to be conducted in the same sector in the future.

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Conceptualization, writing-original draft, editing – **AÇ** and **OŞ**, data collection, methodology, formal analysis – **AÇ** and **OŞ**, Final Approval and Accountability – **AÇ** and **OŞ**.

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Bibliometric Analysis of Graduate Theses Containing the Phenomenon of "Marketing Communication" in the Council of Higher Education (CoHE) National Thesis Center Database

YÖK Ulusal Tez Merkezi Veri Tabaninda Adında "Pazarlama İletişimi" Olgusu Bulunan Lisansüstü Tezlerin Bibliyometrik Analizi

Tülin ÇAKIR
Asst. Prof. Dr., Afyon Kocatepe University
tcakir@aku.edu.tr
https://orcid.org/ 0000-0002-7199-7579

Elif CÖNK
Lecturer, Afyon Kocatepe University
elifconk@aku.edu.tr
https://orcid.org/0000-0001-9532-0645

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ABSTRACT

The research was carried out to bibliometric analyze the theses registered in the database of the National Thesis Center of CoHE and with the phenomenon of "Marketing Communication" in their name. This discipline is evolving alongside technology. The study sequentially addresses the scope of marketing communication, previous studies related to the topic in the literature, and the research findings obtained through analyses. The research is significant as it may guide future studies in the context of graduate theses. The data for the study were obtained from the thesis index information pages prepared by the CoHE National Thesis Center. The data collected in the research were evaluated bibliometrically in the context of descriptive statistics as part of content analysis. It is believed that the findings obtained will shed light on other studies to be conducted in the relevant discipline and assist in determining thesis topics.

Anahtar Kelimeler:
Pazarlama İletişimi,
YÖK Ulusal Tez Merkezi,
Bibliyometrik Analiz
Jel Kodları:
M31 M39 C40

ÖZET

Araştırma, YÖK'e ait Ulusal Tez Merkezi'ndeki veri tabanında kayıtlı ve adında "Pazarlama İletişimi" olgusu bulunan tezleri bibliyometrik yönlü analiz etmek için yapılmıştır. Bu disiplin, teknoloji ile birlikte gelişim içerisindedir. Çalışmada sırasıyla pazarlama iletişiminin kapsamına, literatürde konuyla ilgili yapılmış olan çalışmalara ve analizler ile elde edilen araştırma bulgularına yer verildi. Araştırma, sonraki yapılacak çalışmalar ile lisansüstü tezlere yön vermesi açısından önem taşımaktadır. Çalışmanın verileri, YÖK Ulusal Tez Merkezi'nin hazırladığı tez dizin bilgisi sayfalarında yer alan bilgilerden sağlandı. Araştırmada elde edilen veriler, içerik analizi kapsamında bibliyometrik olaraktanımlayıcı istatistikler bağlamında değerlendirildi. Elde edilen bulguların ilgili disiplin alanında yapılacak diğer çalışmalara ve tez konularının belirlenmesine ışık tutacağı düşünülmektedir.

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1. INTRODUCTION

Marketing communication is a vital pillar of both brands and companies as an important and integral part of marketing. Therefore, marketing communication is a pathway for most organizations to influence their target audiences in the desired manner regarding their brands. However, this discipline occupies a significant area where new marketing practices, which are continuously evolving alongside technology, converge. In other words, marketing communication is a crucial strategic area that not only contributes to the continuous renewal of marketing but also showcases new applications regarding how brands can effectively reach their target audiences in various ways.

Since its inception, the development and evolution of this discipline have occurred at a rapid pace, in line with the speed of technology. Although marketing communication practices, which were initially executed as promotion in the context of early marketing understanding, were used by businesses to introduce and convey their products to customers and other stakeholders, the perspective of businesses towards marketing communication changed with the consumer-centric approach that emerged after the 1990s (Gökaliler, 2015: 299). Today, businesses approach marketing communication as a dialogical and integrated process, both consumer-centered and linked to changes arising from technology. For marketing communication to be executed integratively across all forms of communication, it is essential for organizations to identify all communication resources and determine which communication methods are more suitable and effective for the target audiences (Başok Yurdakul, 2007: 312). Naturally, as a field of discipline, marketing communication has faced certain changes due to the expanding scope of all forms of communication used in both theoretical frameworks and strategic modeling. Therefore, it is seen that the situation is reflected in the scientific studies carried out in this field from the beginning.

The aim of this study is to conduct a bibliometric analysis of theses registered in the CoHE National Thesis Center database that contain the phenomenon of "Marketing Communication" in their titles. Thus, a general evaluation of the bibliometric analysis findings of master's and doctoral theses conducted on "Marketing Communication" in Turkey up to December 2020 will be provided. The study will address the scope of marketing communication, followed by bibliometric analysis and the related studies in the fields of marketing communication and marketing. Finally, the findings of the conducted research will be presented.

2. SCOPE OF MARKETING COMMUNICATION

Upon considering that marketing began in the 1800s, it can be stated that marketing communication also took shape during those years within the framework of marketing understanding, as emphasized by Barker (2013: 107), based on the use of broad-based mass communication tools to reach large customer markets through advertising and promotional activities. Initially regarded as a sub-discipline of marketing, the concept of "promotion," which was referred to as part of the marketing mix known as the 4Ps by Jerome McCarthy, was expressed as "promotion" or "advertising" and became established in the literature as marketing communication in the 1990s (Ilgaz Sümer & Eser, 2006: 167; Yong Shin, 2013: 5; Tunçel, 2009: 117). The main reason for this is that before 1990, as a result of the production of messages from different sources that did not complement each other, the purchasing decision processes of consumers were adversely affected (Erciş, 2010: 153), and the idea of being an umbrella that covers all of them instead of using different methods added to the methods known as promotion mix, and then the necessity of connecting the methods used over time with each other, the phenomenon of integrated marketing communication emerged. has taken it out (Yolaç & Demir, 2004: 122). According to Yong Shin (2013: 8), the American Association of Advertising Agencies defined integrated marketing communication in 1989 within a framework that included comprehensive planning, where the strategic roles of different communication disciplines were clearly evaluated in terms of consistency and maximum communication impact.

As stated by Kim et al. (2004), the development of marketing communication is shaped by the changing attitudes of both technology and consumers according to the changing market and marketing environment. Especially by the 2000s, the scope of integrated marketing communication and branding diversified as a hybrid of traditional and digital methods, influenced by developments in interactive media, synergy, and planning (Barker, 2013: 108), as well as advancements in information technology (Durmuş Şenyapar, 2024: 198). Particularly today, phenomena referred to as digital media strategies, such as social media marketing, content marketing, and metaverse marketing, are seen as part of marketing communication practices.

3. BIBLIOMETRIC APPLICATIONS RELATED TO MARKETING COMMUNICATION IN THE LITERATURE

Bibliometric analysis is a technique that aims to statistically analyze scientific publications by examining various elements, thereby revealing trends related to research topics within a specific scientific field (Çetinkaya Bozkurt & Gürbüz, 2018: 4; Zeren & Kaya, 2020: 37-38). The strength of this analytical technique, which is frequently used in the systematic analysis of data, lies in its comprehensive access and complex details, allowing for quantitative analysis of scientific studies (Lim & Kumar, 2024: 17). Additionally, bibliometric analysis enables the testing and visualization of networks formed by other bibliometric data such as co-citations, co-authorships, and keywords, allowing us to efficiently and intuitively explore the patterns and trends in the literature (Passas, 2024: 1016). Choudhri et al. (2015) argue that bibliometric analysis, while not an ideal tool, can assist in the effective evaluation of academic performance by utilizing modern analytical tools that go beyond simple analyses, from publication totals to impact factors. Therefore, bibliometric analyses can also measure the publication performance of countries, researchers, or institutions (Denktaş Şakar & Cerit, 2013: 40). For this purpose, it is essential to conduct content analysis through document examination in this analytical technique to obtain data and quantify it in the context of descriptive statistical techniques (Çatı & Alpay, 2019: 376).

As noted by Qian & Sun (2021), data in bibliometric analysis can be obtained not only from frequencies but also through complex calculations. However, the use of this analysis in the social sciences is significant for determining the direction of scientific development. According to Hicks (1999), understanding the literature in social sciences and its characteristics and outcomes requires a good knowledge of the Social Sciences Citation Index (SSCI) scope and the interpretation of its indicators. This is because scientific development is closely related to the articles written and the journals in which these articles are published.

As in all social science fields, there are evaluative research articles in the marketing field that have examined the scientific literature at different times. However, according to Kumar et al. (2020), researchers have primarily used bibliometric analysis to analyze journals such as the Journal of Advertising, Journal of Consumer Research, Journal of Travel and Tourism Marketing, and the European Journal of Marketing. The bibliometric study conducted by Donthu et al. (2022) in the Journal of Strategic Marketing, published between 1993 and 2019, is another example in this context.

International studies related to bibliometric research on “Marketing Communication” include the article by Muñoz-Leiva et al. titled “Discovering prominent themes in integrated marketing communication research from 1991 to 2012: a co-word analytic approach,” published in 2015, and the article by Kim et al. published in 2021 titled “Evolution of digital marketing communication: Bibliometric analysis and network visualization from key articles.” In recent years, studies in the field of marketing communication have included a 2023 article by Simabur et al. examining documents related to the tourism sector in Scopus, the article by Ki et al. that analyzed 219 articles on “relationship management,” which is part of the public relations discipline within marketing communication and an article written in 2024 by Dipa et al. and published in Jurnal Kajian Communikasi. Additionally, there are published proceeding paper analyzing digital marketing strategies by Guerrero-Velastegui et al. that examine articles found in Scopus and Web of Science.

In Turkey, there are marketing-oriented research studies conducted through journals. Examples include “Bibliometric Analysis of Journal Marketing and Marketing Research” by Çetinkaya Bozkurt & Gürbüz (2018), Eren & Eren’s (2020) “Bibliometric Analysis of Electronic Word-Of-Mouth Communication in Marketing Literature” and Kurnaz’s (2021) “The Bibliometric Analysis of The Three Journals with The Highest Impact Factors in The Marketing Discipline”, etc. In the field of marketing communication, Durmuş Şenyapar’s study published in 2024 is the first bibliometric study concerning marketing communication research.

It can be observed that bibliometric studies have been examined more through databases in both international and national contexts. Furthermore, it can be stated that this analytical method is used not only for journals but also for the examination of graduate theses that provide big data opportunities. The CoHE National Thesis Center, which has a significant infrastructure as a database in Turkey, offers access to and examination of theses in the field of marketing science for both master’s and doctoral studies. Particularly in Turkey, many bibliometric-based articles related to “marketing” have been encountered based on the data available on the CoHE National Thesis Center website. For example; "Bibliometric Analysis of Graduate Theses Written on Internet-Mediated Marketing Concepts in Turkey" by Çatı & Alpay (2019), "Examination of Doctoral Theses Written in the Field of Marketing in Turkey" by Gülmez et al. (2019), "Bibliometric Analysis of Articles Published on Sustainable and Environmental Marketing in Ulakbim Database" by Çelik & Canoğlu (2019), Öcel (2019) "Doctoral Theses Written on Brand in Turkey Bibliometric Analysis", "Digital Marketing: Bibliometric Analysis of National

Writing" by Zeren & Kaya (2020), "Investigation of the Bibliometric Profile of Master's and Doctoral Theses Written in the Department of Marketing" by Kavak & Kazancı Sunaoğlu (2020), etc. Despite the numerous articles addressing theses related to marketing and marketing topics in the national literature, no bibliometric analysis specifically focusing on "marketing communication" has been identified. The conducted studies appear to be more related to topics concerning the marketing communication mix.

4. METHODOLOGY AND FINDINGS OF THE RESEARCH

The aim of this study is to conduct a bibliometric analysis of theses registered in the CoHE National Thesis Center database that contain the phenomenon of "Marketing Communication" in their titles. The scope of the research includes theses that are registered in the CoHE National Thesis Center database and relate to "Marketing Communication" phenomena (such as Marketing Communication, Integrated Marketing Communication, etc.) up to December 2020. Therefore, the study is limited to the information available on the pages containing the thesis index data prepared by the CoHE National Thesis Center, and data were obtained through content analysis of the information presented on the index pages. The data obtained from the 160 thesis index records subjected to analysis were presented using descriptive statistical techniques suitable for bibliometric analysis.

According to the thesis index information subjected to analysis, out of n=160 theses, only n=7 were written in English. Among the indexed information under examination, the number of master's theses related to the research topic was identified as n=125, while the number of doctoral theses was determined to be n=35. Additionally, it was noted that the topic was first addressed in the context of a doctoral thesis in 1994 with n=1. According to the data presented in Figure 1, it can be observed that "Marketing Communication" has been increasingly addressed in theses, particularly in the context of master's theses, since 1999. From 2017 onwards, it was determined that the titles of master's theses included "Marketing Communication" and related phenomena more frequently compared to previous years (2017 n=13; 2018 n=11; 2019 n=23). In the titles of doctoral theses, it was found that "Marketing Communication" and related phenomena were more prominently featured in 2014 (n=6).

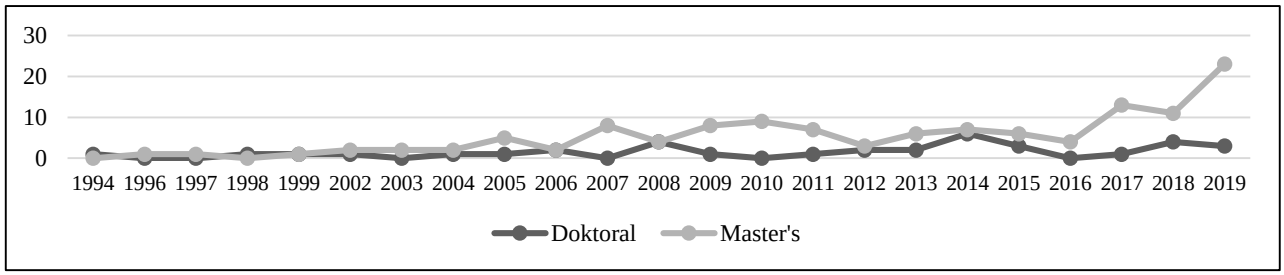

Figure 1. Distribution of Theses Titles Containing "Marketing Communication" and Related Concepts by Type and Year

In Figure 2, the distribution of the theses under examination according to universities is presented in terms of the type of thesis. From this figure, it can be understood that master's and doctoral theses containing the phenomenon of "Marketing Communication" and related concepts have been conducted at 54 universities. One noteworthy point is that the titles of master's theses predominantly include "Marketing Communication" or related phenomena. Additionally, when looking at the universities, it is observed that there are n=20 master's theses related to the research topic conducted at Marmara University. The highest number of doctoral theses related to the research topic was conducted at Ege University (n=6). Based on the data from both Figure 2 and Figure 3, it can be stated that theses containing "Marketing Communication" and related phenomena have been produced at universities located in the Marmara and Aegean regions. This may be related to the number of businesses operating in these regions and the number of agencies engaged in the field of marketing communication. Furthermore, most universities in these regions have both a Faculty of Communication and a Faculty of Economic and Administrative Sciences.

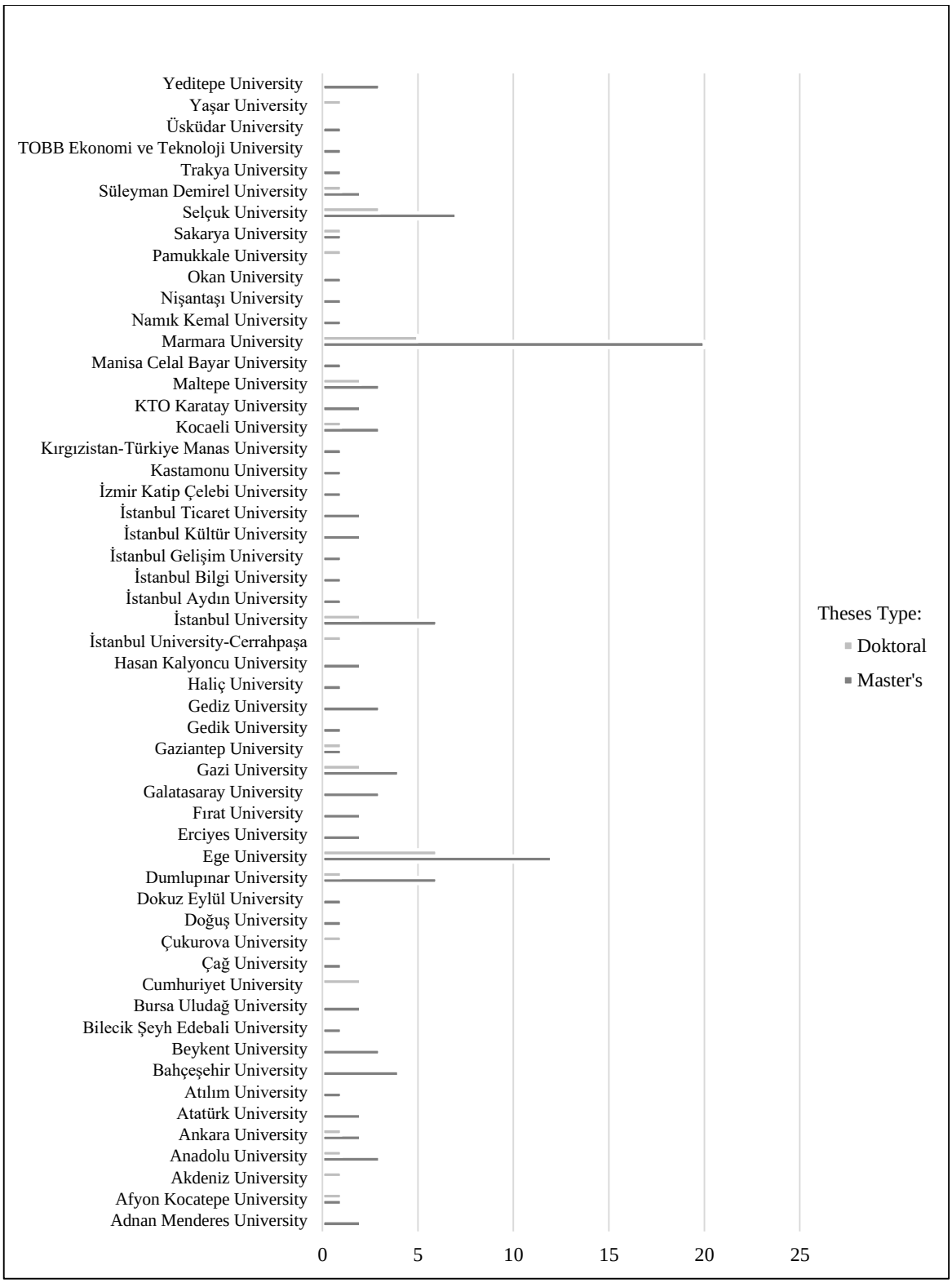

Figure 2. Distribution of Theses Titles Containing "Marketing Communication" and Related Concepts by Type and Universities

The distribution of theses related to our research topic according to the regions of Turkey is presented in Figure 3 according to the thesis types. As previously mentioned, according to the obtained data, it is observed that the majority of theses related to the topic have been conducted in the Marmara, Aegean, and Central Anatolia regions in the context of master's and doctoral studies. However, the region with a notably significant proportion, particularly concerning master's theses, is the Marmara Region. Furthermore, from a holistic perspective, it can be seen that most of the theses registered in CoHE's National Thesis Center related to our research topic have been conducted at universities in the Marmara Region (n=124). Therefore, this situation reflects that the majority

of the theses examined in the research were carried out by universities in Istanbul. Additionally, it has been determined that there is only one master's thesis conducted abroad at Kyrgyzstan-Turkey Manas University.

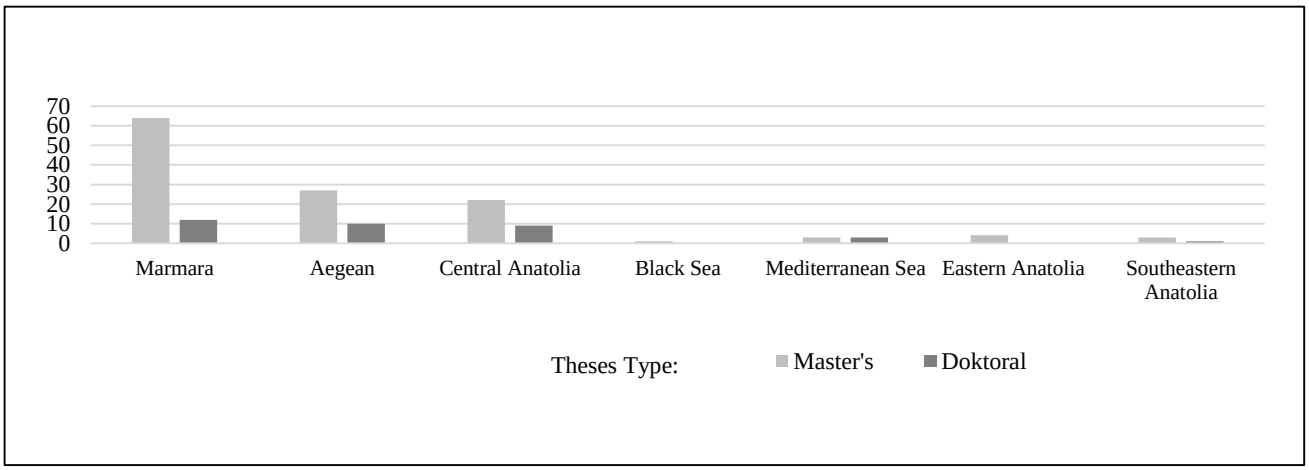

Figure 3. Distribution of Theses Titles Containing "Marketing Communication" and Related Concepts by Type Across Regions in Turkey.

The distribution of the theses under examination by the institutes to which they are registered is presented in Table 1. As can be understood from the data in the table, it is observed that the majority of the theses are registered in Social Sciences Institutes (n=118). However, it has also been noted that there are theses registered as both master's and doctoral theses in other institutes, albeit in smaller numbers. This situation reflects that the field of "Marketing Communication" possesses attractive topics not only for the relevant discipline but also for other disciplines.

Table 1. Distribution of Theses Titles Containing "Marketing Communication" and Related Concepts by Type and Registered Institutes.

Institutes	**Master's (n)**	**Doctoral (n)**
Graduate Programs Institute	1	0
Institute of Social Sciences	118	33
Institute of Foreign Trade	1	0
Institute of Graduate Education	0	1
Institute of Middle Eastern and Islamic Studies	1	0
Institute of Science	2	1
Institute of Health Sciences	1	0
Institute of Educational Sciences	1	0
Total	**125**	**35**

The distribution of the theses under examination by their main fields of study has also been analyzed, and the obtained data is presented in Figure 4. According to the data in this figure, the highest number of theses has been conducted in the Department of Business Administration for both master's (n=48) and doctoral (n=14) degrees. This is followed by the Department of Public Relations and Advertising (master's n=28; doctoral n=11). Additionally, it has been determined that there is also one thesis each from various other departments, and these theses are generally at the master's level. It was observed during the examination that research related to our topic has also been conducted in main fields that are not classified under social sciences.

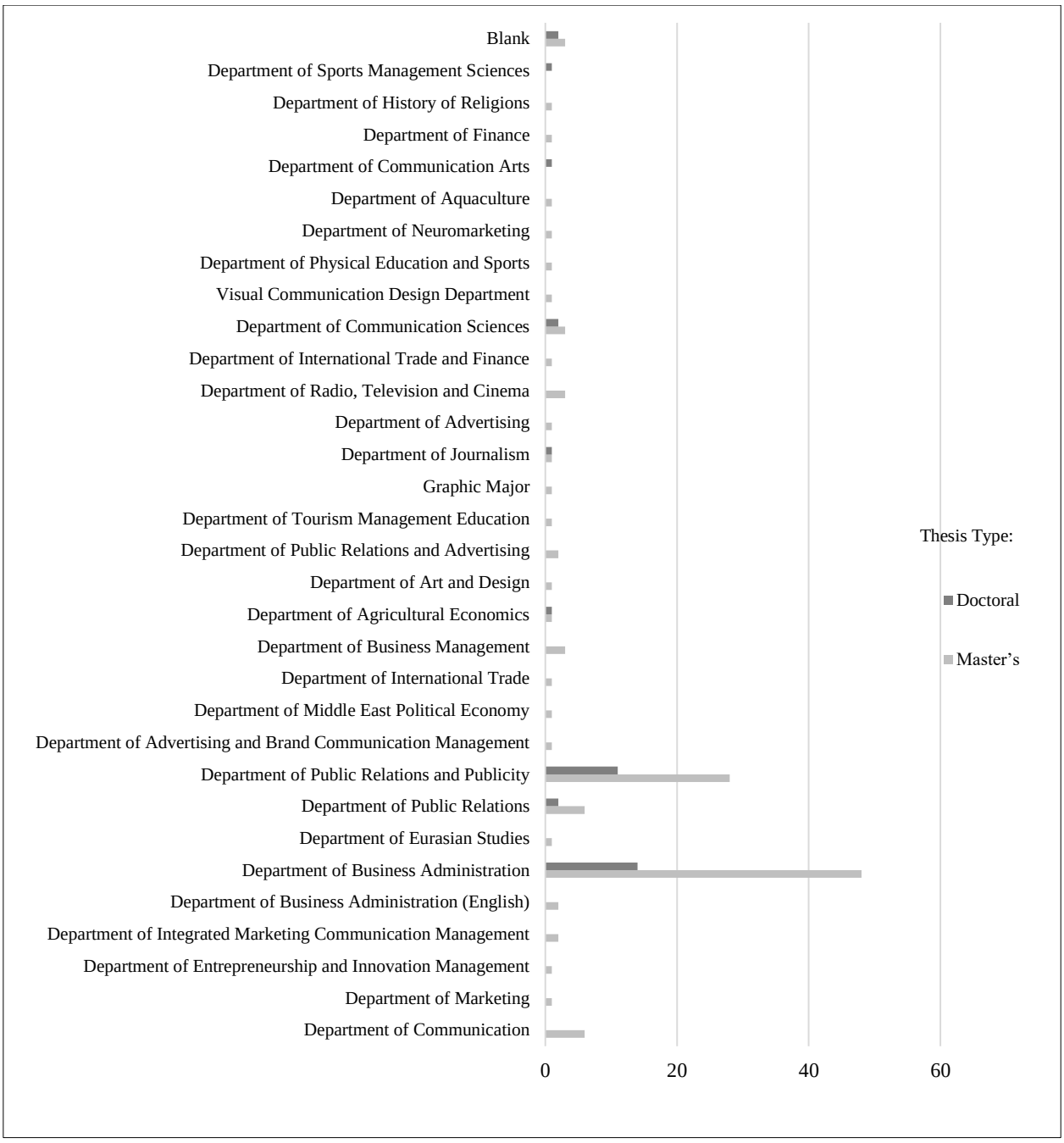

Figure 4. Distribution of Theses Titles Containing "Marketing Communication" and Related Concepts by Type and Main Fields of Study.

Another point that draws attention is that the number of theses related to the subject of the study in the Department of Marketing, the Department of Neuromarketing, the Department of Integrated Marketing Communication Management, the Department of Advertising and Brand Communication Management, the Department of Public Relations and Advertising and the Department of Advertising, which are considered to have a direct relationship with marketing communication, is low and these theses have usually made as master's degrees. The reason for this is that investigations may have been carried out in theses within the framework of the components and strategic tools used in marketing communication rather than integrity. In other words, it can be thought that this situation is related to the examination of thesis topics within the scope of marketing communication components such as advertising, public relations, sponsorship, or strategically important topics such as corporate social responsibility, brand positioning, word-of-mouth.

In the study, the topics listed in the thesis index of the CoHE National Thesis Center database were also examined. The data obtained from the analysis is presented in the table below based on topic clusters. The topic clusters in Table 2 have been organized under this name to indicate the order of topics specified in the thesis index information. In this context, when the thesis index information was reviewed, it was observed that the topic of

"Marketing Communication" was not mentioned in any of the topic clusters. However, it has been determined that "Advertising" (Master's: 15; Ph.D.: 3) and "Public Relations" (Master: 39; Ph.D.: 7) which are included in the marketing communication mix, it has been determined that it is generally in the 1st subject cluster as a subject. It was also noted that the topic name "Business" was mentioned in almost all topic clusters except for the fourth cluster in the examined thesis index information. This may be related to the perception among thesis authors that the phenomenon of "Marketing Communication" mentioned in the thesis title is generally associated with the topic of Business. Another noteworthy point is that when determining the topic names in the topic clusters, thesis authors generally preferred topic names according to the main field in which they wrote their thesis.

Table 2. Distribution of Theses Titles Containing "Marketing Communication" and Related Concepts by Type and Registered Topic Names According to Specified Topic Clusters.

Topics	**Topic 1**		**Topic 2**		**Topic 3**		**Topic 4**		**Topic 5**	
	Master's	**Doctoral**	**Master's**	**Doctoral**	**Master's**	**Doctoral**	**Master's**	**Doctoral**	**Master's**	**Doctoral**
Advertising	15	3	4	5	0	0	0	0	0	0
Communication Sciences	9	4	14	6	3	3	1	0	0	0
Tourism	5	1	1	0	0	0	0	0	0	0
Business Administration	69	11	25	5	10	7	0	0	1	0
Public Relations	39	7	1	0	0	0	0	0	0	0
Civil Aviation	1	0	0	0	0	0	0	0	0	0
Sports	2	1	0	0	0	0	0	0	0	0
International Relations	1	0	0	0	0	0	0	0	0	0
Political Science	2	0	1	0	0	0	0	0	0	0
Clothing Industry	1	0	0	0	0	0	0	0	0	0
Health Institutions Management	2	0	0	0	0	0	0	0	0	0
Education and Teaching	0	3	0	0	0	0	0	0	0	0
Radio-Television	1	1	0	0	0	0	0	0	0	0
Performing and Visual Arts	0	0	1	0	0	0	0	0	0	0
Agriculture	0	1	0	0	0	0	0	0	0	0
Insurance	1	0	0	0	0	0	0	0	0	0
Fine Arts	1	0	0	0	0	0	0	0	0	0
Banking	1	0	0	0	0	0	0	0	0	0
Sociology	0	0	1	0	0	0	0	0	0	0
Journalism	0	2	0	0	0	0	0	0	0	0
Aquaculture	1	0	0	0	0	0	0	0	0	0
Economics	1	0	0	0	0	0	0	0	0	0
Engineering Sciences	1	0	0	0	0	0	0	0	0	0
Finance	1	0	0	0	0	0	0	0	0	0

In the study, the cases included in the index information of the theses were examined on the basis of the specified order and it was seen that a maximum of 14 index concepts were specified. When looking at the distributions of "Marketing Communication" and related phenomena according to thesis type in the first three index information clusters, it was found that in "Index 1," the predominant concepts were "Integrated Marketing" (Master's n=40; Doctoral n=11), "Marketing" (Master's n=9; Doctoral n=3), and "Marketing Communication" (Master's n=3; Doctoral n=2). In "Index 2," the predominant concepts included "Marketing" (Master's n=18; Doctoral n=4), "Marketing Communication" (Master's n=12; Doctoral n=4), and "Public Relations" (Master's n=4; Doctoral n=2). In "Index 3," the predominant concepts were "Marketing" (Master's n=20; Doctoral n=6), "Marketing Communication" (Master's n=16; Doctoral n=9), and "Brand" (Master's n=6; Doctoral n=0). Table 3 presents the phenomena specified in the first three index clusters of the examined theses. In light of the research data, it can be said that master's and doctoral students mainly consider the departments while determining the indexes. In addition, since these data reflect that graduate students try to create indexes from different points in determining priorities for index clusters, it creates the opinion that they do not have sufficient knowledge on this subject.

Table 3. Distribution of Theses Titles Containing "Marketing Communication" and Related Concepts by Type and Registered Phenomena in the First 3 Index Clusters.

Concepts	Cluster 1		Cluster 2		Cluster 3	
	Master's	Doctoral	Master's	Doctoral	Master's	Doctoral
Linguistic Communication	1	0	0	0	0	0
Generic Strategies	1	0	0	0	0	0
Mobile Marketing	1	0	0	0	0	0
Integrated Marketing	40	11	0	2	0	1
Commonwealth of Independent States	1	0	0	0	0	0
Emojis	1	0	0	0	0	0
Airlines	1	0	1	0	0	0
Word-of-Mouth Communication	3	0	0	0	0	0
Marketing	9	3	18	4	20	6
Guerrilla Marketing	2	0	1	0	0	0
Azerbaijan	1	0	0	0	0	0
Electronic Marketing	3	0	2	0	0	0
Brand	2	1	3	1	6	0
Cognition	0	1	0	0	0	0
Comparative Analysis	1	0	0	0	0	0
Information Technology	1	0	0	0	0	0
Campaign	1	0	0	0	0	0
Positioning	1	0	1	0	0	0
Arçelik	2	0	0	0	0	0
Red Crescent	1	0	0	0	0	0
American Cinema	1	0	0	0	0	0
Facebook	1	0	1	0	1	0
Fair Trade	1	0	0	0	0	0
Intercultural Communication	1	0	2	0	0	0
Akbank	0	1	0	0	0	0
General Elections	1	0	0	0	0	0
Marketing Communication	3	2	12	4	16	9
Ethics	0	1	1	0	0	0
Critical Discourse Analysis	0	1	0	0	0	0
Independent Audit	0	1	0	0	0	0
Context	0	1	0	0	0	0
Industrial Marketing	1	0	0	0	0	0
Shopping Malls	0	1	0	0	0	0
All-Inclusive	1	0	0	0	0	0
SMEs	2	0	0	0	0	0
Insurance	1	0	0	0	0	0
Open Education	0	1	0	0	0	0
Fashion	0	1	0	0	0	0
Service Enterprises	0	1	0	0	0	0
Graphic Arts	1	0	0	0	0	0
Elazığ	1	0	0	0	0	0
Corporate Culture	1	0	0	0	0	0
Banking Sector	1	0	0	0	0	0
Firm Performance	1	0	0	0	0	0
Public Relations	2	0	4	2	1	1
Cultural Adaptation	1	0	0	0	0	0

Customer Perception	1	0	0	0	0	0
Local Advertising	0	1	0	0	0	0
Brand Preference	1	0	0	0	0	0
Aquaculture	1	0	0	0	0	0
Individual Marketing	1	0	0	0	0	0
Mobile Phone	1	0	0	0	0	0
Konya	0	1	0	0	0	0
European Union	1	0	0	0	0	0
Packaging	1	0	0	0	0	0
Developing Countries	0	1	0	0	0	0
Research and Development	1	0	0	0	0	0
Direct Marketing	1	0	1	0	0	0
Tourism	0	0	1	0	0	0
Globalization	0	0	1	1	1	0
Fairs	0	0	1	0	0	0
Communication	0	0	1	0	0	0
Customer Behavior	0	0	1	0	0	0
Customer Value	0	0	1	0	1	0
Television Advertisements	0	0	0	1	0	0
Customer Relations	0	0	1	0	0	0
Cooperatives	0	0	2	0	0	0
Market Selection	0	0	1	0	0	0
Crisis	0	0	2	0	0	0
Banks	0	0	1	0	0	0
Corporate Communication	0	0	1	0	0	0
Culture	0	0	1	0	0	0
Entrepreneurship	0	0	1	0	0	0
Corporate Responsibility	0	0	1	0	0	0
Brand Positioning	0	0	1	0	0	0
Corporate Reputation	0	0	0	1	0	0
Mardin	0	0	1	0	0	0
Film	0	0	2	0	1	0
Fashion Industry	0	0	1	0	0	0
Political Communication	0	0	1	0	0	0
Hospitals	0	0	0	1	0	0
Media	0	0	2	1	0	0
Brand Value	0	0	0	1	0	0
Price	0	0	1	0	0	0
Culinary Tourism	0	0	1	0	0	0
Effective Communication	0	0	0	1	0	0
Independent Auditing Firms	0	0	0	1	0	0
Republican Era	0	0	1	0	0	0
Agricultural Products	0	0	0	1	0	0
Football	0	0	1	1	0	0
Fast Food	0	0	1	0	0	0
Brand Image	0	0	0	1	0	0
Medical Sector	0	0	1	0	0	0
White Goods Sector	0	0	1	0	0	0
Archery	0	0	1	0	0	0
Animation	0	0	1	0	0	0
Decision Tree	0	0	0	1	0	0

5. CONCLUSION

This study reflects the trends of graduate thesis research conducted in Turkey on "Marketing Communication," an increasingly important subfield of marketing, through a bibliometric analysis. A significant observation from the bibliometric analysis is that thesis research in the field of "Marketing Communication" is predominantly conducted within Social Sciences Institutes (n=118). However, it has also been identified that other institutes have related theses. From another perspective, it has been noted that thesis research in the field of "Marketing Communication" has primarily been carried out in the main fields of Business and Public Relations, as expected, which aligns with the nature of the relevant disciplines. Nonetheless, the presence of a considerable number of theses in other main fields is significant for the development of this discipline. This also represents an important aspect from an interdisciplinary perspective, as it is believed that new viewpoints and approaches to "Marketing Communication" can contribute to its nourishment and development. Particularly, it influences the development of multidisciplinary perspectives.

The examination revealed that there has been a steadily increasing number of theses in the field of "Marketing Communication" from 1994 until the end of 2019. However, considering the limitation of thesis titles, it is possible that there are theses that do not explicitly mention "Marketing Communication" in their titles and thus fall outside the scope of this study. Therefore, it can be said that this study provides only one perspective. Additionally, this study encompasses theses registered up to December 2020, making it a preliminary step. Future studies with a broader perspective can address all topics that fall within or will fall within the field of "Marketing Communication."

When viewed from the perspective of universities, the fact that thesis research related to "Marketing Communication" has been predominantly conducted at universities in the Marmara, Aegean, and Central Anatolia regions can be explained by the close relationship of the main fields present at these universities with the topic. Especially considering the increasing number of universities and main fields after the 2000s, it is a reality that universities in other regions will contribute more to thesis research in "Marketing Communication."

In the examination of the topic names provided in the thesis index information from CoHE's National Thesis Center, it was found that topics outside of public relations, advertising, and business were also mentioned. Particularly, when viewed from the perspective of master's and doctoral studies, it was observed that the thesis index information predominantly included public relations and advertising. However, despite the presence of "Marketing Communication" in the thesis title, the absence of "Marketing Communication" as a topic name in the index information reflects that thesis authors tend to align their index information more with their main fields. On the other hand, this situation indicates that the topic has been approached from different sectors and researched in the context of applications.

When examining the phenomena specified in the thesis index information, it was determined that the maximum number of 14 index concepts were mentioned, with "Marketing Communication" primarily found in "Index 1." From the perspective of master's and doctoral studies, it was noted that this phenomenon was predominantly included in the master's thesis index information. This demonstrates that thesis authors consider not only the thesis title but also the main field when providing index information.

In light of all these indicators, it reflects the scientific examination of marketing communication practices in Turkey in terms of the development of the "Marketing Communication" discipline. The rapid development and expansion of the marketing communication mix today have led to each component being addressed separately and becoming the subject of scientific investigations. Naturally, this situation reflects the diversification of theses related to the phenomenon of "Marketing Communication" both in terms of topics and titles in CoHE's National Thesis Center. In the context of the expanding scope of marketing communication, this situation creates a richness in the field of science. However, when viewed holistically, the breadth of scope for future research presents a challenge for researchers. This means that researchers should focus on sub-areas of marketing communication. Therefore, it is recommended that those who want to work in this field consider the scope of marketing communication, determine the topics they will research within this scope, and approach the issues from a more holistic perspective.

AUTHORS' DECLARATION:

This paper complies with Research and Publication Ethics, has no conflict of interest to declare, and has received no financial support. Regarding the conduct of this research, an "*Ethics Permission Certificate*" dated 16/04/2021 and numbered 06 was obtained from the Ethics Committee of the University of Afyon Kocatepe/Social Sciences and Humanities Scientific Research and Publication Ethics Committee.

AUTHORS' CONTRIBUTIONS:

Conceptualization, writing-original draft, editing – **TÇ** and **EC**, data collection, methodology, formal analysis – **TÇ and EC,** Final Approval and Accountability – **TÇ** and **EC.**

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Analysis of Business Sophistication Performance in G7 Countries: An Application of the MIEXCF-based CODAS Method

G7 Ülkelerinde İş Dünyası Sofistikasyonu Performansının Analizi: MIEXCF Tabanlı CODAS Yöntemi Uygulaması

Furkan Fahri ALTINTAŞ
Asst. Prof. Dr., Aydın Provincial Gendarmerie Command
furkanfahrialtintas@yahoo.com
https://orcid.org/ 0000-0002-0161-5862

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ABSTRACT

The business sophistication (BS) performance of major economies significantly influences global BS and the global economy. Consequently, analyzing the BS performance of these economies is crucial. Therefore, the aim of this study is to evaluate the BS performance of G7 countries using the MIEXCF-based CODAS method, based on the most recent Global Innovation Index - Business Sophistication (GII-BS) criteria. Empirical findings reveal that "Knowledge Workers" and "Knowledge Absorption" are the most significant criteria for countries, according to the MIEXCF method. Therefore, G7 countries should place greater emphasis on the "Knowledge Workers" and "Knowledge Absorption" BS criteria to make a greater contribution to global business development and the economy. Furthermore, the BS performance of countries was measured using the MIEXCF-based CODAS method, and the performance rankings were determined as follows: USA, Japan, UK, France, Germany, Canada, and Italy. Additionally, the study calculated the average BS performance value, and it was found that Germany, Canada, and Italy had below-average BS performance values. Therefore, it is concluded that these countries need to improve their BS performance to contribute more to global BS and the global economy. Methodologically, sensitivity, comparative, and simulation analyses indicate that the MIEXCF-based CODAS method can be effectively used to measure the BS performance of countries using the GII-BS criteria.

Anahtar Kelimeler:
İş Gelişmişliği,
G7,
MIEXCF,
MIEXCF Tabanlı CODAS
Jel Kodları:
F29, M19, C44

ÖZET

Büyük ekonomilerin iş dünyası sofistikasyonu (BS) performansı, küresel BS ve küresel ekonomi üzerinde önemli bir etkiye sahiptir. Bu nedenle, bu ekonomilerin BS performanslarının analiz edilmesi kritik bir öneme sahiptir. Dolayısıyla bu çalışmanın amacı G7 ülkelerinin BS performansını, en güncel Küresel İnovasyon Endeksi-İş Dünyası Sofistikasyonu (GII-BS) kriterlerine dayalı olarak MIEXCF tabanlı CODAS yöntemiyle ölçmektedir. Ampirik bulgular, MIEXCF yöntemine göre "Bilgi İşçileri" ve "Bilgi Emme" kriterlerinin ülkeler için en önemli kriterler olduğunu ortaya koymaktadır. Bu nedenle, G7 ülkelerinin, küresel iş dünyası gelişimine ve ekonomiye daha büyük katkı sağlamak için "Bilgi İşçileri" ve "Bilgi Emme" BS kriterlerine daha fazla önem vermesi gerekmektedir. Ayrıca, MIEXCF tabanlı CODAS yöntemi kullanılarak ülkelerin BS performansları değerlendirilmiş ve performans sıralaması şu şekilde belirlenmiştir: ABD, Japonya, Birleşik Krallık, Fransa, Almanya, Kanada ve İtalya. Çalışma ayrıca ortalama BS performans değerini hesaplamış ve Almanya, Kanada ve İtalya'nın ortalama BS performans değerinin altında kaldığını ortaya koymuştur. Bu nedenle, bu ülkelerin küresel BS ve küresel ekonomiye daha fazla katkıda bulunabilmek için BS performanslarını iyileştirmesi gerektiği sonucuna varılmıştır. Metodolojik olarak, duyarlılık, karşılaştırmalı ve simülasyon analizleri, MIEXCF tabanlı CODAS yönteminin GII-BS kriterlerini kullanarak ülkelerin BS performansını ölçmede etkili bir şekilde kullanılabileceğini doğrulamaktadır.

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1. INTRODUCTION

Assessing a nation's business sophistication (BS) is crucial for understanding its global competitiveness and developing strategies for sustainable growth (Schwab & WEF, 2019). BS encompasses productivity, innovation, labor efficiency, and firm competitiveness (WIPO, 2022), making it a key indicator of economic well-being. It aids policymakers in crafting effective economic policies and supports businesses in making informed investment decisions and integrating into global value chains (Kindersley, 2018). By identifying a nation's strengths and weaknesses, BS benchmarks are vital in recognizing competitive advantages and promoting long-term prosperity (Joshi & Klein, 2018).

BS performance of G7 nations, key players in global trade, finance, and innovation (Oldani & Wouters, 2018), has significant implications for the global economy. The BS of these countries not only influences their own economic growth and competitiveness but also impacts the business performance of other nations (Fälth & Rañola, 2021). Success in G7 business development can enhance global business environments and innovation capacities, making BS performance a critical indicator of global economic health (Hajnal, 2020).

This research employed the MIEXCF-based CODAS Multi-Criteria Decision Making (MCDM) method to evaluate the BS performance of G7 countries using the BS criteria from the latest 2023 Global Innovation Index (GII-BS). The primary motivation behind this study was to identify the specific BS criteria that G7 countries should prioritize to foster positive contributions to global business and the economy. Secondly, the research aimed to determine which G7 country or countries needed to enhance their BS performance to drive global business and economic growth. Finally, the study sought to assess the feasibility of using the MIEXCF-based CODAS method with GII-BS data to measure the BS performance of G7 countries.

A comprehensive review of the BS literature revealed an absence of studies employing any MCDM method to evaluate the BS performance of countries. Consequently, given its novel subject matter and methodology, this study is considered to be a contribution to the field of BS research. As such, it is expected to make significant contributions to both the business sophistication and MCDM literatures. The literature review section of the study provides a detailed overview of business sophistication and related research, while the methodology section outlines the research design. In the results and discussion section, a quantitative analysis of the findings is presented, followed by a comprehensive discussion.

2. LITERATURE REVIEW

BS encompasses all activities aimed at fostering growth, profitability, and market strength (Cherunilam, 2015; Daum, 2020). The literature offers various perspectives on BS (Spender, 2014). Strategically, BS involves implementing effective organizational strategies for improved business performance (Siegfried, 2021; Hermanni, 2022). Operationally, it focuses on process improvement and cost efficiency (Brown et al., 2018; Robosky, 2023). Financially, BS emphasizes profit maximization and resource allocation (Sofat & Hiro, 2015; Chandra, 2014). From an innovation standpoint, it involves developing new products or models (Amit & Zott, 2020; Velu, 2024). Competitively, BS leads to creating a competitive edge (David & David, 2022; Dinçer, 2013). Lastly, from a human resources perspective, it includes enhancing employee competencies and motivation (Henderson, 2017; Ghosh & Ghosh, 2022).

At a macro level, a nation's BS is a crucial factor shaping its economic, social, and political landscape (Schwab and WEF, 2017). BS enhances international competitiveness and innovation capacity, positively impacting economic growth. Empirical studies show that countries with strong BS demonstrate higher innovation and competitiveness, key drivers of economic development (Terzić, 2021; Doroudi et al., 2022; Mariš, 2022; Alexandroa & Basrowi, 2024; Omonovich, 2023; Hysai & Sulçaj, 2024). Thus, measuring a country's BS performance is vital (Cornell University et al., 2020).

Evaluating BS performance is instrumental in enabling countries to gain deeper insights into their strengths and weaknesses, formulate more effective future plans, and assume a more prominent role in the global arena. These evaluations serve as a compass for both governments and the private sector in their decision-making processes (Cornell University et al., 2016). Specifically, nations leverage BS performance metrics to inform policy and strategy development aimed at enhancing economic power and competitiveness, attracting investment, fostering sustainable development, promoting employment and social welfare, and driving innovation and technological advancements. Consequently, countries seek metrics to measure their BS performance to bolster their economic attractiveness and competitiveness on the global stage (Schwab & WEF, 2015).

Two primary metrics have been employed internationally to assess countries' BS performance: the World Economic Forum's (WEF) Global Competitiveness Index (GCI) and the Global Innovation Index (GII). The GCI, developed by the WEF, measured countries' competitiveness from 2006 to 2020. The index included a criterion for measuring countries' BS performance, but the latest data on this criterion was available up to 2017 (Schwab et al., 2020). While the GCI continued to measure countries' competitiveness until 2020, the "business dynamism" criterion replaced BS as a key indicator from 2018 onwards (Schwab & WEF, 2018; Schwab and WEF, 2019; Schwab et al., 2020). The GII, initially developed by INSEAD in 2007, has been used to assess countries' innovation performance since then. The World Intellectual Property Organization (WIPO) joined the initiative in 2011, followed by Cornell University in 2013 (Cornell University et al., 2020). WIPO has been solely responsible for measuring countries' innovation performance from 2021 to 2023 (WIPO, 2021; WIPO, 2022; WIPO, 2023). The GII includes a BS criterion as an input indicator, which is assessed based on three sub-criteria: knowledge workers, innovation linkages, and knowledge absorption. Knowledge workers refer to individuals employed in knowledge-intensive roles. Innovation linkages represent the connections that facilitate the sharing of knowledge, technology, and innovations among different actors. Finally, knowledge absorption refers to a company or organization's ability to acquire, comprehend, assimilate, and apply external knowledge (WIPO, 2023). Methodologically, the values for each criterion range from 0 to 100, providing a standardized measure of a country's BS performance.

As the world's largest economies, the G7 nations play a pivotal role in shaping the global economic landscape. Consequently, measuring the BS performance of these countries holds immense significance for the global economy. Their business practices and policies not only influence their domestic economies but also exert a direct impact on the BS of other nations (Schwab & WEF, 2018). The economic decisions made by G7 countries significantly shape global trade, investment flows, and innovation processes, thereby influencing the overall state of the global economy. Monitoring the BS performance of G7 countries is thus crucial for understanding global economic dynamics and forecasting future economic trends. Moreover, these countries serve as benchmarks for other nations seeking to develop successful business models and policies (WIPO, 2022). According to the latest 2023 GII report, the average BS performance of G7 countries is 56.8, compared to the global average of 40.8. This indicates that the G7 nations' BS performance is 39% higher than the global average. Such a significant disparity underscores the substantial influence of these major economies on the overall global BS score, thereby highlighting the importance of analyzing their BS performance (WIPO, 2023).

Upon reviewing the literature, it is evident that numerous studies have explored the economic and social dimensions of BS. However, no research has been identified in the literature that evaluates the BS performance of countries using any MCDM method. Accordingly, this study is the first in the literature to evaluate the BS performance of countries using an MCDM method. Therefore, it is considered that this research contributes to both the BS and MCDM (MIEXCF-CODAS) literature. A review of the literature reveals that studies on the measurement of countries' BS performance are limited, while the BS dimension has been examined in relation to social and economic aspects. In this context, Gaile-Sarkane & Andersone (2011) proposed a mathematical model to analyze corporate investment returns, identify key investment areas, and enhance BS, claiming it would improve consumer behavior analysis. Vesal et al., (2013) explored the relationship between labor market factors and BS using canonical correlation analysis on 142 countries within the framework of the GCI, finding a significant positive relationship between the labor market and BS. Similarly, Razavi et al., (2012) analyzed the relationship between business sophistication (BS) and innovation using GCI data from 142 countries (2011-2012), finding a significant positive canonical correlation between the two. Suryaman et al., (2015) examined BS and labor market efficiency in Southeast Asia (2008-2014) using MANOVA, revealing a positive link. Balotić et al., (2016) explored the impact of BS on macroeconomic performance in six countries (2006-2014), showing BS positively affected exports and industrial value according to Wald and Wooldridge’s tests. Cuellar & González (2015) found a significant linear regression influence of culture on BS using Hofstede's Cultural Index (1969-2009) and GCI (2006-2012) data. Bazargan et al., (2017) demonstrated a positive canonical correlation between "Higher Education and Training" and BS for 144 countries (2014-2015), where 77.85% of BS changes could be predicted by education improvements. Mussina & Bachisse (2018) investigated the relationship between business sophistication (BS) and macroeconomic environment dimensions for 102 countries using GII data from 2016-2017 through canonical correlation analysis, finding a significant positive relationship. Salas-Velasco (2018) assessed the impact of macroeconomic conditions and innovation on BS in OECD countries with a stochastic frontier model, concluding that countries with more sophisticated production processes and higher innovation capacity demonstrated greater efficiency. Çetingüç et al., (2020) employed structural equation modeling to explore the effect of BS on long-term orientation across 86 countries, utilizing GII and Hofstede Culture Index data for 2019. Their findings indicated a significant, positive, and moderate influence of BS on long-term

orientation. Rahayu (2020) explored the relationship between business sophistication (BS) and technology readiness across 139 countries using GII data from 2010, finding a significant positive canonical correlation. Ceko (2022) analyzed the link between global innovation and BS for 131 countries with 2021 GII data through regression analysis, concluding a significant positive relationship. Pedro & Rodrigues (2022) examined the impact of BS on market sophistication in 50 countries based on GII components using multiple linear regression, revealing a significant positive effect. Lastly, Kırıkkaleli & Ozun (2019) investigated the connections among innovation capacity, BS, and macroeconomic stability in OECD countries employing various methodologies (Pedroni and Kao cointegration, fully modified ordinary least squares, dynamic ordinary least squares, Granger causality, and Dumitrescu-Hurlin causality tests). Their findings indicated that enhancements in BS fostered innovation capacity and contributed to macroeconomic stability.

A comprehensive review of the literature reveals a dearth of studies, aside from WIPO's 2023 report, that have explicitly measured the BS performance of countries. In its 2023 GII, WIPO provided a ranking of countries based on their BS performance using specific criteria within the index. The study found that the United States, Japan, the United Kingdom, Germany, France, Canada, and Italy ranked highest in terms of BS. Additionally, the research calculated the average BS performance across all countries and identified the United States, Japan, the United Kingdom, and Germany as having above-average performance (WIPO, 2023).

3. MATERIAL AND METHOD

3.1. Data Set and Analysis of the Research

The dataset for this study comprises the BS criterion scores of G7 countries as reported in the latest 2023 Global Innovation Index. To facilitate analysis, the abbreviations for the business sophistication criteria are presented in Table 1.

Table 1. Abbreviation of BS Criteria

BS Criteria	Abbreviation
Knowledge Workers	KW
Innovation Linkages	IL
Knowledge Absorption	KA

This study evaluated the BS performance of G7 countries using the MIEXCF-based CODAS MCDM method. The GII was selected as the data source due to its more current data compared to the GCI. The MIEXCF method possesses a unique nonlinear structure that accurately models complex relationships among variables compared to other objective weighting methods. Therefore, unlike conventional objective weighting approaches, considering the nonlinear and intricate relationships among criteria provides a more accurate and realistic explanation for criterion weighting. Its integral-based approach evaluates the mutual interactions between variables without requiring additional transformations, ensuring that the criterion weights reflect the true relationships. Moreover, unlike traditional linear methods, MIEXCF has the capability to enhance the influence of less significant criteria (Altıntaş, 2024). The CODAS method combines the strengths of the SAW and WPM methods, enabling precise evaluation of decision alternatives. Therefore, since the CODAS method incorporates the advantages of SAW and WPM in performance assessment, it proves to be an effective approach for measuring the performance of decision alternatives (Ecer, 2020; Demir et al., 2021). Accordingly, based on the benefits of the aforementioned methods, the weights of BS criteria for each country were determined using the MIEXCF method, while the BS performance of countries was assessed using the MIEXCF-based CODAS method.

3.2. MIEXCF Method

The MIEXCF (Measurement Relying on the Impacts of an Exponential Curve Function) method is an innovative MCDM approach based on exponential functional relationships among criteria. It employs an integral-based mathematical model to precisely calculate the exponential values assigned to criteria and their influence. This nonlinear method effectively captures complex relationships between variables (Altıntaş, 2024). However, due to its recent development, literature specifically focused on the MIEXCF method is limited. The application stages of the method are outlined below (Altıntaş, 2024).

Step 1: Constructing the decision matrix (DM)

i: $1, 2, 3 \ldots p$: where p indicates the number of decision alternatives

j: $1, 2, 3 \ldots r$: where r indicates the number of criteria

DM: Decision matrix

CR: Criterion

dm_{ij}: The decision matrix is formulated based on Equation 1, where "ij" denotes the performance of $i-th$ decision alternative on $j-th$ criterion.

$$DM = [dm_{ij}]_{pxr} = \begin{bmatrix} CR_1 & CR_2 & \dots & CR_r \\ x_{11} & x_{12} & & x_{1r} \\ x_{21} & x_{22} & \dots & x_{2r} \\ \vdots & \vdots & \vdots & \vdots \\ x_{p1} & x_{p2} & \cdots & x_{pr} \end{bmatrix} \quad (1)$$

Step 2: Decision matrix normalization (dm_{ij}^{*})

Benefit oriented criteria:

$$dm_{ij}^{*} = \frac{min.d_{ij}}{d_{ij}} \quad (2)$$

Cost oriented criteria:

$$dm_{ij}^{*} = \frac{d_{ij}}{max.d_{ij}} \quad (3)$$

Step 3: Exponential function generation

Exponential curve functions $(f(x) = y = t.u^{zx})$ were generated for up to r variables using SPSS regression, based on the exponential relationships.

(1) $f(CR_1) = CR_2, f(CR_1) = CR_3, \dots\dots f(CR_1) = CR_r$ (4)

(2) $f(CR_2) = CR_1, f(CR_2) = CR_3, \dots\dots f(CR_2) = CR_r$ (5)

(3) $f(CR_3) = CR_1, f(CR_3) = CR_2, \dots\dots f(CR_3) = CR_r$ (6)

$\vdots \ \vdots \ \vdots \qquad \vdots \ \vdots \ \vdots \qquad \vdots \ \vdots \ \vdots$
$\vdots \ \vdots \ \vdots \qquad \vdots \ \vdots \ \vdots \qquad \vdots \ \vdots \ \vdots$
$\vdots \ \vdots \ \vdots \qquad \vdots \ \vdots \ \vdots \qquad \vdots \ \vdots \ \vdots$

(r) $f(CR_r) = CR_1, f(CR_r) = CR_2, \dots\dots f(CR_r) = CR_{r-1}$ (7)

Step 4: Determining the exponential curve impact score for criteria

To understand the effect of an independent variable on a dependent variable within its minimum and maximum values, we employ definite integral calculations. The exponential curve impact score, $''E''$ is obtained from this analysis.

(1) $f(CR_1) = CR_2$, $\int_{CR_{1min.}}^{CR_{1maks.}} (f'(CR_1))\,dx = \left|E_{CR_1 \to CR_2}\right|$ (8)

(2) $f(CR_1) = CR_3$, $\int_{CR_{1min.}}^{CR_{1maks.}} (f'(CR_1))\,dx = \left|E_{CR_1 \to CR_3}\right|$ (9)

(3) $f(CR_1) = CR_4$, $\int_{CR_{1min.}}^{CR_{1maks.}} (f'(CR_1))\,dx = \left|E_{CR_1 \to CR_4}\right|$ (10)

$\vdots \ \vdots \ \vdots \qquad \vdots \ \vdots \ \vdots \qquad \vdots \ \vdots \ \vdots$
$\vdots \ \vdots \ \vdots \qquad \vdots \ \vdots \ \vdots \qquad \vdots \ \vdots \ \vdots$
$\vdots \ \vdots \ \vdots \qquad \vdots \ \vdots \ \vdots \qquad \vdots \ \vdots \ \vdots$

$$\left(\frac{r!}{(r-2)!}\right) f(C_r) = C_{r-1}\,,\ \int_{CR_{rmin.}}^{CR_{rmaks.}} (f'(CR_r))\,dx = \left|E_{CR_r \to CR_{r-1}}\right| \tag{11}$$

Step 5: Computing the cumulative exponential curve impact value per criterion (S_{CR})

By computing the aggregate exponential curve impact value for each criterion, we assess the combined effect of a criterion on the remaining ones.

$$(1)\ S_{CR_1}: \left|E_{CR_1 \to CR_2}\right| + \left|E_{CR_1 \to CR_3}\right| + \left|E_{CR_1 \to CR_4}\right| \ldots + \left|E_{CR_1 \to CR_r}\right| = \left(\sum_{j=1}^{r-1} \left|E_{CR_1 \to CR_{j+1}}\right|\right) \tag{12}$$

$$(2)\ S_{CR_2}: \left|E_{CR_2 \to CR_1}\right| + \left|E_{CR_2 \to CR_3}\right| + \left|E_{CR_2 \to CR_4}\right| \ldots + \left|E_{CR_2 \to CR_r}\right| = \left(\sum_{\substack{j=0 \\ j \neq 1}}^{r-1} \left|E_{CR_2 \to CR_{j+1}}\right|\right) \tag{13}$$

$$(3)\ S_{CR_3}: \left|E_{CR_3 \to CR_1}\right| + \left|E_{CR_3 \to CR_2}\right| + \left|E_{CR_3 \to CR_4}\right| \ldots + \left|E_{CR_3 \to CR_p}\right| = \left(\sum_{\substack{j=0 \\ j \neq 2}}^{r-1} \left|E_{CR_3 \to CR_{j+1}}\right|\right) \tag{14}$$

$$\vdots \quad \vdots \quad \vdots \qquad \vdots \quad \vdots \quad \vdots \qquad \vdots \quad \vdots \quad \vdots$$
$$\vdots \quad \vdots \quad \vdots \qquad \vdots \quad \vdots \quad \vdots \qquad \vdots \quad \vdots \quad \vdots$$
$$\vdots \quad \vdots \quad \vdots \qquad \vdots \quad \vdots \quad \vdots \qquad \vdots \quad \vdots \quad \vdots$$

$$(r)\ S_{CR_3}: \left|E_{CR_r \to CR_1}\right| + \left|E_{CR_r \to CR_2}\right| + \left|E_{CR_r \to CR_3}\right| \ldots + \left|E_{CR_r \to CR_{r-1}}\right| = \left(\sum_{j=1}^{r-1} \left|E_{CR_r \to CR_j}\right|\right) \tag{15}$$

Step 6: Determination of Criterion Weight Values (w)

The relative importance of each criterion is determined by dividing its total exponential curve impact by the sum of the impacts of all criteria.

$$w_j = \frac{S_{CR_j}}{\sum_{j=1}^{r} S_{CR_j}} \tag{16}$$

3.3. CODAS Method

CODAS (Combinative Distance-based Assessment) is an effective MCDM method that ranks decision alternatives by integrating two established techniques: SAW (Simple Additive Weighting) and WPM (Weighted Product Method). This hybrid approach leverages the strengths of both methods. Performance scores are derived using Euclidean and Taxicab distances from the negative-ideal solution (Keshavarz-Ghorabaee et al., 2016; Ecer, 2020). Euclidean distance measures the shortest path between two points, represented mathematically in a right-angled triangle as the square root of the sum of the squares of its sides. In contrast, Taxicab distance is calculated by summing the absolute differences of the coordinates of the two points (Demir et al., 2021; Alpar, 2017). A review of the literature reveals that many researchers have utilized the CODAS method in measuring decision alternatives or solving selection problems. Relevant studies on the CODAS MCDM method are presented in Table 2.

Table 2. CODAS Literature

Author's	Method(s)	Theme
Amari et al., 2023	CRITIC-CODAS	New parking lot selection
Aal et al., 2024	CODAS	Optimal charcoal company selection
Alkan & Kahraman, 2024	CODAS	Assessment of strategy for IOT-based sustainable supply chain
Amusan et al., 2024	CRITIC-CODAS	Determining of hybrid energy system

Azim et al., 2024	q-Spherical Fuzzy Rough CODAS	Renewable energy site selection
Elsayed & Arain, 2024	OWCM-CODAS	Assessment of healthcare waste treatment devices
Fan et al., 2024	COPRAS-CODAS	Optimization of railway transportation scheme
Hussain & Hussain, 2024	CODAS	Novel modified CODAS
Kannan et al., 2024	Linear diophantine fuzzy CODAS	Analysis of logistic specialist
Kavitha et al., 2024	q-rung orthopair hesitant fuzzy CODAS	Evaluation of multi-label feature
Khargotra et al., 2024	BMW-CODAS	Analysis of design parameter of V-shaped perforated blocks

The application steps of the method are detailed below, as outlined in previous studies (Keshavarz-Ghorabaee et al., 2016; Ecer, 2020; Demir et al., 2021).

Step 1: Constructing the decision matrix (DM)

i: $1, 2, 3 \ldots p$: where p indicates the number of decision alternatives

j: $1, 2, 3 \ldots r$: where r indicates the number of criteria

DM: Decision matrix

$$DM = \left[dm_{ij}\right]_{pxr} = \begin{bmatrix} CR_1 & CR_2 & \ldots & CR_r \\ x_{11} & x_{12} & & x_{1r} \\ x_{21} & x_{22} & \ldots & x_{2r} \\ \vdots & \vdots & \vdots & \vdots \\ x_{p1} & x_{p2} & \cdots & x_{pr} \end{bmatrix} \quad (17)$$

Step 2: Decision matrix normalization (n_{ij})

Benefit oriented criteria:

$$n_{ij} = \frac{x_{ij}}{mak.\, x_{ij}} \quad (18)$$

Cost oriented criteria:

$$n_{ij} = \frac{min.\, x_{ij}}{x_{ij}} \quad (19)$$

Step 3: Construction of the Weighted Normalized Decision Matrix (k_{ij})

$$k_{ij} = w_j n_{ij} \quad (20)$$

In Equation 3, w_j $(0 < w_j < 1)$ represents the weight of the j. criterion. Additionally, it must satisfy the condition $(\sum_{j=1}^{m} w_j = 1)$.

Step 4: Calculation of the Negative Ideal Solution (n_{sj})

$$ns = \left[ns_j\right]_{1xr} \quad (21)$$

$$ns_j = min_{k_{ij}} \quad (22)$$

Step 5: Measurement of Euclidean (E_i) and Taxicab Distances (T_i)

$$E_i = \sqrt{\sum_{j=1}^{r} \left(k_{ij} - ns_j\right)^2} \quad (23)$$

$$T_i = \sum_{j=1}^{r} \left| k_{ij} - ns_j \right| \tag{24}$$

Step 6: Construction of the Relative Evaluation Matrix (REM)

$$REM = [h_{iu}]_{pxp} \tag{25}$$

$$h_{it} = (E_i - E_u) + (\psi(E_i - E_u)x(T_i - T_k) \tag{26}$$

In Equation 26, ψ is a threshold function used to distinguish the equality of Euclidean distances between two alternatives, and it is defined as indicated in Equation 27.

$$\psi(x) = \begin{cases} If\ |x| \geq \tau\ , 1 \\ If\ |x| < \tau\ , 0 \end{cases} \tag{27}$$

In Equation 27, τ is a threshold parameter determined by the decision-maker, and it is recommended to take a value between 0.01 and 0.05. If the difference between the Euclidean distances of two alternatives is less than τ, these alternatives are compared using Taxicab distances. In the literature, a value of $\tau = 0.02$ is generally accepted.

Step 7: Measurement of the Performance Scores of Alternatives (H_i)

$$H_i = \sum_{j=1}^{r} h_{it} \tag{28}$$

According to the equation given in Equation 28, the alternative with the highest H_i value is identified as the best alternative.

4. RESULTS

4.1. Computational Analysis

Initially, the MIEXCF method was employed to calculate the weights of the BS criteria for each country. In this regard, the decision matrix was computed using Equation 1 as the first step of the MIEXCF method, followed by the calculation of the normalized decision matrix using Equation 2. The decision and normalized decision matrices are presented in Table 2.

Table 2. Decision and Normalized Decision Matrix Value

Decision Matrix			
G7	**KW**	**IL**	**KA**
Canada	50.7	65.7	51.6
France	69.1	47.3	51.9
Germany	59	63.1	48.6
Italy	37.9	45.6	40.4
Japan	62.9	50.2	66.6
UK	67.1	62.4	45.7
USA	76.8	75.8	57.2
Normalized Decision Matrix			
Criteria	**KW**	**IL**	**KA**
Criteria Directions	**Benefit**	**Benefit**	**Benefit**
Canada	0.748	0.694	0.783
France	0.548	0.964	0.778
Germany	0.642	0.723	0.831
Italy	1.000	1.000	1.000
Japan	0.603	0.908	0.607
UK	0.565	0.731	0.884
USA	0.493	0.602	0.706

In the third step, exponential curve functions, which describe the relationships between criteria, were generated using SPSS 23 (curve estimation). These functions, corresponding to Equations 4 through 7, are presented in Table 3.

Table 3. Exponential Curve Functions Inferred from the Interrelationship of Criteria

IDC (x)	DC (y)	Function
KW→	IL	$y = 38.10\ e^{(0.007x)}$
	KA	$y = 33.14\ e^{(0.007x)}$
IL→	KW	$y = 33.20\ e^{(0.01x)}$
	KA	$y = 43.69\ e^{(0.003x)}$
KA→	KW	$y = 26.28\ e^{(0.016x)}$
	IL	$y = 49.34\ e^{(0.003x)}$

IDC: Independent criteria, DC: Dependent criteria

In the fourth step, the exponential curve influence values among the criteria were calculated using Equations 8 to 11. Subsequently, the total exponential curve influence values of the criteria were determined using Equations 12 to 15. Finally, the last step of the method involved measuring the criteria using Equation 16. The calculated exponential curve influences values among the criteria, the total exponential curve influences values of the criteria, and the criteria weights are presented in Table 4.

KW

KW → IL

$y = 38.1\ e^{(0.007x)}$

$$\frac{dy}{dx} = \frac{2667\boldsymbol{e}^{\frac{7x}{1000}}}{10000}$$

$$\int_{0.493}^{1} \frac{2667\boldsymbol{e}^{\frac{7x}{1000}}}{10000}dx = \frac{381\boldsymbol{e}^{\frac{7}{1000}} - 381\boldsymbol{e}^{\frac{3451}{1000000}}}{10} = 0{,}136$$

KW → KA

$y = 33.14\ e^{(0.007x)}$

$$\frac{dy}{dx} = \frac{11599\boldsymbol{e}^{\frac{7x}{1000}}}{50000}$$

$$\int_{0.493}^{1} \frac{11599\boldsymbol{e}^{\frac{7x}{1000}}}{50000}dx = \frac{1657\boldsymbol{e}^{\frac{7}{1000}} - 1657\boldsymbol{e}^{\frac{3451}{1000000}}}{50} = 0{,}118$$

IL

IL → KW

$y = 33.20\ e^{(0.01x)}$

$$\frac{dy}{dx} = \frac{83\boldsymbol{e}^{\frac{x}{100}}}{250}$$

$$\int_{0.602}^{1} \frac{83\boldsymbol{e}^{\frac{x}{100}}}{250}dx = \frac{166\sqrt[100]{\boldsymbol{e}} - 166\boldsymbol{e}^{\frac{301}{50000}}}{5} = 0{,}133$$

IL → KA

$y = 43.69\ e^{(0.003x)}$

$$\frac{dy}{dx} = \frac{13107\boldsymbol{e}^{\frac{3x}{1000}}}{100000}$$

$$\int_{0.602}^{1} \frac{13107\boldsymbol{e}^{\frac{3x}{1000}}}{100000}\,dx = \frac{4369\boldsymbol{e}^{\frac{3}{1000}} - 4369\boldsymbol{e}^{\frac{903}{500000}}}{100} = 0{,}052$$

$$\boldsymbol{KA}$$

$$\boldsymbol{KA \rightarrow KW}$$

$$y = 26.28\, e^{(0.016x)}$$

$$\frac{dy}{dx} = \frac{1314\boldsymbol{e}^{\frac{2x}{125}}}{3125}$$

$$\int_{0.607}^{1} \frac{1314\boldsymbol{e}^{\frac{2x}{125}}}{3125}\,dx = \frac{657\boldsymbol{e}^{\frac{2}{125}} - 657\boldsymbol{e}^{\frac{607}{62500}}}{25} = 0{,}167$$

$$\boldsymbol{KA \rightarrow IL}$$

$$y = 49.34\, e^{(0.003x)}$$

$$\frac{dy}{dx} = \frac{7401\boldsymbol{e}^{\frac{3x}{1000}}}{50000}$$

$$\int_{0.607}^{1} \frac{7401\boldsymbol{e}^{\frac{3x}{1000}}}{50000}\,dx = \frac{2467\boldsymbol{e}^{\frac{3}{1000}} - 2467\boldsymbol{e}^{\frac{1821}{1000000}}}{50} = 0{,}058$$

Table 4. Exponential Curve Impact Scores from the Interrelationship of Criteria

DC	IDC	Impact Score	Total Impact Score	w	Rank
KW→	IL	0.136	0.254	0.383	1
	KA	0.118			
IL→	KW	0.133	0.185	0.279	3
	KA	0.052			
KA→	KW	0.167	0.225	0.338	2
	IL	0.058			
	Sum		0.664		
		Mean		0.333	

IDC: Independent criteria, DC: Dependent criteria

An analysis of Table 4 reveals that the criteria are ranked in terms of their weights (importance levels) as KW, KA, and IL. Furthermore, based on Table 4, the average weight values of the criteria were measured, and it was determined that the BS criteria KW and KA had weight values higher than the average. Consequently, considering the weight values of the BS criteria, it was concluded that IL exhibits a significant difference compared to the other BS criteria in terms of having a lower criterion value. Based on these quantitative values, it was concluded that KW and KA criteria have a significant impact on the development of countries' BS performance.

Secondly, the study assessed the BS performance of countries using the CODAS method, building on the MIEXCF method. The decision matrix was created following Equation 17, as shown in Table 2. In the second step of the CODAS method, normalized values were derived from the decision matrix using Equation 18. The third step involved calculating the weighted decision matrix values through Equation 20 and determining the negative ideal solution values of the BS criteria using Equations 21 and 22. The resulting normalized values, weighted normalized values, and ideal solution values within the CODAS framework are summarized in Table 5.

Table 5. Normalized Decision Matrix, Weighted Normalized Decision Matrix and Negative Ideal Solution

Normalized Decision Matrix

G7	KW	IL	KA
Canada	0.660	0.867	0.775
France	0.900	0.624	0.779
Germany	0.768	0.832	0.730
Italy	0.493	0.602	0.607
Japan	0.819	0.662	1.000
UK	0.874	0.823	0.686
USA	1.000	1.000	0.859
Weighted Normalized Decision Matrix			
Criteria	**KW**	**IL**	**KA**
w	0.383	0.279	0.338
Max./Min.	Max.	Max.	Max.
Canada	0.253	0.242	0.263
France	0.345	0.174	0.264
Germany	0.294	0.232	0.247
Italy	0.189	0.168	0.206
Japan	0.314	0.185	0.339
UK	0.335	0.230	0.233
USA	0.383	0.279	0.291
Negative Ideal Solution			
Criteria	**KW**	**IL**	**KA**
Score	0.189	0.168	0.206

In the fourth step, Euclidean and Taxicab distances were computed using Equations 23 and 24, respectively. The calculated values are presented in Table 6.

Table 6. Euclidean Distance and Taxicab Distance Scores

Euclidean Distance Scores				
G7	**KW**	**IL**	**KA**	**Euclidean**
Canada	0.004	0.005	0.003	0.113
France	0.024	0.000	0.003	0.166
Germany	0.011	0.004	0.002	0.130
Italy	0.000	0.000	0.000	0.000
Japan	0.016	0.000	0.018	0.183
UK	0.021	0.004	0.001	0.160
USA	0.038	0.012	0.007	0.239
Taxicab Distance Scores				
G7	**KW**	**IL**	**KA**	**Taxicab**
Canada	0.064	0.074	0.057	0.195
France	0.156	0.006	0.059	0.220
Germany	0.105	0.064	0.042	0.211
Italy	0.000	0.000	0.000	0.000
Japan	0.125	0.017	0.133	0.275
UK	0.146	0.062	0.027	0.234
USA	0.194	0.111	0.086	0.391

In the sixth step, the relative evaluation matrix was constructed considering Equations 25, 26, and 27. In the final step, the BS performance of the countries was measured using Equation 28. Accordingly, the values related to the relative evaluation matrix and the BS performance values of the countries are presented in Table 7.

Table 7. Relative Evaluation Matrix and Performance Scores

G7	Relative Evaluation Matrix							Total (Performance)	Rank
	Canada	France	Germany	Italy	Japan	UK	USA		
Canada	0.000	-0.053	-0.017	0.308	-0.070	-0.047	-0.126	-0.006	6
France	0.028	0.000	0.045	0.387	-0.017	0.006	-0.073	0.376	4
Germany	0.017	-0.036	0.000	0.342	-0.053	-0.030	-0.109	0.131	5
Italy	-0.308	-0.166	-0.130	0.000	-0.182	-0.160	-0.238	-1.183	7
Japan	0.150	0.017	0.117	0.458	0.000	0.063	-0.056	0.750	2
UK	0.087	-0.006	0.053	0.395	-0.023	0.000	-0.079	0.428	3
USA	0.322	0.243	0.288	0.630	0.172	0.235	0.000	1.891	1
Mean								0.353	

An examination of Table 7 reveals that the countries' BS performance values are ranked as follows: the USA, Japan, the UK, France, Germany, Canada, and Italy. According to Table 7, the USA exhibits a significantly higher BS performance compared to other countries, while Italy shows a significantly lower performance. Furthermore, when evaluating Table 7, it is observed that countries with a BS performance higher than the average are the USA, Japan, the UK, and France. Consequently, considering the relationships between innovation, competition, economic growth, and BS dimensions in a global context, the quantitative findings suggest that countries with below-average BS performance, such as Italy, Canada, and Germany, should adopt strategies to enhance their BS performance to contribute to global economic development.

4.2. Sensitivity Analysis

Sensitivity analysis in MCDM entails applying various criteria weighting methodologies to assess a dataset. This approach enables a comparative evaluation of the resultant values and rankings. To validate the sensitivity of the selected weighting method, it is anticipated that the rankings from the objective method will diverge from those derived using alternative objective weighting methodologies, with at least one method displaying a discrepancy (Gigovič et al., 2016). Consequently, the weights for the business sophistication (BS) criteria across countries were calculated using several widely used objective weighting methods in MCDM literature, including ENTROPY, CRITIC, SD, SVP, MEREC, and LOPCOW, each employing distinct calculation techniques. The resulting values are detailed in Table 8.

Table 8. Weight Values of BS Criteria according to ENTROPY, CRITIC, SD, SVP, MEREC, and LOPCOW Methods

Method	Score/Rank	KW	IL	KA
ENTROPY	Score	0.344	0.341	0.315
	Rank	1	2	3
CRITIC	Score	0.259	0.405	0.336
	Rank	3	1	2
SD	Score	0.324	0.362	0.314
	Rank	2	1	3
SVP	Score	0.460	0.344	0.196
	Rank	1	2	3
MEREC	Score	0.551	0.184	0.265
	Rank	1	3	2
LOPCOW	Score	0.019	0.589	0.392
	Rank	3	1	2

Secondly, the BS performance values of countries were assessed using the CODAS method based on ENTROPY, CRITIC, SD, SVP, MEREC, and LOPCOW, and the obtained results are presented in Table 9.

Table 9. BS Performance of G7 according to ENTROPY, CRITIC, SD, SVP, MEREC, and LOPCOW-based CODAS

G7	ENTROPY-CODAS		CRITIC-CODAS		SD-CODAS	
	Score	Rank	Score	Rank	Score	Rank
Canada	0.083	6	0.216	4	0.120	6
France	0.287	4	0.123	6	0.263	4
Germany	0.160	5	0.185	5	0.170	5
Italy	-1.151	7	-1.096	7	-1.137	7
Japan	0.580	2	0.623	2	0.605	2
UK	0.399	3	0.274	3	0.377	3
USA	1.924	1	1.901	1	1.926	1
G7	**SVP-CODAS**		**MEREC-CODAS**		**LOPCOW-CODAS**	
	Score	**Rank**	**Score**	**Rank**	**Score**	**Rank**
Canada	-0.034	6	-0.242	6	0.639	2
France	0.410	3	0.591	4	-0.356	6
Germany	0.217	5	0.172	5	0.370	4
Italy	-1.296	7	-1.399	7	-1.153	7
Japan	0.382	4	0.707	2	0.509	3
UK	0.628	2	0.683	3	0.260	5
USA	2.166	1	2.117	1	2.043	1

A comparative analysis of Tables 7 and 9 reveals that the rankings of G7 countries' BS performance determined by the MIEXCF-based CODAS method differ from those calculated using the CRITIC, SVP, and LOPCOW-based CODAS methods, despite the limited number of criteria and decision alternatives. Based on the values presented in Tables 6 and 8 and the relevant literature on sensitivity analysis, it is concluded that the MIEXCF-based CODAS method is more sensitive in measuring the BS performance of G7 countries using GGI-BS criteria values.

4.3. Comparative Analysis

A comparative analysis evaluates the relationships and rankings of the proposed method in relation to other techniques used for calculating MCDM methods. The proposed approach should demonstrate credibility and reliability alongside other methodologies, while also exhibiting a favorable and statistically significant correlation with various weight coefficient methods (Keshavarz-Ghorabaee et al., 2021). In this study, the BS performance of G7 countries was assessed using a variety of MCDM methods (MABAC, WASPAS, MAUT, GRA, MARCOS, TOPSIS) that are widely employed in the literature due to their distinct technical characteristics. The resulting performance scores and rankings are tabulated in Table 10.

Table 10. BS Performance of G7 according to MIEXCF-based MABAC, WASPAS, MAUT, GRA, MARCOS and, TOPSIS

G7	MIEXCF MABAC		MIEXCF WASPAS		MIEXCF MAUT	
	Score	Rank	Score	Rank	Score	Rank
Canada	0.002	6	0.754	6	0.156	6
France	0.017	5	0.778	4	0.245	3
Germany	0.021	4	0.773	5	0.162	5
Italy	-0.454	7	0.561	7	0.000	7
Japan	0.173	2	0.832	2	0.459	2
UK	0.057	3	0.794	3	0.237	4
USA	0.425	1	0.951	1	0.766	1
G7	**MIEXCF GRA**		**MIEXCF MARCOS**		**MIEXCF TOPSIS**	
	Score	**Rank**	**Score**	**Rank**	**Score**	**Rank**
Canada	0.489	6	0.637	6	0.420	6
France	0.531	4	0.638	5	0.561	4
Germany	0.494	5	0.647	4	0.501	5
Italy	0.334	7	0.469	7	0.000	7
Japan	0.666	2	0.681	2	0.596	2

UK	0.534	3	0.664	3	0.581	3
USA	0.859	1	0.795	1	0.850	1

A comparative analysis of Tables 7 and 10 reveals that the rankings of countries' BS performance values measured using the MIEXCF-based CODAS method differ from those obtained using the MIEXCF-based MABAC, MAUT, and MARCOS MCDM methods. This finding suggests that the performance calculation techniques employed in the MIEXCF-based CODAS method are substantially different from those used in the MIEXCF-based MABAC, MAUT, and MARCOS MCDM methods. Consequently, the positions of countries determined by the MIEXCF-based CODAS method relative to other MIEXCF-based MCDM methods are illustrated in Figures 1, 2 and 3.

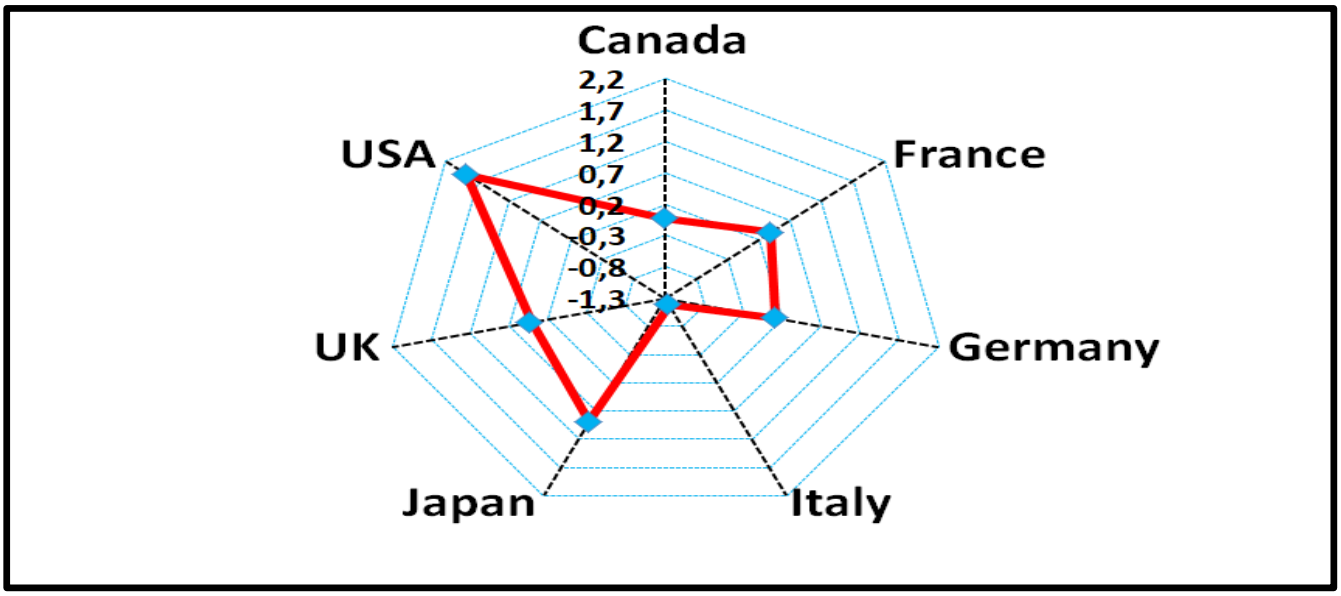

Figure 1. Position of MIEXCF based CODAS Method

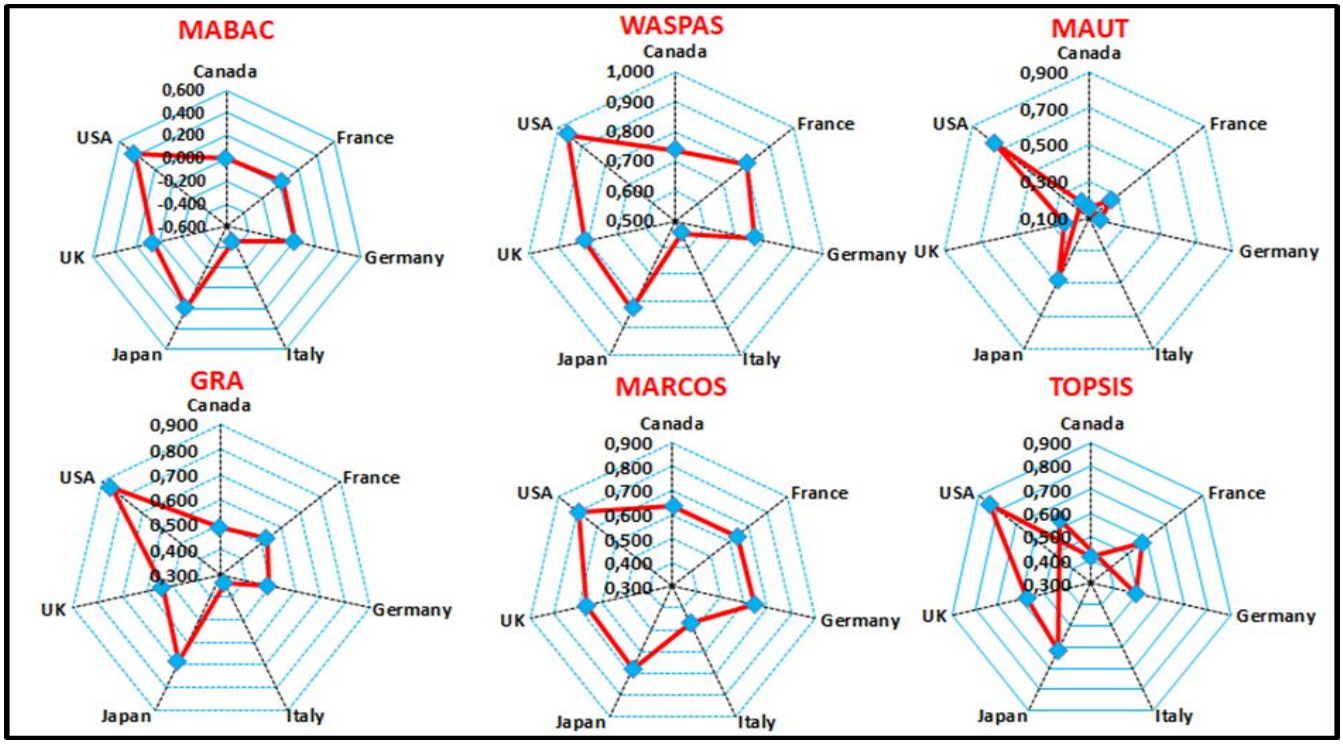

Figure 2. Position of MIEXCF based CODAS Method

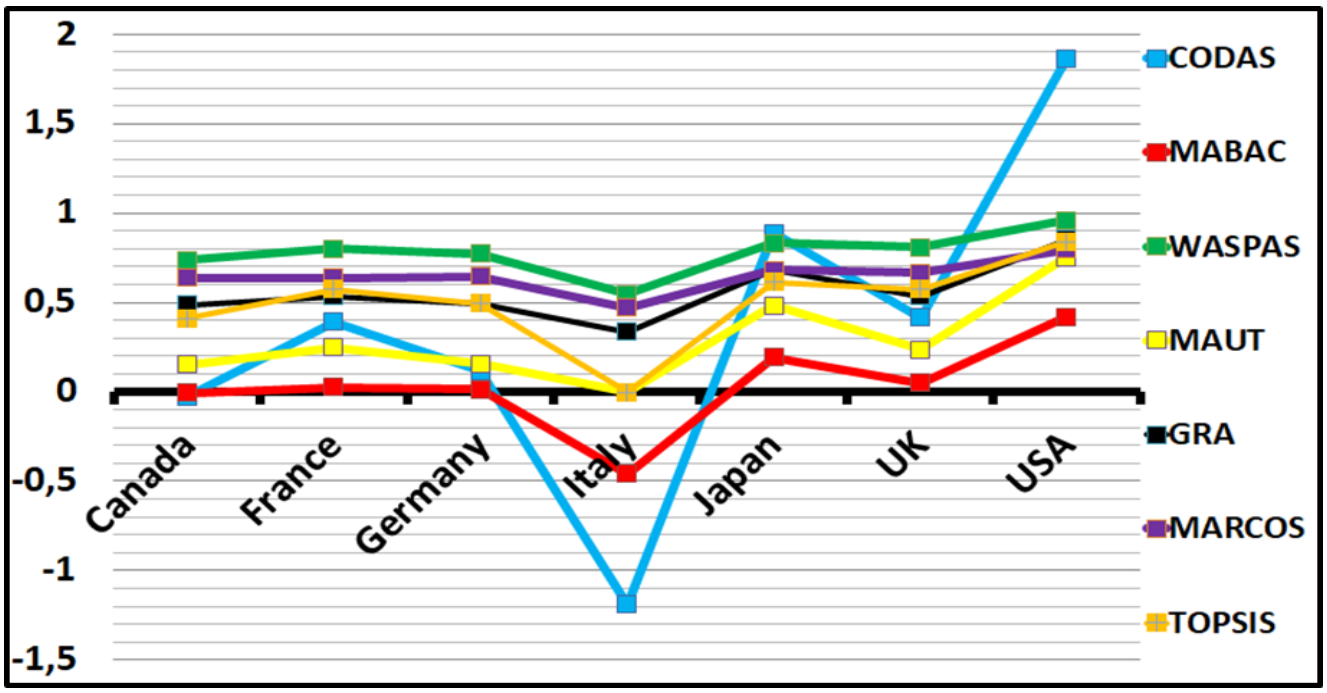

Figure 3. Position of MIEXCF-based MCDM Methods-2

A comparative analysis of Figures 1, 2, and 3 reveals a strong correlation between the health performance rankings derived from the MIEXCF-based CODAS method and those obtained using other MIEXCF-based MCDM techniques. Furthermore, Figure 2 reveals that the disparities in BS performance scores among countries, as assessed by the MIEXCF-based CODAS method, are more pronounced compared to those obtained from other MIEXCF-based MCDM) methods. Consequently, the distinctive characteristics of countries based on their criteria, as determined by the MIEXCF-based CODAS method, are more evident when compared to other MIEXCF-based MCDM approaches. The fluctuations in performance values across countries, as determined by CODAS, closely align with the trends observed in the alternative methods. This consistency suggests a positive association between the BS performance assessments generated by CODAS and those produced by other MIEXCF-based MCDM approaches. Table 11 presents the Spearman Rank Correlation (rho) values between the BS performance scores of countries measured by the MIEXCF-based CODAS method and those obtained using other MIEXCF-based MCDM methods.

Table 11. *rho* Analysis of the MIXCEF-based CODAS Method in Relation to Other MIXCEF-based MCDM Techniques

rho	**MABAC**	**WASPAS**	**MAUT**	**GRA**	**MARCOS**	**TOPSIS**
CODAS	0.964**	0.999**	0.964**	0.999**	0.964**	0.999**

p*<.05. p**<.01

Upon examining Table 11, it is evident that the rho coefficients between the BS performance scores of countries assessed using the MIEXCF-based CODAS method and those derived from other MIEXCF-based MCDM techniques are significantly positive and exceptionally high. Consequently, it can be concluded that the MIEXCF-based CODAS method is both reliable and credible for evaluating the BS performance of G7 nations within the GII-BS framework.

4.4. Simulation Analysis

To evaluate the robustness and stability of our proposed method, we will conduct a simulation analysis. We will generate various scenarios by changing the values in the decision matrices. A reliable method should show increasing differences in its results compared to others as the number of scenarios grows. Additionally, the average variance of criterion weights calculated by our method should be significantly higher than at least one other weighting method. This demonstrates our method's ability to distinguish the relative importance of criteria. Finally, It has to be checked if the variance of criterion weights is consistent across all methods within each scenario (Keshavarz-Ghorabaee et al., 2021). Table 12 presents the correlation coefficients between the MIEXCF-based CODAS method and other MIEXCF-based MCDM methods, as computed using the first ten scenarios from the simulation analysis.

Table 12. Correlations of the MIEXCF-based CODAS Method with Other MCDM Techniques under Various Scenarios

Methods	MABAC	WASPAS	MAUT	GRA	MARCOS	TOPSIS
1. Scenario	0.968**	0.999**	0.969**	0.999**	0.970**	0.999**
2. Scenario	0.971**	0.999**	0.972**	0.999**	0.966**	0.998**
3. Scenario	0.963**	0.995**	0.961**	0.995**	0.954**	0.993**
Methods	**MABAC**	**WASPAS**	**MAUT**	**GRA**	**MARCOS**	**TOPSIS**
4. Scenario	0.956**	0.996**	0.949**	0.996**	0.951**	0.991**
5. Scenario	0.946**	0.990**	0.937**	0.990**	0.946**	0.982**
6. Scenario	0.941**	0.986**	0.931**	0.986**	0.941**	0.976**
7. Scenario	0.934**	0.982**	0.928**	0.982**	0.933**	0.968**
8. Scenario	0.931**	0.977**	0.925**	0.977**	0.928**	0.956**
9. Scenario	0.926**	0.971**	0.922**	0.971**	0.925**	0.947**
10. Scenario	0.921**	0.966**	0.916**	0.966**	0.924**	0.943**

**p<.01; *p<.05

Table 12 classifies the 10 scenarios into two groups. The initial three scenarios form the first group, while the subsequent scenarios constitute the second. According to Table 12, the correlation values between the MIEXCF-based CODAS method and other methods exhibit a decreasing trend with an increasing number of scenarios. This trend is graphically illustrated in Figure 4.

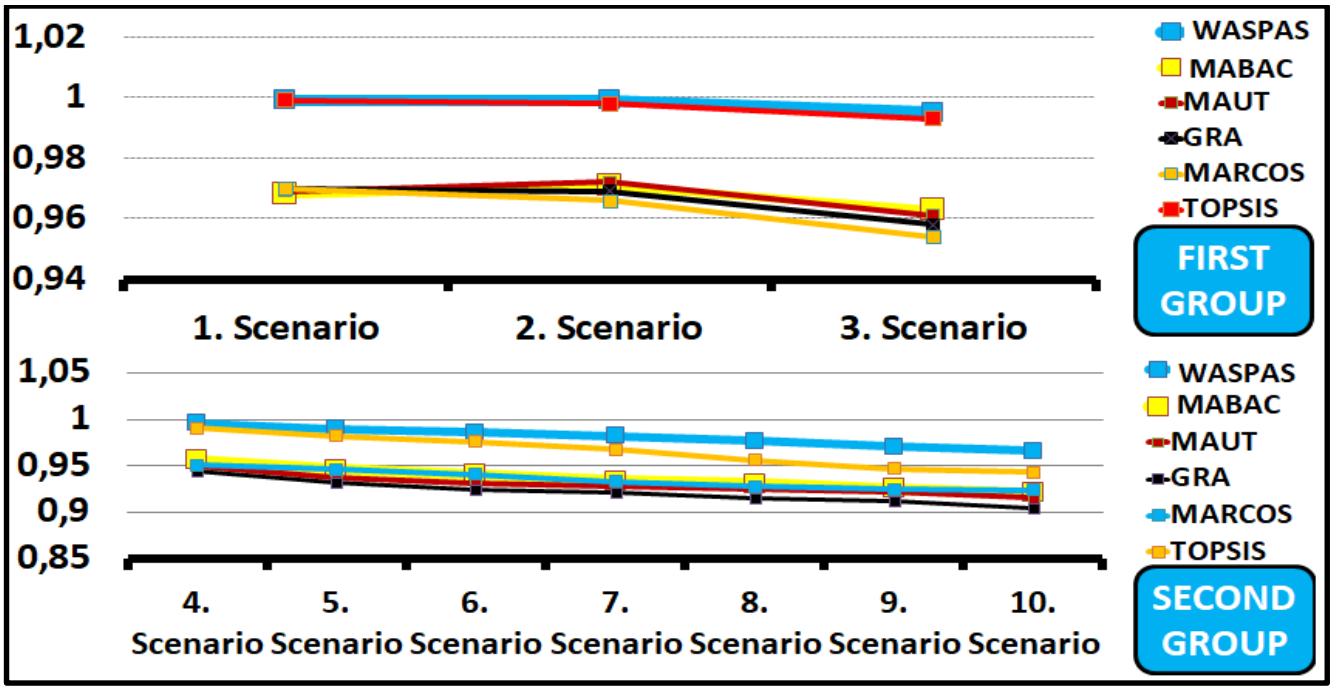

Figure 4. Placement of MIEXCF-based CODAS Relative to Other MIEXCF MCDM Techniques

Figure 4 demonstrates that the MIEXCF-based CODAS method increasingly differentiates itself from other MIEXCF-based MCDM methods as the number of scenarios increases. This observation highlights the unique characteristics of the CODAS method, which become more apparent with a larger number of scenarios.

To further analyze the simulation results, we employed an Analysis of Means (ANOM) for variances, specifically utilizing the Levene statistic (ADM). This statistical method assesses the consistency of variances in the criterion weights assigned by the MIEXCF-based CODAS method across various scenarios. A graphical representation of the ADM findings includes a central line denoting the overall mean ADM, along with upper and lower decision limits (UDL and LDL). If a group's standard deviation falls outside these limits, it signifies a significant deviation from the mean ADM, indicating heterogeneity in variances. In contrast, if all group standard deviations remain within the UDL and LDL boundaries, it confirms variance homogeneity (Keshavarz-Ghorabaee et al., 2021). For this analysis, we calculated variance values for the performance scores of countries, as determined by the MIEXCF-based CODAS and other MCDM methods, for each scenario. These variance values are presented in Table 13.

Table 13. Variance Scores of MCDM Methods across Scenarios

Methods	CODAS	MABAC	WASPAS	MAUT	GRA	MARCOS	TOPSIS
1. Scenario	0.856	0.095	0.018	0.079	0.035	0.015	0.074
2. Scenario	0.87	0.088	0.016	0.074	0.033	0.014	0.071
3. Scenario	0.723	0.81	0.012	0.071	0.034	0.011	0.069
4. Scenario	0.705	0.073	0.012	0.062	0.031	0.009	0.065
5. Scenario	0.654	0.063	0.011	0.058	0.025	0.009	0.064
6. Scenario	0.602	0.061	0.009	0.055	0.022	0.008	0.058
7. Scenario	0.555	0.055	0.009	0.051	0.019	0.008	0.052
8. Scenario	0.501	0.049	0.007	0.046	0.017	0.007	0.047
9. Scenario	0.488	0.044	0.006	0.043	0.016	0.006	0.044
10. Scenario	0.421	0.041	0.006	0.039	0.016	0.006	0.042
Mean	0.638	0.138	0.011	0.058	0.025	0.009	0.059

A closer examination of Table 13 indicates that the MIEXCF-based CODAS method exhibits a notably higher average variance across the analyzed scenarios when compared to other MIEXCF-based MCDM methods. This observation suggests that the CODAS method possesses a greater capacity to differentiate between criteria, potentially resulting in more nuanced performance evaluations.

In the final phase of the simulation analysis, the homogeneity of criterion weight variances in the CSBA method was evaluated using ADM (ANOM for variances based on Levene) analysis across various scenarios. This approach offers a visual tool to assess the consistency of variances. The graphical representation consists of three key elements: the overall average ADM as the central reference line (Average Decision Limit: ADL), along with the upper decision limit (UDL) and the lower decision limit (LDL). If the standard deviation of a particular group (or cluster) exceeds these decision limits, it signifies a significant divergence from the overall average decision ADM, indicating variance heterogeneity. Conversely, if the standard deviations for all clusters remain within the UDL and LDL boundaries, it confirms the presence of variance homogeneity. Figure 5 presents the graphical outcomes of the ADM analysis.

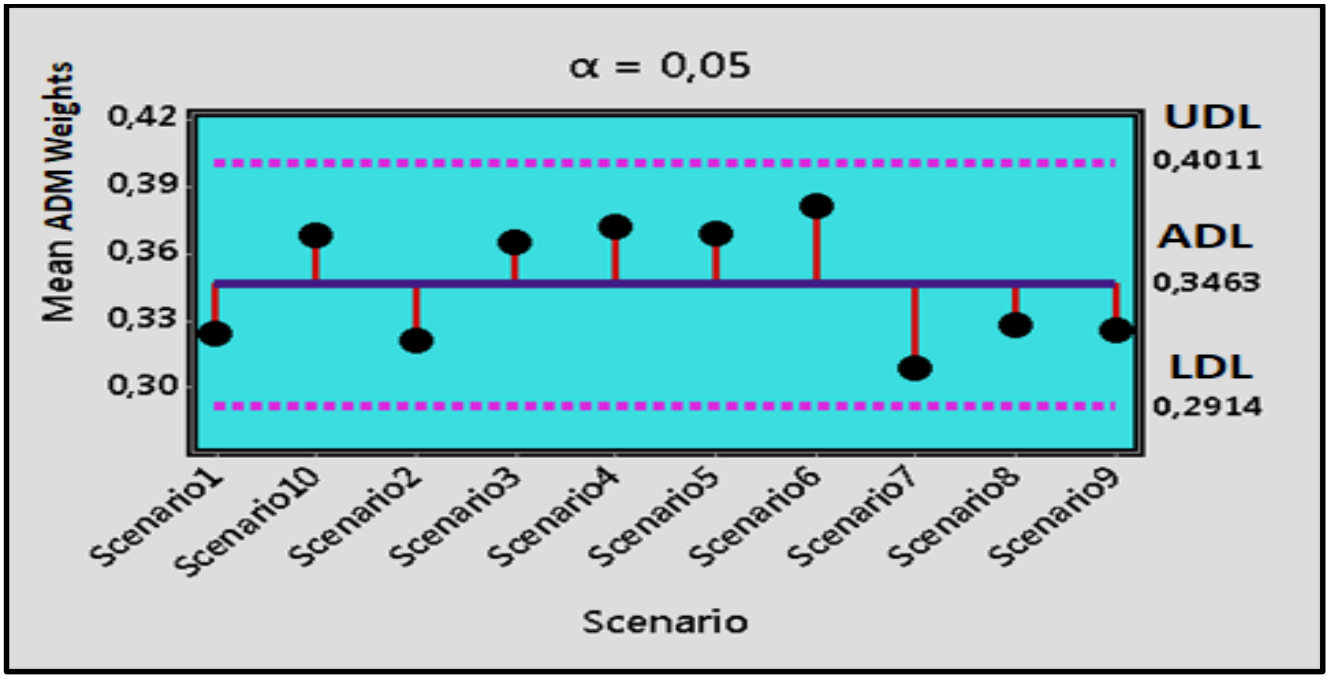

Figure 5. ADM Chart

A homogeneous band of calculated ADM values is depicted in Figure 5 for all scenarios. Crucially, all values are contained within the established UDL and LDL. This observation suggests consistent weight variances across the scenarios. Levene's Test, with its key statistics reported in Table 14, provides further evidence in support of this conclusion.

Table 14. Levene's Test

Levene Statistic	df1	df2	p (Significant)
0.312	2	10	0.191

p*<.05

A closer examination of Table 14 indicates that the Levene Statistic value is 0.312, with a p-value greater than 0.05 (p=0.191>0.05). This suggests that the variances are homogeneous. Consequently, when considering the overall results of the simulation analysis, it can be concluded that the MIEXCF-based CODAS method demonstrates robustness and stability in evaluating countries' climate change performance within the GII-BS framework.

5. CONCLUSION

Assessing the business development performance of major economies is of paramount importance for understanding global business development and its impact on the world economy. As significant players in the international market, these countries exert a substantial influence on economic trends, innovation, and competitiveness. Consequently, the business development performance of major economies has been deemed crucial. Within this context, the study measures the BS performance of these countries using the MIEXCF-based CODAS method, based on the latest and most up-to-date 2023 GII-BS criteria values.

The empirical findings indicated that, according to the MIEXCF method, the weights of the BS criteria for countries were ranked as follows: Knowledge Workers (KW), Knowledge Absorption (KA), and Innovation Linkages (IL). Significant differences were observed between KW and KA, with both exhibiting above-average weight values. This suggests that KW and KA could enhance the BS performance momentum of G7 countries. To optimize their contributions to the global economy, it is recommended that G7 countries prioritize fostering creativity and problem-solving abilities among KW, enhancing technology utilization, continuous learning, and innovative thinking and promoting collaboration, risk-taking, and effective leadership practices. Additionally, G7 countries should focus on improving their ability to access and monitor information, evaluate and internalize knowledge, transform this knowledge into gains, solicit stakeholder feedback, integrate an internal innovation culture, and support organizational learning within the context of KA.

Secondly, the MIEXCF-based CODAS method was employed to measure the BS performance of countries, resulting in the following performance rankings: the USA, Japan, the UK, France, Germany, Canada, and Italy. Notably, the USA exhibited significantly higher BS performance values compared to other countries, while Italy displayed the lowest values. Furthermore, the study calculated the average BS performance value, revealing that the USA, Japan, the UK, and France outperformed this average. WIPO (2023) ranked the G7 countries' BS performance based on the 2023 GII-BS data as follows: USA, Japan, Germany, France, Canada, and Italy. Considering both studies, the ranking of the USA, Japan, France, and Canada was consistent. Additionally, WIPO (2023) found that the USA, Japan, and UK exceeded the average performance value. Based on these findings from both studies, it can be concluded that the USA, Japan, and the UK have achieved higher BS performance compared to other G7 countries. These quantitative results suggest that the USA, Japan, and the UK have placed greater emphasis on BS criteria in developing their BS performance. Apart from WIPO (2023), no study in the literature has been found that analyzes the BS performance of countries. Furthermore, no research has been identified that evaluates the BS performance of countries using any BS-related criteria within an MCDM framework. Therefore, this study contributes to both the BS and MCDM literature by examining and measuring the BS performance of countries. A review of the literature reveals that the BS dimension has generally been analyzed in relation to other social and economic dimensions. In this context, Gaile-Sarkane and Andersone (2011), Razavi et al., (2012), Vesal et al., (2013), Suryaman et al., (2015), Balotić et al., (2016), Ceko (2022), Cuellar & González (2015), Kırıkkaleli & Ozun (2019), Mussina & Bachisse (2018), Pedro & Rodrigues (2022), and Salas-Velasco (2018) have examined the relationship between the BS dimension and economic factors, as well as dimensions directly linked to the economy (such as innovation, the labor market, and industrial values). Bazargan et al., (2017) and Çetingüç et al., (2020) have investigated the relationship between the BS dimension and culture as a social structure. Thus, a comprehensive review of the BS-related literature indicates that, apart from WIPO (2023), no study has exclusively focused on describing the BS structure of countries. This highlights the significant impact of BS capacities both at the national and global levels in terms of spatial implications. Consequently, this study aligns with WIPO (2023) in its exclusive focus on the BS performance of countries, while it differs from other studies that address the BS dimension in relation to broader socioeconomic factors. In the study, BS criterion weights for the countries were measured using the ENTROPY, MEREC, SD, SVP,

LOPCOW, and CRITIC methods. Subsequently, the BS performance of the countries was evaluated using the CODAS method based on these weighting techniques. Furthermore, According to the research findings, the BS performance rankings obtained through the MIEXCF-based CODAS method were found to be fully consistent with those measured using the ENTROPY, MEREC, and SD-based CODAS methods. Therefore, considering the ranking of countries' BS performance from a methodological perspective, it has been concluded that the MIEXCF-based CODAS method exhibits similar characteristics to the ENTROPY, MEREC, and SD-based CODAS methods.

The observed BS performance differences among G7 countries stem from various structural factors when analyzed in terms of economic and social dynamics. Primarily, countries' innovation ecosystems, investment policies, R&D expenditures, and education systems directly influence their BS performance. For instance, countries such as the United States and Japan enhance their BS performance through high-tech investments, an entrepreneurial culture, and R&D incentives. In contrast, countries like Italy and Canada exhibit relatively limited incentive mechanisms and investment deficiencies in these areas, which may result in lower performance. Furthermore, when assessed within the framework of the Knowledge Workers criterion, significant differences exist among countries regarding their education systems and talent development policies. The United States and the United Kingdom, for example, possess globally prestigious universities and a robust academic research infrastructure. Meanwhile, in other countries, regional disparities in education quality and policies that fail to fully align with labor market demands contribute to a decline in BS performance. From a social perspective, factors such as innovation culture, digitalization levels, and flexibility in the business environment vary across countries. In the USA and Japan, strong collaborations between the private sector and academia play a crucial role in enhancing BS performance.

Conversely, in countries like Germany and France, stricter bureaucratic constraints and regulatory processes may slow down innovation, thereby limiting BS performance. Lastly, macroeconomic stability and industrial policies are also critical determinants of these performance differences. The United States, the United Kingdom, and Japan have adopted a knowledge-based economic growth model, whereas countries like Italy and Canada have a higher reliance on traditional industries. The relatively limited investments in digitalization and innovation in these nations contribute to their lower BS performance. Thus, BS performance disparities are not solely reflected through MCDM-based performance indicators but are also deeply intertwined with the broader economic and social structures of the respective countries.

Considering the relationship between economic growth and improvement and BS performance, the current research findings suggest that Italy, Canada, and Germany, in particular, need to implement measures, strategies, methods, and practices to enhance their BS performance in order to contribute more significantly to the global economy. In this context, it is particularly recommended that these countries, especially Italy, prioritize the development of KW and KA criteria and undertake innovative activities to enhance these criteria. Additionally, to improve their overall BS performance, these countries should focus on increasing investments in innovation and technology, education, and talent development programs, as well as expanding international market access. Furthermore, they should optimize their supply chains and collaborations, strengthen their management and organizational structures, and develop strategies to promote collaboration and clustering in the business world. Policy recommendations for countries with low BS performance should focus particularly on the Knowledge Workers and Knowledge Absorption criteria.

First, these countries need to implement structural reforms in their education systems to enhance the quality of their knowledge workers. For instance, incentive mechanisms should be established to strengthen university-industry collaboration, and technology-driven regional development projects should be promoted. Additionally, greater investments in digitalization processes should be made to support collaboration between the public and private sectors. Specifically, for countries with low BS performance, policies should focus on strengthening the innovation ecosystem through the development of incubators, technology transfer offices, and startup support programs. Moreover, interactions between large-scale corporations and innovative startups should be encouraged to facilitate knowledge exchange and technological advancements. At the macroeconomic level, policies that attract foreign direct investment (FDI) should be adopted, ensuring that global corporations direct their R&D investments toward these countries. In particular, countries such as Italy, Canada, and Germany could enhance tax incentives and funding mechanisms to support innovation and knowledge transfer, thereby fostering the growth of technology-driven industries. In summary, policy recommendations for countries with low BS performance should be formulated by considering their economic and social structures. Education reforms, increased R&D investments, the restructuring of industrial policies with an innovation-oriented approach, and

stronger collaboration between the private and public sectors will play a crucial role in enhancing these countries' global competitiveness and BS performance.

Thirdly, from a methodological perspective, sensitivity analysis revealed that the measurement of BS performance of G7 countries is sensitive, comparative analysis indicated it is credible and reliable, and simulation analysis confirmed its robustness and stability. Consequently, these findings support the conclusion that the MIEXCF-based CODAS method can be effectively employed to measure the BS performance of G7 countries using the GII-BS criteria.

In terms of the study's limitations, only the BS criterion values of G7 countries for the year 2023 have been considered. To enhance the scope and comprehensiveness of the research, it is recommended that the BS performance of countries be analyzed by incorporating data from multiple years.

To enhance the comprehensiveness of future studies, different objective weighting techniques such as CILOS and IDOCRIW can be employed to measure the weights of BS criteria. Additionally, to assess the BS performance of countries, various performance calculation methods beyond CODAS and the other MCDM methods discussed in this study can be utilized, including WASPAS, EDAS, MOOSRA, ROV, COPRAS, DNMA, MABAC, MARCOS, MAIRCA, RAFSI, PIV, WEDBA, SECA, OPA, VIKOR, ELECTRE, COCOSO, OWA Operator, TODIM, and MULTI-MOORA. This will allow for a comparative analysis of countries' BS performance values and rankings based on different methods. Furthermore, instead of limiting the analysis to G7 countries, the BS performance of member countries of supranational and international economic organizations that influence the global economy (such as the EU, G20, BRICS, OECD, SCO, MERCOSUR, and EAEU) can be measured and compared on an organizational basis.

AUTHORS' DECLARATION:

This paper complies with Research and Publication Ethics, has no conflict of interest to declare, and has received no financial support.

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The entire research is written by the author.

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Economic Uncertainty on Social Media: The Impact of X Posts on Economic and Financial Indicators

Sosyal Medyada Ekonomik Belirsizlik: X Gönderilerinin Ekonomik ve Finansal Göstergeler Üzerindeki Etkisi

Muhammed Fatih YÜRÜK
Asst. Prof. Dr., Dicle University
mfyuruk@gmail.com
https://orcid.org/0000-0001-7429-2278

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D81, E01, E32

ABSTRACT

This study explores the influence of posts on the social media platform X (formerly Twitter) concerning economic uncertainty on key economic and financial indicators, including GDP, commercial bank loans, and the New York Stock Exchange (NYSE). The analysis focuses on the United States due to its pivotal role in global financial markets and the significant presence of U.S. users, who account for 50% of English-speaking X users, offering a rich dataset for studying social media-driven economic sentiment. Variables such as the USA Gross Domestic Product Index, Commercial Bank Loans, New York Stock Exchange Composite, and X-based Economic Uncertainty Index (TEU) were analyzed using monthly data from June 2011 to April 2023. Employing a Vector Autoregressive (VAR) model, the study finds that fluctuations in commercial bank loans and the NYSE Composite significantly impact GDP, while posts reflecting economic uncertainty, as captured by the TEU, primarily respond to changes in bank loans. The results reveal a bidirectional relationship between GDP and commercial bank loans, where loans can drive economic growth through increased consumer spending and investment, though excessive borrowing may lead to instability and crises. Furthermore, the TEU is influenced solely by variations in commercial bank loans, highlighting social media sentiment's sensitivity to credit dynamics in the U.S. economy.

Anahtar Kelimeler:
Ekonomik Belirsizlik,
Sosyal Medya,
X,
GSYİH,
VAR
Jel Kodları:
D81, E01, E32

ÖZET

Bu çalışma, X (eski adıyla Twitter) sosyal medya platformunda ekonomik belirsizliğe dair paylaşımların, GSYİH, ticari banka kredileri ve New York Borsası (NYSE) gibi ekonomik ve finansal göstergeler üzerindeki etkisini incelemektedir. Analiz, ABD'ye odaklanmıştır çünkü ülke, küresel finansal piyasalardaki lider konumu ve İngilizce X kullanıcılarının %50'sini oluşturan geniş kullanıcı kitlesiyle, sosyal medya kaynaklı ekonomik duyarlılık çalışmalar için ideal bir örnek teşkil etmektedir. Çalışmada, USA Gross Domestic Product Index, Commercial Bank Loans, New York Stock Exchange Composite ve X tabanlı Ekonomik Belirsizlik Endeksi (TEU) değişkenleri, Haziran 2011 - Nisan 2023 dönemine ait aylık verilerle analiz edilmiştir. Vektör Otoregresif (VAR) model yapılan araştırmada, ticari banka kredileri ve NYSE'deki değişimlerin GSYİH'yi önemli ölçüde etkilediği, TEU ile ölçülen ekonomik belirsizlik paylaşımlarının ise esasen banka kredilerindeki dalgalanmalara tepki verdiği bulunmuştur. Bulgular, GSYİH ile ticari banka kredileri arasında çift yönlü bir ilişki olduğunu göstermektedir; krediler, tüketici harcamaları ve yatırımlar yoluyla büyümeyi teşvik edebilirken, aşırı borçlanma istikrarsızlık ve krizlere yol açabilir. Ayrıca, TEU'nun yalnızca banka kredilerindeki değişimlerden etkilenmesi, sosyal medya duyarlılığının ABD ekonomisindeki kredi dinamiklerine özel bir hassasiyet gösterdiğini ortaya koymaktadır.

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1. INTRODUCTION

Nowadays, people are more connected to technology. As technology has evolved, investors' sources of information have shifted. The desire for rapid access to information and the pursuit of quick profits drive investors to social media platforms like X (formerly Twitter). For economic managers and decision-makers, social media can serve as a tool to predict investors' economic tendencies within a country. It also provides insights into changes and sensitivities in consumer behavior, which can inform financial and economic decisions such as investments, interest rates, and loans. Economic crises may be signaled by shifts in consumer and investor attitudes, enabling policymakers to devise strategies to anticipate future crises.

Investors' emotions can be analyzed through X posts. Research has identified significant relationships between financial markets and X posts, highlighting their influence on equilibria such as stock markets, gross domestic product, inflation, interest rates, and bank credit volumes. Behavioral and mood shifts in X posts demonstrate sensitivity across domains like health, communication, information, and technology. Increased pessimism on social media correlates with heightened trading activity, and negative sentiment in X posts often leads to more aggressive trading behavior in financial markets (Zeitun et al., 2023). X has emerged as a key platform for business and finance discussions.

Social media platforms have transformed how individuals acquire information, communicate, and share ideas. Their impact on economic and financial markets is growing, with investors, consumers, and policymakers increasingly turning to social media data to gauge market sentiment, consumer behavior, and economic expectations. However, the use of social media data to measure economic uncertainty and its effects on macroeconomic variables remains underexplored. Traditional methods—such as surveys, news texts, or market volatility—dominate the literature but often fail to capture the real-time, direct sentiment analysis offered by social media. This study addresses this gap by examining economic uncertainty through X discourse and its impact on macroeconomic variables, focusing on the United States. The U.S. was selected due to its dominant role in global financial markets, the prominence of the NYSE, and the substantial engagement of U.S. users on X, who represent 50% of the platform's English-speaking population (Baker et al., 2021). Additionally, the U.S.'s reliance on credit markets, a key driver of consumer spending and economic growth, makes it an ideal case for exploring the interplay between social media sentiment and real economic activity. While traditional measures provide valuable insights, this study offers a novel, real-time measure via X, capturing instantaneous investor and consumer sentiments.

Communication dynamics on X are influenced by an attention economy in which users interact with trending hashtags and mentions to expand their reach and influence within the platform (Shultz, 2023). Discussions on X also extend to topics such as the circular economy, with stakeholders prioritizing economic benefits, environmental impacts and resource scarcity in their conversations, and highlighting the platform's role in fostering dialogues on sustainability and resource management (Grover & Kar, 2020). The relationships built on X go beyond mere interactions, as users build meaningful connections and relationships through the platform, highlighting its role in fostering interpersonal communication and relationship building (Bertapelle & Ballard-Reisch, 2015). These relationships can be classified as either informational, such as sharing news, or social, e.g. interactions with friends and followers (Alshammari et al., 2019). In the financial context, access to finance and financial literacy have been identified as critical factors affecting the growth of small and medium-sized enterprises (SMEs) in developing countries, highlighting the interface between financial access and economic development (Bongomin et al., 2017).

In the political sphere, X serves as a platform for political discussions, with users engaging in conversations that reflect their interests and affiliations, highlighting the role of social media in shaping political discourse among users (Choi et al., 2014). Personality traits have also been linked to social media usage patterns, with platforms such as X and Facebook serving as tools for individuals to express themselves, connect with others, and share information based on their personality traits (Hughes et al., 2012). Furthermore, the role of X as a social network and news medium has been examined and its evolution into a powerful information- sharing platform with extensive user engagement and diverse content distribution has been demonstrated (Kwak et al., 2010).

Social media platforms have fundamentally changed the way individuals acquire information, communicate, and share their ideas today. The impact of these platforms on economic and financial markets is also increasing.

Investors, consumers, and policymakers are increasingly interested in social media data to understand the market sentiment, consumer behavior, and economic expectations. However, the issue of how social media data can be used to measure economic uncertainty and analyze its impact on macroeconomic variables is still under-researched. The existing literature generally measures economic uncertainty using traditional methods such as surveys, news texts, or market volatility. While these methods provide important information, they are insufficient in capturing the real-time and direct sentiment analysis offered by social media. In this context, this study contributes significantly to the literature by examining the measurement of economic uncertainty through social media discourse and its impact on macroeconomic variables. While existing literature predominantly relies on traditional measures of economic uncertainty, such as surveys, news sentiment, and market volatility, this research offers a novel, real-time, and direct measure derived from social media platforms, specifically Twitter (now X). This approach captures the instantaneous sentiments and expectations of investors and consumers, providing insights beyond those offered by conventional methods. This study's findings reveal a significant negative relationship between the Twitter-based Economic Uncertainty Index (TEU) and commercial bank lending. This suggests that adverse economic narratives on social media can amplify perceived uncertainty in credit markets, influencing both credit demand and supply, and consequently exerting substantial effects on the real economy. This dynamic, often overlooked in the existing literature, underscores the evolving role of social media in contemporary economies. Moreover, the conditional/time-varying relationship observed between the TEU and other macroeconomic indicators, including GDP and the NYSE, highlights the context-dependent nature of social media's impact, a dimension previously unexplored in the literature.

2. LITERATURE REVIEW

Researchers are studying the connection between social media activity and market prices to improve investment strategies (Ahmed & Watters, 2018). Studies have shown that X discussions can influence economic uncertainty, with non-fossil fuel energy indices showing strong coherence with economic uncertainty on X for short- and medium-term investment horizons (Durani, 2024). Additionally, X has been used to study the stock market through trust networks between users, offering insights into how platform interactions impact market dynamics (Ruan et al., 2015). In hotel management, X's role as a facilitator of electronic word-of-mouth (eWOM) and customer relationship management has been recognized, highlighting its influence across industries (Kim & Chae, 2018). During the COVID-19 pandemic, X users expressed concerns about the economy and employment, demonstrating the platform's utility in reflecting public sentiment and capturing socioeconomic discussions (Deng & Yang, 2021). Research has also examined X's role in crowdfunding networks, showing how social media and crowdsourcing attract external funding and early-stage customers for entrepreneurs (Lynn et al., 2020).

To explore X users' relationship with business and finance, particularly in the context of economic uncertainty, several studies provide valuable insights. Kılınç et al. (2023) estimated the Baltic Dry Index using a NARX neural network model, incorporating the X-based Economic Uncertainty Index (TEU) and Market Uncertainty Index (TMU), emphasizing X data's integration into economic analysis. Yeşiltaş et al. (2022) developed a high-frequency Economic Policy Uncertainty (TEPU) index based on expert opinions on X, highlighting the platform's influence on financial market dynamics. Nazir et al. (2023) examined the impact of various uncertainty sources, including X-based uncertainty, on stock prices in emerging markets, underscoring social media's role in shaping market sentiments. Wu et al. (2021) analyzed economic policy uncertainty's effect on cryptocurrency markets using X-based measures, demonstrating X data's relevance across financial domains.

Moreover, early studies like Gilbert & Karahalios (2010) demonstrated that widespread worry expressed on social media correlates with stock market declines, suggesting that collective sentiment can serve as an economic indicator. Bollen et al. (2011) further advanced this field by showing that X mood can predict stock market movements, providing a foundation for real-time sentiment analysis in financial research. Similarly, Sprenger et al. (2014) found that X posts contain valuable information for stock trading, with specific sentiments linked to market returns. These studies primarily focus on stock markets, leaving the relationship between social media sentiment and real economy variables like commercial bank lending underexplored. This study addresses this gap by examining the TEU's connection to credit markets, offering a novel perspective on how X-based uncertainty influences macroeconomic dynamics beyond financial markets. Researchers have also investigated various

applications of VAR models. For instance, Lu (2001) used VAR models for dynamic analysis of geographic processes, while Bringmann et al. (2018) developed a time-varying VAR (TV-VAR) model to capture temporal dependencies. Bayesian methods have improved VAR model efficiency (Yang et al., 2021), and algorithms for recursive identification of large VAR models have enhanced their adaptability (Monchen et al., 2019).

3. METHODOLOGY AND DATA

The Vector Autoregressive (VAR) model was employed in this study due to its ability to simultaneously estimate relationships among multiple variables and capture their dynamic dependencies over time (Ibrahim et al., 2020; Souza et al., 2017). This feature is particularly valuable when analyzing systems in which variables influence each other, making VAR models a suitable choice for studying complex phenomena such as economic dynamics, climate trends, and disease patterns.

VAR models are preferred because of their flexibility in dealing with multivariate time series data. They can take exogenous variables into account and provide a comprehensive framework for incorporating additional factors that may affect the variables of interest (Yasin et al., 2018; Haslbeck et al., 2020). This flexibility improves the model's ability to capture the full range of influences on the system under study, resulting in more accurate forecasts and insightful analyses. In addition, VAR models are versatile and are widely used in various disciplines such as economics, finance and statistics. They are used to analyze trends, predict future outcomes and conduct policy assessments (Rusman et al.,2019; Gunarto et al., 2023).

VAR models provide a structured framework for conducting hypothesis testing, forecasting, and policy analysis (Pripoaie et al., 2022). The Vector Autoregressive (VAR) model was preferred in the analysis of this study due to its flexibility in analyzing multivariate data, its effectiveness in interpreting data in finance and its structured approach to forecasting, as well as its ability to identify complex relationships between variables. Additionally, vector autoregressive (VAR) models are gaining popularity in various fields due to their ability to capture dynamic relationships between multiple time series variables. These models predict each variable based on its own past values as well as the past values of other variables in the system (Dablander et al., 2020; Bulteel et al., 2016; Bulteel et al., 2018). VAR models are particularly useful for analyzing multivariate time series data because they can effectively capture the temporal dynamics of lead-lag (Bai et al., 2021; Bashir & Wei, 2018).

The study utilized the EViews software for statistical and econometric calculations. It examined the association between economic uncertainty expressed on the X platform in the United States and various economic and financial variables, using monthly data from June 2011 to April 2023. Details of the variables are presented in Table 1.

Table 1. Variables Used in the Study

No	Variable	Code	Reference
1	USA Gross Domestic Product Index	GDP	spglobal.com
2	Commercial Bank Loans	LOAN	fred.stlouisfed.org
3	New York Stock Exchange Composite	NYSE	tr.investing.com
4	Twitter (X)-Based Economic Uncertainty Index	TEU	policyuncertainty.com

The TEU variable, developed by Thomas Renault (University of Paris 1 Panthéon-Sorbonne) in collaboration with Scott R. Baker (Northwestern), Nicholas Bloom (Stanford), and Steve Davis (University of Chicago), was derived from all X posts in the U.S. since June 2011 containing keywords related to uncertainty and economics. U.S. users constitute 50% of the English-speaking X population (Baker et al., 2021).

4. RESULTS

The continuity of the series was tested before establishing the VAR model. For series stationarity, Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests were used.

Table 2. Stationary Test Results

	Variables	ADF	PP
I(0)	LNGDP	-0.856955 (0.7991)	-0.748062 (0.8300)
	LNLOAN	0.3028218 (0.9777)	0.4874012 (0.9858)
	LNNYSE	-1.2298955 (0.6605)	-1.038487 (0.7384)
	LNTEU	-3.7617090 (0.0041)	-1,116220 (0.0154)
I(1)	LNGDP	-10.829535 (0.0000)	-13.78817 (0.0000)
	LNLOAN	-6.6087214 (0.0000)	-5.787855 (0.0000)
	LNNYSE	-13.526455 (0.0000)	-13.86655 (0.0000)
	LNTEU	-16.471948 (0.0000)	-26.08785 (0.0000)
	Critical Value %1	-3.477143	-3,474567
	Critical Value %5	-2.881977	-2,880853
	Critical Value %10	-2.577747	-2,577147

In unit root tests, the null hypothesis (H_0) indicates that the series are not stationary. The aim is to reject the H_0 hypothesis. The logarithms of the series were taken before the stationarity tests. The stationary test results are shown in Table 2. The ADF test used the Akaike Information Criterion, commonly applied in financial series. The estimation method for the PP test was Bartlett Kernel, while Newey-West Bandwidth was used for bandwidth selection. According to the stationarity tests, the series become stationary at the first difference in both the ADF and PP tests. Therefore, the null hypothesis H_0, "the series have a unit root," was rejected. The next step of the study examined the lag length.

Table 3. VAR Lag Order Selection Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	458.03776921	NA	1.41e-08	-6.726485	-6.640403	-6.691504
1	1216.2692756	1460.298	2.36e-13	-17.72251	-17.29210	-17.54760
2	1269.5743989	99.50290	1.36e-13	-18.27518	-17.50044*	-17.96034
3	1298.0225851	51.41746	1.13e-13*	-18.45959*	-17.34053	-18.00484*
4	1304.6236123	11.53957	1.31e-13	-18.32035	-16.85695	-17.72567
5	1315.5487813	18.45140	1.41e-13	-18.24517	-16.43744	-17.51056
6	1323.7725184	13.40165	1.60e-13	-18.12996	-15.97791	-17.25543
7	1346.6583652	35.93926*	1.46e-13	-18.23198	-15.73559	-17.21752
8	1354.5536644	11.93067	1.67e-13	-18.11191	-15.27119	-16.95752

As shown in Table 3, an analysis was performed to determine the lag length of the VAR model. To determine the lag length, the lag with the asterisk (*) was selected. The table shows an accumulation of stars at the third lag. Consequently, three lags were chosen, and the model was established.

In the established VAR model, we need to test whether the process is stationary using another method to determine whether it contains a unit root. The stationarity of the model is related to its eigenvalues (Hendry & Juselius, 2001):

$$\begin{pmatrix} x_t \\ x_{t-1} \end{pmatrix} = \begin{pmatrix} \Pi_1 & \Pi_2 \\ I_p & 0 \end{pmatrix} \begin{pmatrix} x_{t-1} \\ x_{t-2} \end{pmatrix} + \begin{pmatrix} \epsilon_t \\ 0 \end{pmatrix} \quad (1)$$

a) if all the eigenvalues of the complementary matrix are in the unit circle, then $\{ x_t \}$ is the constant;

b) if all the eigenvalues are in or above the unit circle, $\{ x_t \}$ is not constant;

c) if any of the eigenvalues is outside of the unit circle, { x_t } is the expansive.

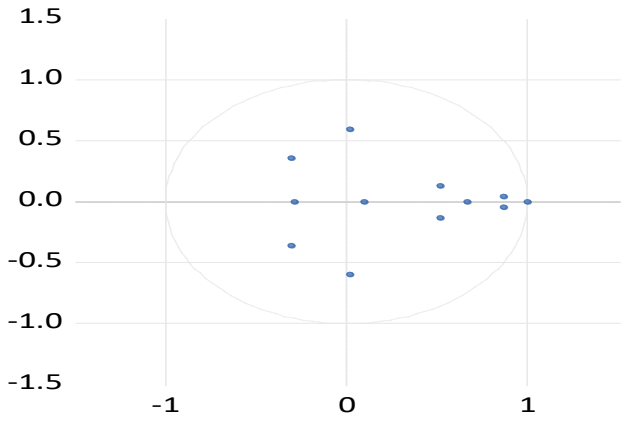

Figure 1. Inverse Roots of AR Characteristic Polynomial

For this purpose, the unit circle position of the inverse roots of the AR characteristic polynomial is analyzed in Figure 1. As can be seen in the figure, all eigenvalues of the coefficient matrix lie within or on the unit circle. This indicates that our VAR model is stationary. The positions of the unit roots, graphically analyzed in Figure 1, within the unit circle are shown in Table 4. Since all values are less than 1, there is no unit root, meaning the model is stationary.

Table 4. Unit Roots of the Coefficient Matrix and Their Positions in the Unit Circle

Root	Modulus
0.999182	0.999181622
0.867345 - 0.044947i	0.868508586
0.867345 + 0.044947i	0.868508586
0.666392	0.666392010
0.016552 - 0.590742i	0.590974080
0.016552 + 0.590742i	0.590974080
0.512364 - 0.130303i	0.528673741
0.512364 + 0.130303i	0.528673741
-0.305736 - 0.356907i	0.469954784
-0.305736 + 0.356907i	0.469954784
-0.290578	0.290578487
0.098329	0.09832942

The LM test is used to test whether the model exhibits autocorrelation. In the LM test, the null hypothesis H_0 is that there is no autocorrelation. To accept the hypothesis H_0, a p-value > 0.05 is required. As can be seen in Table 5, the hypothesis is accepted as the p-values are > 0.05. In other words, there is no autocorrelation in our model.

Table 5. VAR Residual Serial Correlation LM Tests

Lag	LRE* stat	df	Prob.	Rao F-stat	df	Prob.
1	20.4514	16	0.2005	1.289210	(16, 367.2)	0.2007
2	21.1152	16	0.1741	1.332247	(16, 367.2)	0.1742
3	17.3269	16	0.3647	1.087662	(16, 367.2)	0.3649

4.1. Impulse-Response Function Graphical Results

Impulse-response functions were used to examine the response of the variables of interest to a one standard deviation (SD) shock to GDP, LOAN, NYSE, and TEU variables. The impulse-response functions in the 4-variable VAR model are plotted in Figure 2 over 10 periods. When analyzing the relationship between the TEU variable and other variables in the graphs, it is observed that GDP does not respond to a 1 SD shock applied to the TEU variable. Despite a 1 SD shock applied to the TEU variable, the LOAN variable shows a slight increase before stabilizing after the third period. Despite a 1 SD shock applied to the TEU variable, the NYSE variable shows no response after the second period. In response to a 1 SD shock applied to TEU, TEU itself responds with a rapid increase followed by a decrease, and by the end of the 10th period, its effect approaches zero. GDP can be influenced by its own lagged values and shocks.

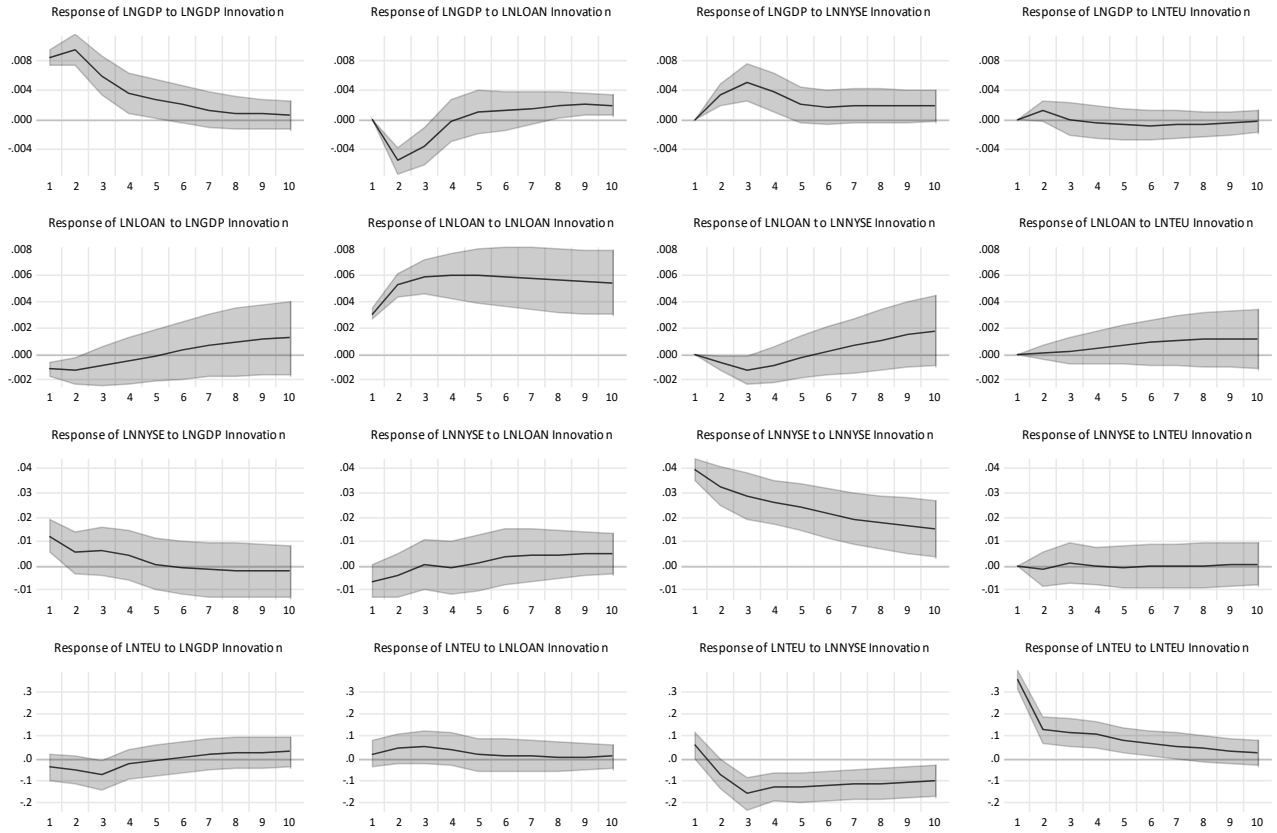

Figure 2. Response to Cholesky One S.D. (d.f. adjusted) Innovations

4.2. Results of Variance Decomposition

Variance decomposition offers a method to observe the movements of the established VAR model in detail. In the established model, the proportion of movements in the dependent variables is attributed to shocks from other variables, in addition to shocks from the same variable. For example, a shock applied to one variable will directly affect that variable, but importantly, the shock will also propagate to all other variables in the model structure. Variance decomposition measures how much of the forecast error variance of a given variable is explained by the innovations in each explanatory variable for i=1,2,3 (Sarıkovanlık et al., 2020).

Table 6. Variance Decomposition

Variance Decomposition of LNGDP:					
Period	**S.E.**	**LNGDP**	**LNLOAN**	**LNNYSE**	**LNTEU**
1	0.009327	100	0	0	0
2	0.013833	83.44557	7.909523	8.143257	0.501645
3	0.016120	71.58195	14.52368	13.37183	0.522523
4	0.017118	65.65912	16.77198	16.84101	0.727875
5	0.017511	63.02310	16.78595	19.27282	0.918117
6	0.017701	61.68228	16.42893	20.87730	1.011487
7	0.017865	60.56066	16.54090	21.86502	1.033403
8	0.018045	59.36186	17.14719	22.46840	1.022528
9	0.018236	58.12745	17.99113	22.87897	1.002427
10	0.018425	56.94369	18.86049	23.21388	0.981922
Variance Decomposition of LNLOAN:					
Period	**S.E.**	**LNGDP**	**LNLOAN**	**LNNYSE**	**LNTEU**
1	0.003332	12.07354	87.92645	0	0
2	0.006387	7.280231	91.58140	1.058601	0.079766
3	0.008970	4.571294	94.06899	1.116308	0.243396
4	0.011027	3.125336	95.65011	0.890271	0.334279
5	0.012660	2.372518	96.57889	0.677609	0.370977
6	0.013992	1.991601	97.02425	0.612022	0.372120
7	0.015124	1.796587	97.10820	0.740111	0.355091
8	0.016130	1.687565	96.92363	1.057745	0.331051
9	0.017057	1.616450	96.54119	1.536463	0.305889
10	0.017934	1.562810	96.01403	2.140995	0.282155
Variance Decomposition of LNNYSE:					
Period	**S.E.**	**LNGDP**	**LNLOAN**	**LNNYSE**	**LNTEU**
1	0.042381	4.875689	2.808296	92.31601	0
2	0.054482	3.615368	2.398511	93.59255	0.393569
3	0.062167	3.048282	1.899765	94.66254	0.389406
4	0.067671	2.726726	1.606617	95.29388	0.372774
5	0.071829	2.540728	1.473259	95.63760	0.348408
6	0.075092	2.433287	1.432844	95.80724	0.326617
7	0.077709	2.372700	1.441979	95.87648	0.308834
8	0.079840	2.339176	1.478871	95.88719	0.294757
9	0.081596	2.320467	1.534666	95.86122	0.283644
10	0.083054	2.309431	1.606509	95.80926	0.274793
Variance Decomposition of LNTEU:					
Period	**S.E.**	**LNGDP**	**LNLOAN**	**LNNYSE**	**LNTEU**
1	0.372807	1.481761	0.932534	1.018070	96.56763
2	0.419500	4.254512	2.207735	3.844734	89.69301
3	0.468641	4.066774	4.272650	10.39533	81.26524
4	0.504419	3.598828	5.173628	16.78393	74.44360
5	0.532223	3.236507	5.367420	22.41217	68.98389
6	0.554147	2.985472	5.280771	27.10423	64.62951
7	0.571991	2.802598	5.133541	30.93759	61.12626
8	0.586817	2.667596	5.004808	34.03189	58.29569
9	0.599263	2.570711	4.917624	36.50645	56.00520
10	0.609719	2.503240	4.874894	38.46781	54.15405

Table 6 shows the results of the 10-period variance decomposition of the variables. According to the results, in the 10th period, about 57% of the error variance in the GDP variable is explained by itself, while the remaining approximately 43% is explained by the LOAN and NYSE variables. The results of the 10-period variance decomposition of the LOAN variables are presented in Table 6. According to the results, a significant part of the error variance in the LOAN and NYSE variables is explained by themselves, while the remaining part is explained

by other variables. For the TEU variable, about 54.15% of its variance in the final period is explained by itself, approximately 39% by the NYSE variable, and approximately 5% by LOAN.

4.3. Granger Causality Test Results

The Granger causality test was performed to determine the relationship between variables. The Granger causality test is used to assess the direction of causality in the lagged relationship between the variables analyzed as a function of time. According to Granger (1969), A is the Granger cause of B if the prediction of B is more successful when A's past values are used than when A's past values are not used (Sarıkovanlık et al., 2020).

Table 7. VAR Granger Causality/Block Exogeneity Wald Tests

Dependent variable: LNGDP			
Excluded	Chi-sq	df	Prob.
LNLOAN	37.86858	2	0.0000
LNNYSE	29.17402	2	0.0000
LNTEU	2.802127	2	0.2463
All	94.72243	6	0.0000
Dependent variable: LNLOAN			
Excluded	Chi-sq	df	Prob.
LNGDP	10.12201	2	0.0063
LNNYSE	5.921556	2	0.0517
LNTEU	0.417331	2	0.8116
All	22.44935	6	0.001
Dependent variable: LNNYSE			
Excluded	Chi-sq	df	Prob.
LNGDP	0.750964	2	0.6869
LNLOAN	3.380836	2	0.18444
LNTEU	0.992576	2	0.60878
All	8.436135	6	0.2078
Dependent variable: LNTEU			
Excluded	Chi-sq	df	Prob.
LNGDP	2.356065	2	0.3078
LNLOAN	10.61641	2	0.0049
LNNYSE	23.03027	2	0.9779
All	37.610335	6	0.0000

Table 7 shows the results of the Granger causality test. Changes in LOAN and NYSE are the Granger causes of changes in GDP. Changes in GDP and NYSE are the Granger causes of changes in LOAN. Only changes in LOAN are found to be the Granger cause of changes in TEU. Changes in the NYSE affect GDP, while changes in GDP do not affect NYSE. Another finding is that changes in the TEU do not affect other variables. The only variable that affects the TEU variable is LOAN.

The relationships between commercial bank loans, stock market fluctuations (specifically the NYSE), and GDP changes have been explored in various studies, revealing insights that align with the findings of this study. The literature indicates that economic policy uncertainty and the credit supply from banks significantly influence economic growth and market dynamics. Bordo et al. (2016) highlight that economic policy uncertainty is closely linked to slower loan growth, suggesting that banks adjust their lending practices in response to uncertainty, which in turn can affect broader economic indicators like GDP. This aligns with our finding that changes in commercial bank loans are a Granger cause of changes in economic uncertainty. Similarly, Valencia (2013) discusses how

aggregate uncertainty is countercyclical, leading to reduced bank lending during periods of weak economic activity, reinforcing the notion that economic conditions and bank lending are interdependent. Moreover, Ashraf (2021) provides evidence that heightened economic uncertainty leads banks to increase loan pricing, which can further restrict lending and impact economic growth. This supports our assertion that changes in commercial bank loans can influence economic uncertainty, as banks may react to perceived risks by tightening credit availability. Raunig et al. (2016) also find that banks are likely to lend less during uncertain times, which could explain the cyclical nature of our findings regarding the relationship between NYSE changes and GDP. Several authors further examine the interplay between GDP and the NYSE. While this study posits that changes in GDP do not affect the NYSE, other research suggests that stock market performance can reflect underlying economic conditions. Ghosh (2016) notes that regional economic indicators significantly influence real estate lending, which is often tied to broader economic performance, suggesting that while GDP may not directly impact stock prices, it does play a role in shaping the economic environment that affects market performance. Additionally, the findings of Morina and Özen (2020) indicate a positive relationship between commercial bank lending and economic growth, which supports our conclusion that commercial bank loans can drive changes in GDP. This is consistent with the notion that banks play a crucial role in financing economic activities, thereby influencing overall economic performance. In summary, the literature provides a robust framework that supports our findings regarding the causal relationships among commercial bank loans, the NYSE, and GDP. The studies collectively emphasize the significance of economic uncertainty and bank lending dynamics in shaping economic outcomes.

5. CONCLUSION

This study examines the relationship between the X-based Economic Uncertainty Index (TEU) and the GDP, LOAN, and NYSE variables, while also exploring the interactions among all variables in general. It investigates whether posts by X users in the United States containing words related to economic uncertainty influence or are influenced by the country's economic and financial variables. This question is addressed in the study. The study first tested the stationarity of the series and then established the VAR model. The relationship between the series was observed using the Granger causality test, performed after the model assumptions were met. As a result of the test, changes in LOAN and NYSE are observed to affect GDP. The amount of credit provided by commercial banks can have both negative and positive effects on GDP. Individuals can purchase more goods and services by obtaining loans from banks. This increases consumer spending, which contributes to GDP growth. Companies finance their investments by taking out loans. The increase in productive capacity through investments and the resulting increase in employment contribute to GDP growth. Proper and efficient utilization of credit provided by banks can positively contribute to economic growth, which leads to an increase in GDP in the long run. On the other hand, credit utilization can also have a negative impact on GDP. Excessive borrowing by individuals and businesses can create the risk of non-repayment. This situation can lead to an economic crisis, economic instability, and a decline in GDP. Increasing credit volume can lead to an increase in inflation as demand rises. High inflation can threaten economic stability, and the accompanying crises will have a negative impact on GDP. In short, as noted in the study, changes in LOAN impact GDP. Changes in the NYSE can affect GDP. Changes in major stock market indices such as the NYSE can affect GDP through various channels, such as consumer and business behavior, wealth effects, confidence, and financial crises. This multidirectional effect can impact the economy and thus lead to changes in GDP.

When LOAN is the dependent variable in the study, only changes in GDP are observed to affect LOAN. As already explained, there is a bidirectional relationship between GDP and LOAN. When TEU is the dependent variable, it is observed that only changes in LOAN cause a change in TEU. Changes in the amount of credit provided by banks can directly affect levels of economic uncertainty. While an increase in lending generally indicates greater economic confidence and support for growth, a decrease in lending can indicate heightened uncertainty and risk perception. Changes in the other two variables have no impact on TEU. This could indicate that X users in the U.S. are more sensitive to interest rates, particularly the amount of loans provided by banks. Using credit has become a common behavior in the United States. American citizens often meet their financial needs by using loans for both personal and business purposes. The creditworthiness of individuals in the U.S. is crucial. With this rating, they can secure credit loans. Therefore, American citizens value creditworthiness. The U.S. economy is closely tied to consumer spending. Consumers usually cover their needs with loans from banks.

This spending is linked to economic growth. In short, the use of credit by U.S. citizens has become a part of their life and culture. Loans such as home loans and student loans are particularly important for U.S. citizens. For this reason, it is natural that changes related to creditworthiness will be reflected in the posts of X users. By tracking X posts, economists and policymakers are able to anticipate economic uncertainties in the U.S. and take measures in advance to mitigate financial crises that may occur.

This finding is novel in the literature, as it demonstrates a direct link between real economic activity in the credit markets and social media discourse. While previous studies have examined the relationship between social media sentiment and financial market variables (Bollen et al., 2011; Loughran & McDonald, 2011; Ranco et al., 2015), this study extends the literature by focusing on the connection between social media discourse on economic uncertainty and commercial bank lending, a critical component of the real economy. This highlights the potential of social media data to provide timely insights into credit market dynamics.

This study has several limitations. First, it relies solely on data from X, which may not be representative of the entire population. Second, the TEU is constructed based on a predefined set of keywords, which may not capture all nuances of economic uncertainty. Third, the study focuses specifically on the U.S. economy. Future research could incorporate data from other social media platforms and employ more sophisticated text analysis techniques, as well as examine similar relationships in other countries.

AUTHORS' DECLARATION:

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The entire research is written by the author.

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Testing the Adaptive Market Hypothesis for Fragile Five Countries: Time-Varying KSS Unit Root Test Application

Adaptif Piyasa Hipotezinin Kırılgan Beşli Ülkeleri için Test Edilmesi: Zamanla Değişen KSS Birim Kök Testi Uygulaması

Serkan ERYILMAZ
Res. Asst., Maltepe University
serkaneryilmaz@maltepe.edu.tr
https://orcid.org/0000-0002-8537-5607

Feyyaz ZEREN
Prof. Dr., Yalova University
feyyaz.zeren@yalova.edu.tr
https://orcid.org/0000-0002-0024-3518

Tayfun YILMAZ
Assoc. Prof. Dr., Burdur Mehmet Akif Ersoy University
tayfunyilmaz@mehmetakif.edu.tr
https://orcid.org/0000-0002-7127-2017

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ABSTRACT

In this study, the validity of the Adaptive Market Hypothesis (AMH) for the Fragile Five countries (India, Brazil, Indonesia, Turkey, and South Africa) was investigated through daily data for the period 01.09.2013-30.06.2024. As a result of the time-varying KSS unit root test developed by Kapetanios, Shin and Snell (2003), it was found that the periodic weak form of market efficiency is valid for the Fragile Five countries and the AMH was confirmed for these markets. Therefore, it is understood that the random walk hypothesis is periodically valid and investors who use technical analysis methods have the potential to earn higher-than-normal returns when the random walk is not valid.

Anahtar Kelimeler:
Adaptif Piyasa Hipotezi, Kırılgan Beşli Ülkeleri, Zamanla Değişen KSS Birim Kök Testi
Jel Kodları:
C22, G14, G15

ÖZET

Bu çalışmada, Kırılgan Beşli ülkeleri (Hindistan, Brezilya, Endonezya, Türkiye ve Güney Afrika) için Adaptif Piyasa Hipotezi'nin (APH) geçerliliği 01.09.2013-30.06.2024 dönemine ait günlük veriler kullanılarak araştırılmıştır. Kapetanios, Shin ve Snell (2003) tarafından geliştirilen zamanla değişen KSS birim kök testi sonucunda piyasa etkinliğinin dönemsel zayıf formunun Kırılgan Beşli ülkeleri için geçerli olduğu tespit edilmiş ve bu piyasalar için APH doğrulanmıştır. Dolayısıyla, rassal yürüyüş hipotezinin dönemsel olarak geçerli olduğu ve teknik analiz yöntemlerini kullanan yatırımcıların rassal yürüyüşün geçerli olmadığı durumlarda normalden daha yüksek getiri elde etme potansiyeline sahip olduğu anlaşılmaktadır.

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1. INTRODUCTION

The Adaptive Markets Hypothesis (AMH), introduced by Lo (2004, 2005, 2012), is a theory that integrates principles of evolutionary biology and psychology into finance theory to explain market dynamics. Lo (2005) claims that market efficiency is affected by several environmental factors - e.g. the number of market participants, profit opportunities, and the adaptability of investors. This hypothesis defines traditional market efficiency and behavioral finance concepts by suggesting that market participants adapt to changing market conditions (Enow, 2022).

The AMH suggests that market efficiency is typically not a constant concept but evolves over time as a response to time-varying economic conditions. Kumar (2018) argues that market efficiency characteristics change depending on changing market and macroeconomic conditions (recessions, market failures and crises, bubbles) and institutional factors. AMH views markets as ecological systems in which different agents compete for resources, leading to different degrees of efficiency (Neely et al., 2007), and combines the efficient market hypothesis with behavioral finance to provide a framework that considers the evolutionary nature of human behavior in financial decision-making. The AMH acknowledges the existence of finite rationality among investors and the influence of institutional factors on market dynamics (Dhankar & Shankar, 2016, Shadid 2022). AMH is also significant for understanding how market participants make decisions under conditions of uncertainties and indecision (Shi, 2021).

According to AMH, the fact that market efficiency can change over time has important consequences for the related parties. While it is not possible to generate abnormal returns when the market is efficient, abnormal returns can be generated in inefficient markets by methods such as technical analysis. It will also be possible to achieve abnormal returns in the market if there is a shift away from efficiency due to various environmental factors such as competition and the adaptability of investors. Therefore, for the related parties, the validity of the AMH in any market means that there may be anomalies in the market in question and therefore an abnormal return can be generated. As a result, analysing the validity of AMH in a market can reveal very important results for market participants. Another important aspect of the study is to investigate whether the AMH is valid in the Fragile Five countries. In the literature review, there is no study that investigates the AMH for the Fragile Five sample. Finally, another unique aspect of the paper is the examination of the unit root with the time-varying version of the KSS unit root test developed by Kapetanios, Shin & Snell (2003). Since the nature of financial time series and have an extreme volatility structure such as daily continuously priced stock markets, it is important to examine the KSS with non-linear unit root tests in order to reach more appropriate results.

In sum, AMH represents a breakthrough within financial theory by integrating aspects of behavioral finance and evolutionary principles to provide a more comprehensive understanding of market dynamics. By allowing for the adaptive character of market participants and the time-varying nature of market efficiency, AMH presents a more plausible description of how financial markets do function. Empirical studies conducted for different asset categories and market conditions have revealed both the applicability and plausibility of AMH in explaining the complexity of modern financial markets.

The objective of this study is to explore the validity of the AMH in the Fragile Five countries for the period 2013-2024. In this regard, the main motivation of this study is that, as far as we know, AMH has never been analyzed for the Fragile Five countries. Also, the study is novel in that it is the first study to investigate the AMH with a time-varying unit root test.

The following sections briefly present and discuss the methods and findings of previous studies in literature. Then, the econometric methodology, data, empirical findings and discussion are presented respectively.

2. LITERATURE REVIEW

The Efficient Markets Hypothesis (EMH), introduced by Samuelson (1965) and Fama (1965, 1970), which assumes that markets are efficient or inefficient and that market efficiency is constant over a while, has been criticized heavily since the early 1980s. For instance, Grossman and Stiglitz (1980) stated that market efficiency is impossible, and that information will never have a symmetric spillover. Similarly, Campbell et al. (1998) pointed out that the efficiency of markets is relative and there is no absolute efficiency when comparisons between various markets are considered. Indeed, many empirical studies over the years have provided findings that contribute to the objections to the EMH. Hence, the findings that reject the basic assumptions of the EMH, i.e. that investors do not always behave rationally and that access to information in markets is asymmetric, have undermined the EMH (Kahneman & Tversky, 1979; Ball, 1978). Accordingly, Lo (2004) introduced a version of

the EMH, the AMH, which revises the basic assumptions of the EMH based on the principles of evolutionary biology. The core assumptions of AMH are listed as follows:

- Individuals act in their self-interest,
- Individuals learn and adapt,
- Individuals make mistakes,
- Competition in markets forces adaptation and innovation,
- Market ecology is structured by natural selection,
- Evolutionary principles are the determinants of market dynamics

Accordingly, the AMH hypothesis, as characterized by Lo (2004, 2005), points out that market efficiency is not always valid due to the characteristics of markets and the dynamic behavior of market agents, and that market efficiency is hampered in a cyclical fashion (Urquhart & McGroarty, 2016). As such, the AMH, which can be characterized as a challenge to settled arguments, has attracted great attention from scholars and has been the subject of many studies in the last two decades.

The earliest studies which tested the AMH were performed by Lim & Brooks (2006). Their study investigated the time-varying efficiency of developed and developing stock markets with Portmanteau bicorrelation and found that market efficiency is cyclical over time. Lim (2007) employs the portmanteau bicorrelation test on a rolling sample of eleven developing and two developed markets and found that the efficiency of each market exhibits an evolution over time consistent with the AMH. Todea et al. (2009) showed that returns are cyclical rather than constant by employing linear and nonlinear tests. Ito and Sugiyama (2009) investigate the time-varying autocorrelation of monthly S&P500 returns and show that the market efficiency is not constant, with the market efficiency at its lowest level in the late 1980s and at its most efficient around 2000.

Kim et al. (2011) investigated the predictability of daily DJIA stock returns from 1900 to 2009 using an automatic variance ratio test and an automatic portmanteau test. Using a rolling windows approach, they found clear evidence of time-varying predictability driven by market conditions. Charles et al. (2012) examined the return predictability of major exchange rates between 1975 and 2009 utilizing daily and weekly nominal exchange rates. Applying the automatic variance ratio test, the generalized spectral test and the Dominguez-Lobato consistency test showed that return predictability varies over time depending on changing market conditions, which is consistent with the AMH. Smith (2012) investigated the changing efficiency of 15 European developing stock markets and three developed markets. They used rolling window variance ratio tests and found that return predictability varies significantly, with the 2007-2008 global financial market crisis coinciding with high return predictability in Croatia, Hungary, Poland, Portugal, Slovakia and the United Kingdom. Lim et al. (2013) investigate return predictability for three major US stock indices with a rolling forecast approach using the automatic portmanteau Box-Pierce test and the wild bootstrapped automatic variance ratio test. They found evidence that periods with time-varying return predictability and significant return autocorrelations are broadly correlated with significant external events, hence consistent with the AMH.

Urquhart & Hudson (2013) tested whether the U.S, the U.K, and Japanese stock markets conform to the AMH using linear and nonlinear tests for the independence of stock returns. They demonstrated robust evidence supporting the AMH and claimed that the AMH explains stock return behavior better than the EMH. Zhou &Lee (2013) analyze GYO data using the automatic variance ratio test and automatic portmanteau test and show that market efficiency changes over time depending on market conditions. Dyakova & Smith (2013) analyzed two Bulgarian stock price indices and eight stock prices in a rolling window from October 2000 to August 2012 applying variance ratio tests. They reported the changing level of predictability supporting the AMH. Niemczak & Smith (2013) analyzed 11 Middle Eastern stock markets and found that most markets experienced successive periods of efficiency and inefficiency consistent with the AMH. Hiremath & Kumari (2014) performed linear and non-linear tests for Sensex and Nifty indices and found that the results obtained from linear tests support the AMH, while non-linear tests do not.

Recent studies have mostly confirmed the validity of the AMH hypothesis, similar to the previous ones. Obalade & Muzindutsi (2019) employed a 20-year return series to investigate the validity of the AMH hypothesis for Nigeria, South Africa, Mauritania, Morocco and Tunisia. Their results indicate that AMH is valid in all of these countries. In another study of the variance ratio test, Mandacı et al. (2019) examined Borsa Istanbul and determined that AMH is valid for the XU100. Lekhal & Oubani (2020) measured market efficiency through linear and nonlinear tests using a rolling window approach and daily return series of the MASI index for the period

1992-2019. Their results reveal that the efficiency rate changes over time. Kumar & Anandarao (2021) tested the validity of AMH for the Indonesian Forex market. Their findings conclusively prove that the Indonesian FX market is adaptive and periodically fluctuates between efficiency and inefficiency. Adaramola & Obisesan (2021) examined the validity of AMH for the Nigerian stock market using linear and nonlinear tests and a rolling window approach. The results indicate that the Nigerian stock market aligns with the AMH. Yousuf & Makina (2022), through quantile regression model, found that return estimation in South African markets varies by market conditions and thus AMH is valid. Cruz-Hernandez & Mora-Valencia (2024) tested the validity of AMH in 5 Latin American stock markets. Their findings confirmed the validity of AMH for each country.

Considering the extant literature, Kılıç (2020) is the only study available to the authors that shows that the AMH is not valid. In his study, Kılıç (2020) investigated the validity of the AMH for the XU100 index with an automatic Portmanteau generalized spectral test and automatic variance ratio test. His empirical evidence showed that inconsistent with the previous literature, the AMH is not valid, i.e., the efficiency of the XU100 index does not change over time depending on market conditions.

3. METHODOLOGY

In this research, nonlinear unit root tests are applied due to the financial nature of the time series and their extremely volatile nature as stock markets are priced continuously day-to-day. In this regard, the time-varying specification of the KSS unit root test proposed by Kapetanios, Shin & Snell (2003) was used.

The Star (1) model for nonlinear series is as in Eq. 1.
Exponential function;

$$\Theta(\theta;\ yt-d)\ =\ 1-exp(-\theta y2t-d) \tag{1}$$

$$Yt\ =\ \beta y-1\ +\ \Upsilon yt-1\Theta(\theta;\ yt-d)\ +\ \xi\varepsilon t \tag{2}$$

If the exponential function is replaced in the model;

$$\Delta yt=\ ^{\Phi}yt-1+\Upsilon yt-1[1-exp(-\theta y2t-d)\ +\ \varepsilon t \tag{3}$$

This model with constraints Φ = 0 and d = 1;

$$\Delta yt=\ ^{\Phi}yt-1\,\{1-exp((-\theta y2t-1)\ +\ \varepsilon t \tag{4}$$

where the null hypothesis states that the series is unit rooted and the alternative hypothesis states that the series is stationary. This is an exponential autoregressive process. It is consistent with a stationary ESTAR process.

$$H0:\theta\ =\ 0$$

$$H1:\theta\ <\ 0$$

The Kapetanios, Shin & Snell (2003) (KSS) unit root test tests a nonlinear process alternative to the null hypothesis of a unit root. The test is performed for the entire observation span. However, sometimes some periods of the series may be stationary, and some periods may exhibit unit root behavior. In these cases, the existing KSS test may not give reliable results, and it is necessary to use time-varying techniques to analyze these cases.

To perform the time-varying KSS unit root test, a sample size of N is first selected. The KSS unit root test is applied from the 1st unit to the Nth unit. In the second stage, the KSS test is applied to the sample from the 2nd unit to the N+ 1 unit and this procedure is repeated up to the latest unit. After the implementation to the entire sample, the test statistic obtained is divided by the 10% critical value (-2.66) in line with the normal distribution and the values obtained are graphed. The values above the "1" line indicate the periods when the series is stationary, while the values below it indicate the periods when the series is non-stationary (Kamışlı and Temizel, 2019).

4. DATA

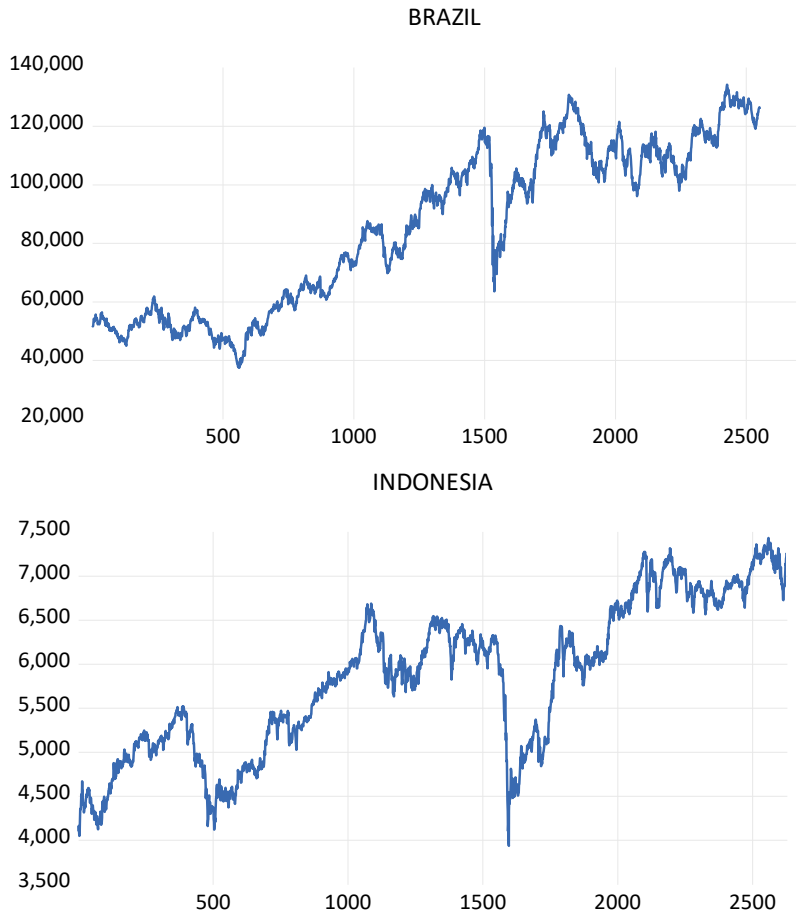
Morgan Stanley identified five countries - India, Brazil, Indonesia, Turkey, and South Africa, as the Fragile Five because of their high inflation, current account deficits, and need for foreign investment. This identification was first proposed by James Lord, one of the bank's analysts, in his August 2013 economic report. Therefore, daily

data as of September 2013 are used in this study. Daily data varies by country due to public holidays and the end date is June 2024. These data were collected from www.ukfinance.yahoo.com and www.investing.com. The summary table of the dataset is presented below.

Table 1. Data

Country	Stock Market	Obs.
India	BSE Sensex 30	2720
Brazil	IBOVESPA	2695
Indonesia	Jakarta Stock Exchange	2680
Türkiye	BIST-100	2653
South Africa	FTSE Johannesburg Top 40	2733

Time series graphs of the data are shown as follows. Time series graphs of the data are shown as follows. In these graphs, the values are shown in non-logarithmic form. In these graphs, the decline in the Covid-19 pandemic period stands out as a common property. In addition, they reflect the results of changes in their own internal economic patterns. For instance, the process of dropping two zeros from the Borsa Istanbul in Turkey can be seen in these graphs.



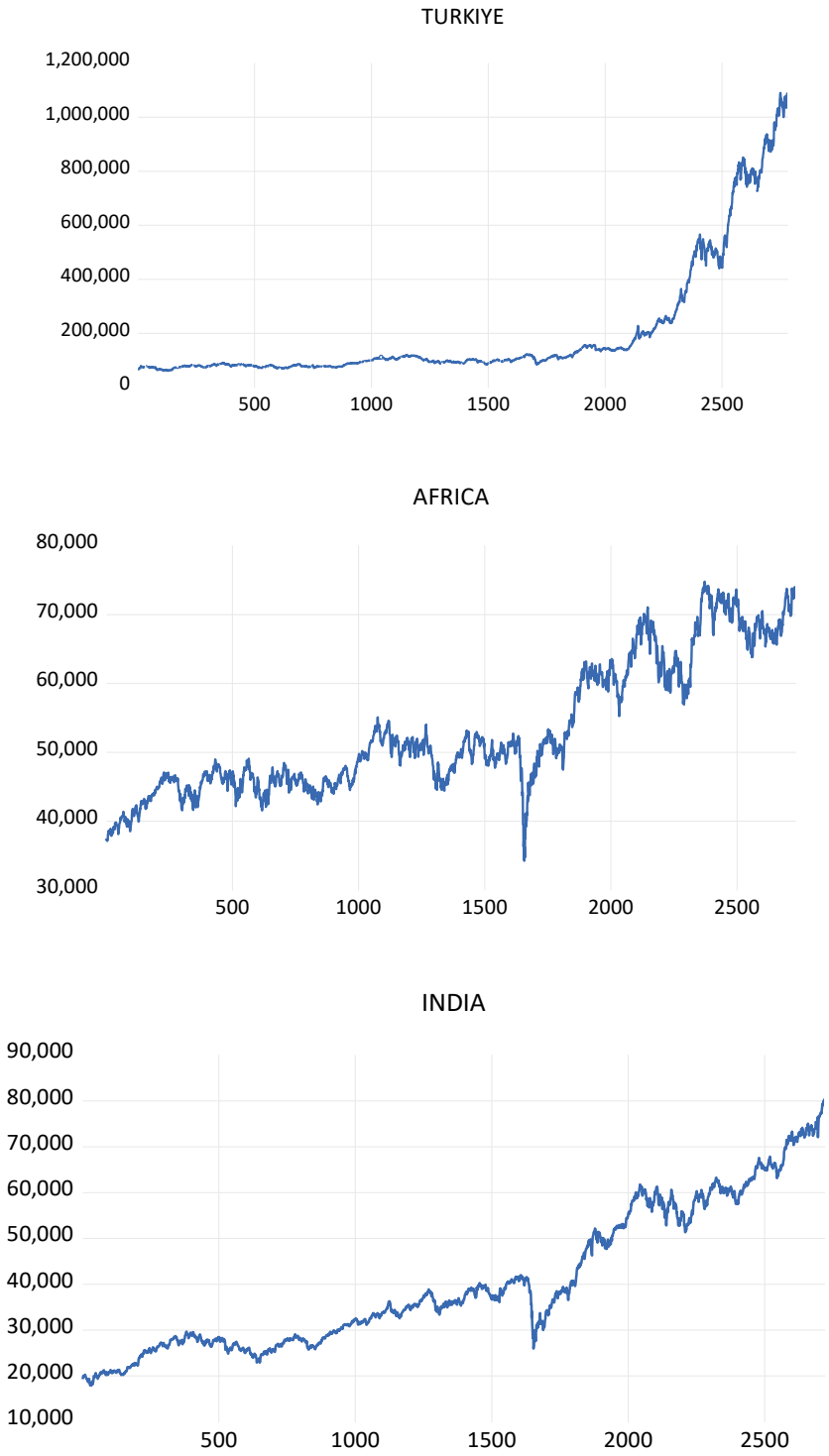
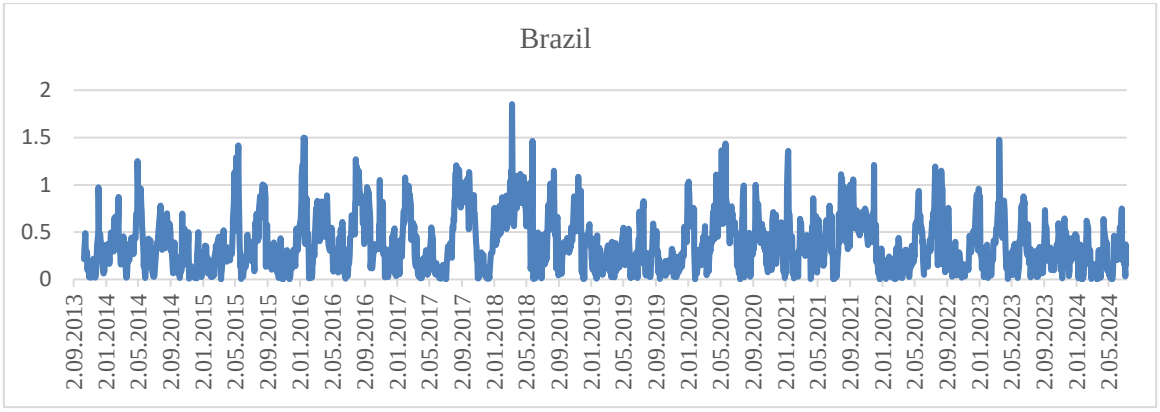


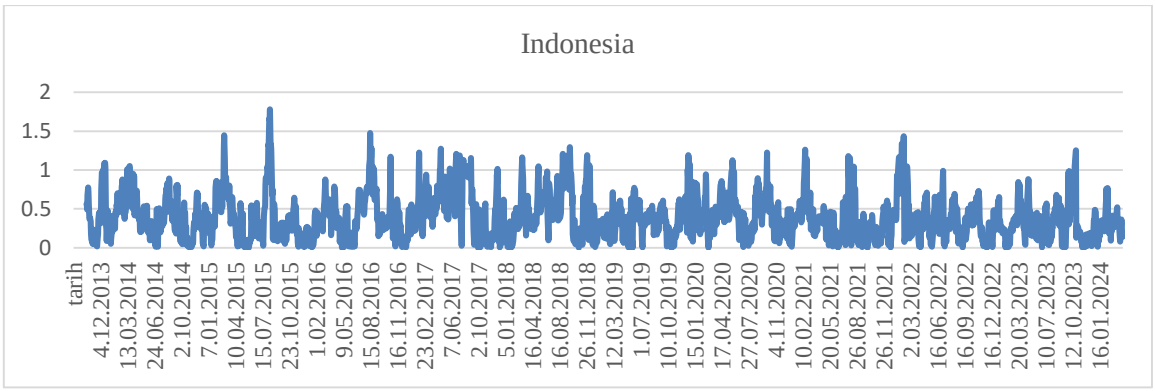
Figure 1-5. Time Series Charts of Variables

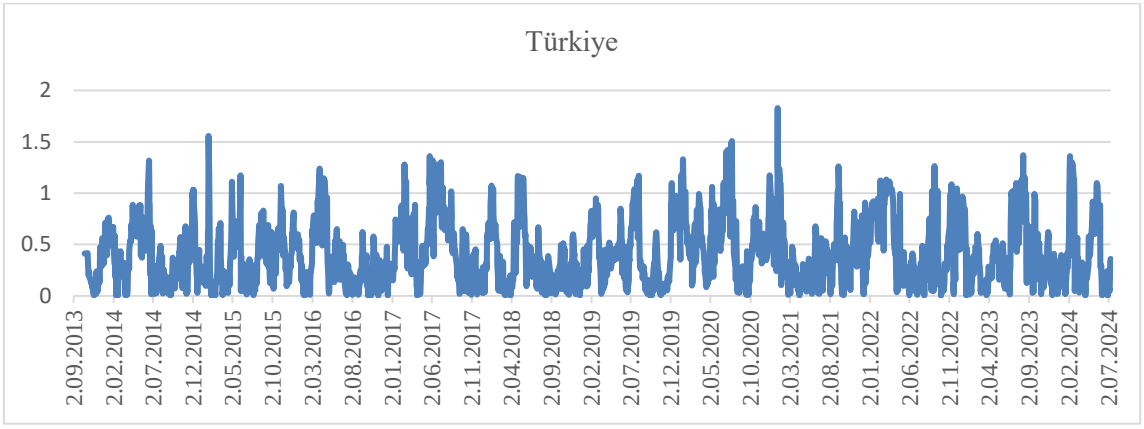
5. EMPIRICAL FINDINGS

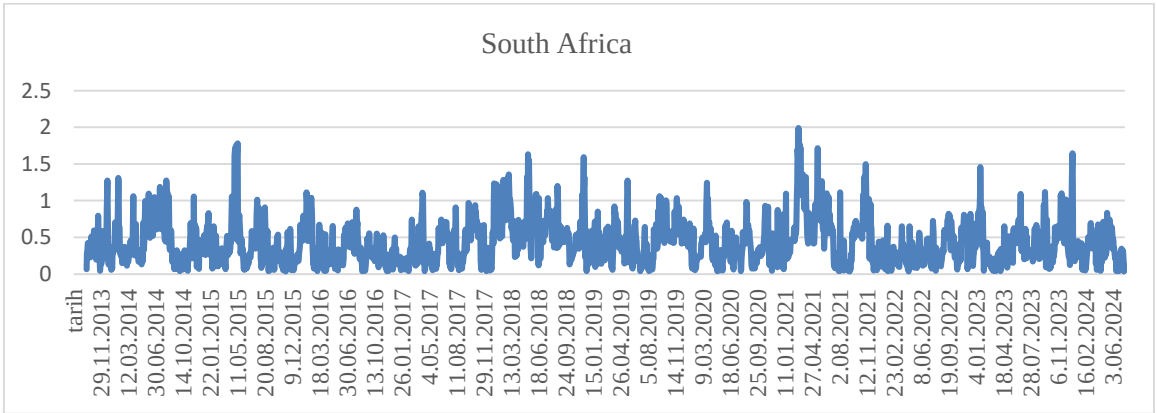
A review of various studies in the literature shows that the weak form of market efficiency can be measured by running tests, variance ratio tests, unit root tests, and many other methods. While some studies point to market efficiency, other studies have shown that market efficiency is not valid and behavioral finance anomalies are valid. In this study, the validity of the AMH, which suggests that both cases may be valid over time, was investigated. Accordingly, the time-varying KSS unit root test was used, which examines the stationarity of time series not for the entire data interval but periodically. In this regard, when the findings obtained with the figures numbered 6, 7, 8, 9 and 10 are analyzed, it is understood that the test statistics are above the 1 line periodically in all country stock markets, i.e. these time series are stationary in the periods above and have a unit root in the following periods. While the weak form of market efficiency is valid for the stock markets of these countries during periods

with unit roots, behavioral finance anomalies may be valid for the rest of the time. The graphs indicate that weak form of market efficiency especially matches the Covid-19 era. As a result, according to the findings obtained, the existence of AMH was found in 5 countries' stock markets as market efficiency is cyclically valid.









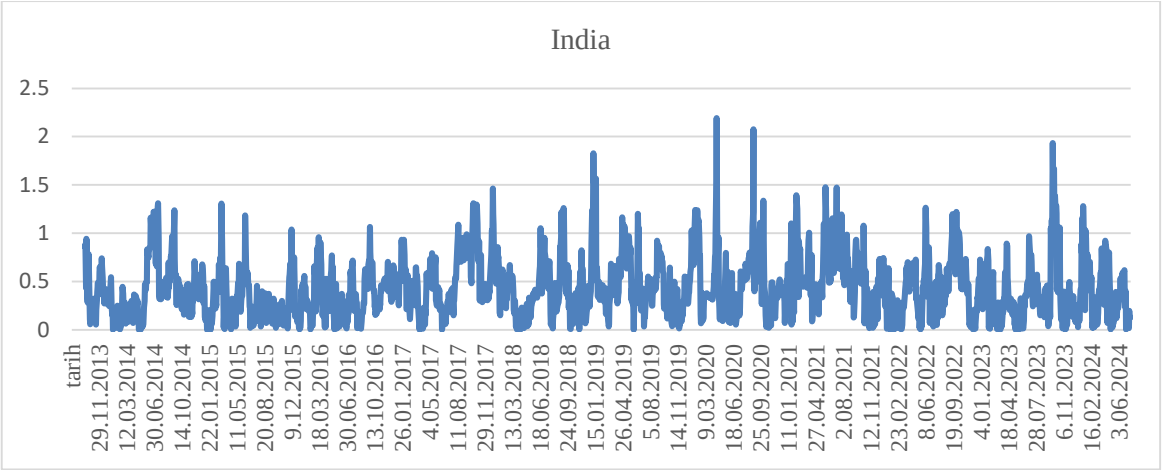


Figure 6-10. Time-varying KSS Unit Root Test Results

6. CONCLUSION AND DISCUSSION

Since its introduction, the efficient markets hypothesis has been one of the widely discussed topics in finance. There have been many empirical studies supporting the hypothesis and many criticisms. Especially the claims that market participants are always rational and that abnormal returns are impossible because prices in the market always include all the information that has been strongly criticized. The theory of Behavioral Finance, which is opposed to the efficient markets hypothesis, argues that there are anomalies in the market and that abnormal returns are possible as various assumptions of the efficient market hypothesis are not valid in financial markets. The AMH, proposed by Lo (2004, 2005, 2012), integrates the Efficient Markets Hypothesis with Behavioral Finance and suggests that markets act like ecosystems that are affected by numerous determinants. Market participants are individuals with limited rationality, competing for resources, and capable of adaptation. Therefore, market efficiency is not constant and financial markets may be efficient in some time intervals and inefficient in other times. The AMH, which integrates two controversial theories of financial markets, has attracted the attention of many researchers and several empirical studies have been conducted on this topic.

In this study, the validity of the AMH for the Fragile Five countries is examined with the time-varying KSS unit root test. With this test developed by Kapetanios, Shin & Snell (2003), it is possible to determine the time-varying periods in which the weak form of market efficiency is valid. Thus, whether the AMH is valid for the sample country stock markets was analyzed. The results of the analysis indicated that the AMH is valid for all Fragile Five countries. Because all the stock market indices analyzed by the study showed cyclical market efficiency. In other words, the time series analyzed cyclically has a unit root structure. These results indicate that the random walk hypothesis is cyclically valid in the investigated stock market indices. Since the weak form of market efficiency cannot be mentioned in periods when the random walk is not valid, investors will have the opportunity to earn above-normal returns by using various technical analysis methods during these periods.

The empirical findings obtained from the study are mostly in line with the other studies in the literature. In this sense, the findings of our study are similar to those of Cruz-Hernandez & Mora-Valencia (2024) for Brazil, Kumar & Anandarao (2021) for Indonesia, and Obalade & Muzindutsi (2019) for South Africa. However, it is partially consistent with Hiremath & Kumari (2014) who find that AMH is valid for India in linear tests but not in non-linear ones. Lastly, the findings of this study are not in line with the findings of Kılıç (2020), who finds that the AMH is not valid for BIST100. Hence, the findings suggest that the empirical evidence in the Fragile Five countries is insufficient to reach a general conclusion and that further research is still required.

Future studies may utilize another method, quantile-based unit root tests, which can provide different results across periods. On the other hand, further studies that will provide new findings for a larger data set and a larger sample will also contribute to literature.

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AUTHORS' CONTRIBUTIONS:

Conceptualization, writing-original draft, editing – **ES**, data collection, methodology, formal analysis – **FZ**, Final Approval and Accountability – **TY**.

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