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ICOAEF XIV

INTERNATIONAL CONFERENCE ON APPLIED ECONOMICS AND FINANCE

WELLCOME MESSAGE

International Conference on Applied Economics and Finance (ICOAEF XIV) held on 28th-29th December, 2025 in Hard Rock Hotel in Madrid/Spain. We are glad ICOAEF-XIV gathered many successful academics and professionals around the World. 68 papers were submitted, and 58 papers presented during ICOAEF-XIV from 16 different countries.

This conference provided as a suitable platform for discussions about the researches. This conference proceedings contains 21 papers presented both online and in person. ICOAEF-XIV participants consisted of from 15 different countries, 22 Turkish universities. Scientific board rejected 11 papers directly due to the inconvenience of conference topics, theme and structure of ICOAEF-XIV. Scientific committee also requested some corrections to 9 different papers then these papers accepted and presented during the conference. All submissions for ICOAEF-XIV scientifically reviewed and evaluated by scientific committee members.

We believe that ICOAEF-XIV provided an opportunity for national and international participants to present, discuss and share practical and theoretical issues in the fields of Economics, Finance and related social sciences. The papers submitted from 16 different countries beyond Türkiye. We accepted papers of the participants from Albania (2), Algeria (1), Cyprus (2), Czechia (3), France (1), Gambia (2), Germany (1), Greece (5), Italy (2), Kosovo (4), Kyrgyzstan (1), Malaysia (2), Poland (1), Romania (1), Russia (1), Türkiye (27), United States (12). Finally, we would like to thank Madrid Hard Rock Hotel in and our esteemed ICOAEF-XIV participants who shared their deep knowledge and experience at ICOAEF-XIV. We would like to be together in our following organizations.

On behalf of Conference Organisation Committee

Prof. H. Murat ERTUGRUL

CONTENTS OF ABSTRACT PROCEEDING

A BIBLIOMETRIC STUDY OF ECONOMIC COMPLEXITY RESEARCH

Hilal ÖNGE[*]

Yağmur ÇETİNTAŞ PALABIYIKOĞLU[**]

Fatih AYHAN[***]

ABSTRACT

Economic complexity, which offers a holistic and multidimensional framework for analyzing countries' production structures and development capacities, has gained increasing importance. This approach, unlike traditional indicators (e.g., per capita income), analyzes the knowledge base of the economy and the sophistication of its production structure. This study aims to contribute to the literature at the meta-level by examining studies on economic complexity between 2009 and 2025, identifying the years in which the economic complexity literature gained momentum, the country and cooperation networks, and the concepts with which it is associated through keyword matching. In this study, the development of scientific research on economic complexity was systematically examined. A total of 1,130 academic papers published in the Scopus database between 2009 and 2025 were evaluated using bibliometric analysis. The analytical process was conducted using VOSviewer software, which enables systematic assessment of key research trends, collaboration networks, and potential gaps in the economic complexity literature.

The findings reveal a significant increase in academic output, particularly in 2023 (202 publications), 2024 (205 publications), and 2025 (217 publications), highlighting the growing importance of the field in both theoretical and applied dimensions. Furthermore, the findings suggest that certain authors and countries take the lead in shaping the research agenda, while keyword use is concentrated within a relatively narrow thematic framework. Ultimately, this study provides a comprehensive and structured overview of the accumulated knowledge in the field of economic complexity, providing a systematic framework that can guide future academic research.

Keywords: *Economic Complexity, Systematic Literature Network Analysis, Citation Analysis, Keyword Network Analysis.*

JEL Codes: *C38, C80, F10.*

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1. INTRODUCTION

With globalization, the production structures of countries have become more complex. In this situation, the quality of products that countries produce is crucial for their economic growth. Therefore, unlike the traditional understanding of production, it is necessary to focus not only on the quantity of products produced but also on the knowledge, diversity, and technological level used in production. In this context, the concept of economic complexity developed by Hidalgo and Hausman (2009) in the literature measures the production structures of countries by focusing on how knowledge-intensive products they can produce, and offers a perspective beyond the traditional understanding of production. Thus, they have introduced a new understanding for measuring the productivity of countries. According to this understanding, the main reason for the differences in growth levels among countries is economic complexity. Economic complexity measures a country's economic capabilities and the complexity level of its information interaction network (Pietronero et al., 2013). The main aim of this approach is to measure the capabilities of a country's production structure by estimating productive knowledge based on the products it exports. The approach argues that countries with more productive capabilities are more complex and capable of producing more complex products (Ourens, 2013; Hausman et al., 2013). Furthermore, the greater the variety of products a country exports, the higher its complexity is considered, and the stronger its international economic interactions are regarded to be (Sepehrdoust et al., 2019).

Hidalgo and Hausman (2009) developed an economic complexity index to determine the complexity level of products in a country. The index measures the complexity level of economies using economic data (especially per capita income) of countries. Thus, it helps in making predictions about the complexity of exports in subsequent periods for countries. The index makes measurements at both the product and product level. The index evaluated for countries is calculated by weighting the shares of the products exported by the countries in their total exports. The index evaluated for products is calculated based on the product diversity of countries that have a comparative advantage in exports (İspiroğlu, 2021).

A review of the relevant literature in parallel with this study reveals that the level of economic complexity of countries is of considerable importance in terms of their economic growth and development goals. Factors affecting the level of economic complexity of countries include export diversification, the ability to export high-tech products, the level of human capital, and R&D expenditures (Zhu and Li, 2017; Yalta and Yalta, 2021). Countries with high economic complexity have a higher level of knowledge and skills than other countries, and their products are produced by fewer countries, thus gaining a competitive advantage in terms of product diversification (Can and Doğan, 2018). Furthermore, as the level of economic complexity increases, the country's production structure

strengthens. Therefore, high-income countries with strong economic structures export products with low prevalence, making them difficult to imitate and compete with.

Economic complexity, a strong indicator of sustainable growth, has recently become an important indicator for countries and a subject of extensive research in the literature. The literature contains numerous studies on economic complexity and its relationship with other economic factors. This study examines existing literature on economic complexity and conducts a bibliometric analysis. Thus, the study not only highlights the importance of economic complexity but also systematically reveals how and by whom knowledge in this field is produced and the themes around which it is shaped. This study aims to contribute to the literature at the meta-level by examining studies on economic complexity between 2009 and 2025, identifying the years in which the economic complexity literature gained momentum, the country and cooperation networks, and the concepts with which it is associated through keyword matching.

In this study, a total of 1,130 academic journals indexed in the Scopus database between 2009 and 2025 were analyzed using bibliometric methods. The analytical processes were carried out using VOSviewer software, which allows for the systematic evaluation of key research trends, collaborative networks, and potential gaps in the economic complexity literature. The following sections of the study describe the research methodology and evaluate and interpret the findings.

2. METHOD

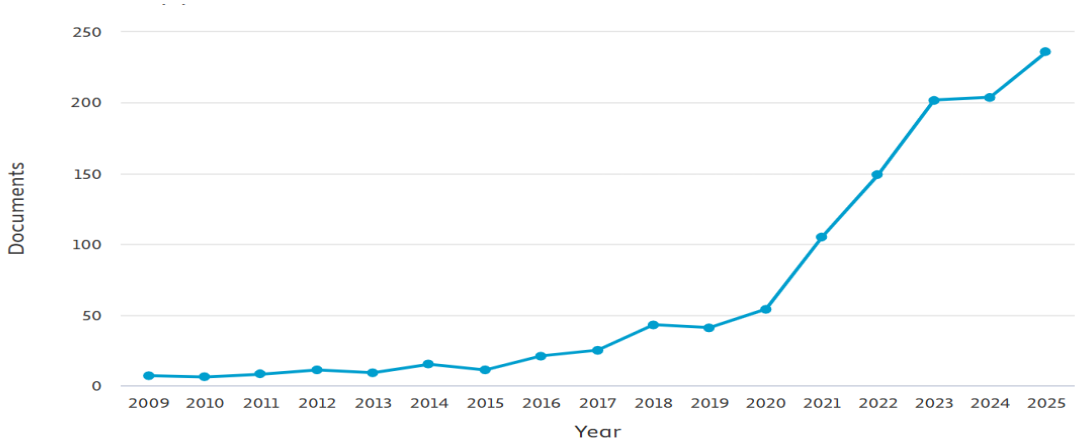
This study employs bibliometric analysis to reveal the current academic body of knowledge in the field of economic complexity. A systematic overview of the field of economic complexity is created by mapping the structure and development of the literature related to bibliometric analysis techniques. Bibliometric analysis is used to make sense of large volumes of data and to reveal accumulated knowledge in a specific field by enabling systematic examination of the data (Aydın, 2024). For the bibliometric analysis in this study, VOSviewer software, which has strong technical features in scientific mapping and visualization, was chosen. VOSviewer's ability to reveal research trends, conceptual structures, and collaboration networks from a multidimensional perspective significantly facilitates the detailed examination of the dataset (Dirik et al., 2023). In this respect, the program offers the opportunity to evaluate the development of the economic complexity literature over time, its dominant themes, and potential research gaps in a holistic structure. The Scopus database was used in the data collection process for the analysis. The primary reason for choosing Scopus was its ability to provide detailed and comprehensive searches thanks to its advanced search filters (Md Khudzari et al., 2018). Furthermore, its inclusion of over 1000 studies in the field of economic complexity was a contributing factor. The time constraint for the research was set as 2009–2025. This period was chosen because the concept of economic complexity began to appear more systematically in the literature with the work of Hidalgo and Hausmann (2009). The Scopus search was conducted on October 26, 2025. The keyword "economic

complexity" was used in the search; the search scope was set to "all fields," the publication type was limited to only "article," and the language filter was restricted to English publications. Additionally, the scope of the study was narrowed to include studies from 2009–2025. As a result of these filters, a total of 1,130 articles were obtained. The resulting dataset was analyzed based on author collaboration structures, citation patterns, country contributions, and keyword relationships to provide a comprehensive profile of the economic complexity literature.

3. FINDINGS

This section presents a comprehensive overview of the bibliometric findings related to the literature on economic complexity. The analysis includes a detailed examination of publication trends over the years, thematic concentration within the literature, the interrelations of key concepts, and the clustering among research areas. Furthermore, the structural characteristics of economic complexity studies have been elucidated by evaluating author collaboration networks, the scientific contributions of various countries, and citation patterns. The resulting maps and network structures visually and analytically illustrate the academic evolution of the literature over time, highlighting key focal points and prominent research trajectories.

Figure 1. Document by Year

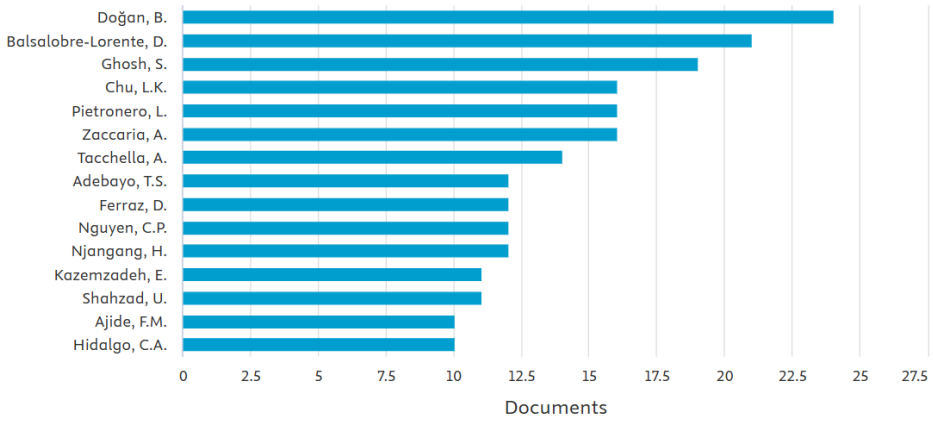


Source: Scopus.

The development of the economic complexity literature over the years, as examined through the graph presented in Figure 1, reveals a very clear upward trend. The number of publications appears to have stagnated during the 2009–2015 period. During this period, annual output generally ranged from 5 to 15 articles, indicating that the field was in its early stages of development. After 2016, a significant acceleration in publications began. It is concluded that academic interest in the concept of economic complexity strengthened particularly between 2018 and 2020, but the real leap in the literature occurred starting in 2021. This upward trend gained momentum in 2022, exceeding 100 publications.

2023 is a turning point in economic complexity studies. In this year, the number of publications reached approximately 150, and the observed increase became even more pronounced in the following years, 2024 and 2025. The graph shows that the number of publications will exceed 230 by 2025, indicating that economic complexity is becoming a central focus for researchers.

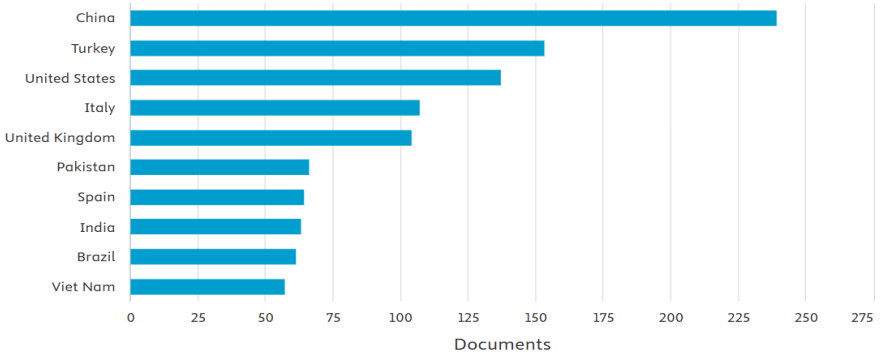
Figure 2. Documents by Author



Source: Scopus.

The top 15 researchers with the most publications are shown in Figure 2. Accordingly, Buhari Doğan has the highest number of publications in the economic complexity literature with 24 studies, making him the most prolific author in the field. He is followed by Daniel Balsalobre-Lorente with 21 publications. The third most prolific author is S. Ghosh with 19 publications. César A. Hidalgo, while ranking lower in terms of publication volume, maintains his influence in the field as one of the founders of the theoretical foundation of the concept. This indicates that economic complexity research has evolved over the years from a purely theoretical framework into a much broader applied literature, with a rapid increase in empirical studies.

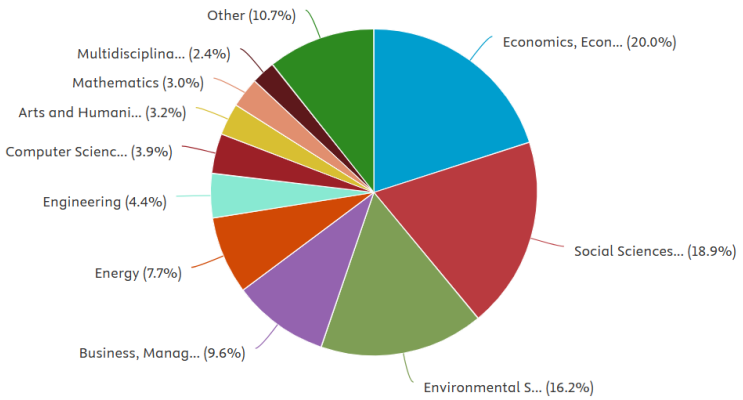
Figure 3. Documents by Country or Territory



Source: Scopus.

Figure 3 shows the countries that have contributed the most to the economic complexity literature. The data reveals that China clearly leads the way. With approximately 250 publications, China has played a decisive role in shaping economic complexity studies and expanding the field. Turkey follows in second place, with approximately 150 publications, demonstrating a rapidly rising research trend in this area, especially in recent years. The ranking continues with the United States, Italy, and the United Kingdom, followed by developing economies such as Pakistan, Spain, India, Brazil, and Vietnam. The increasing number of publications from these countries shows that economic complexity has become a global research area and is not limited to high-income countries. Overall, the graph reveals that the economic complexity literature is expanding geographically; many different academic communities, from Asia to Europe, and from Latin America to South Asia, are contributing to the field. This broad geographical diversity allows the field to develop with a more comprehensive perspective.

Figure 4. Documents by Subject Area



Source: Scopus.

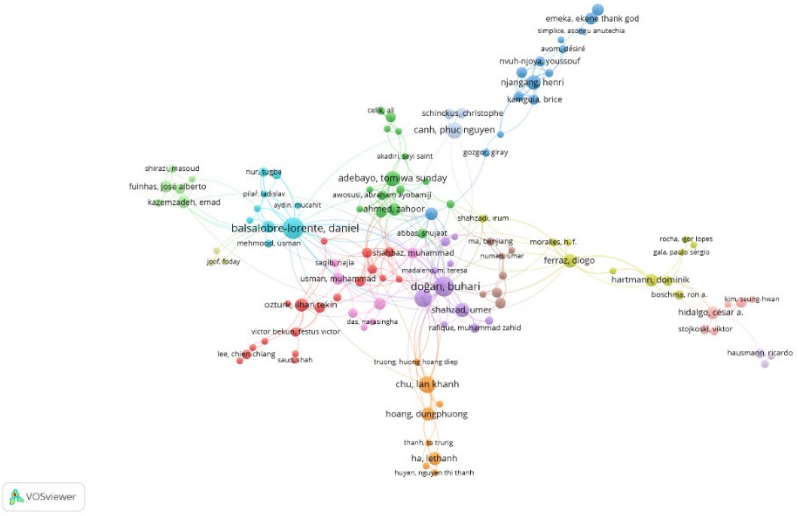
Figure 4 shows the distribution of studies produced in the economic complexity literature according to subject areas. The graph shows that economic complexity is not a concept limited only to the discipline of economics and has transformed into a broad multidisciplinary structure with a wide variety of research areas. The most concentrated area is Economics, Econometrics, and Finance with 20%. This reveals that economic complexity is used as an important tool in macroeconomic indicators, foreign trade structure, and competitiveness analyses. Economics, Econometrics, and Finance is followed by Social Sciences with 18.9%, thus concluding that the concept is also addressed in broader social contexts such as development, innovation, human capital, and socio-economic transformation. The third-ranked Environmental Sciences share with 16.2% shows that economic complexity has a strong relationship with environmentally focused studies such as environmental sustainability, carbon emissions, and the green economy in recent years. Studies in the Business and Management (9.6%) and Energy (7.7%) categories indicate that the concept is used in conjunction with firm-level production processes, innovation dynamics, and energy transformation. In addition, although engineering, computer

science, mathematics, and multidisciplinary studies appear to have lower shares, these fields make significant contributions supporting the technical infrastructure of economic complexity. Tools such as computational modeling, network theory, and statistical methods are particularly developed by these groups.

Finally, the "Other" category, with a share of 10.7%, shows that economic complexity has an increasingly broad application area. Overall, the graph reveals that economic complexity has a strong interdisciplinary character.

3.1. Co-Authorship Analysis of Authors

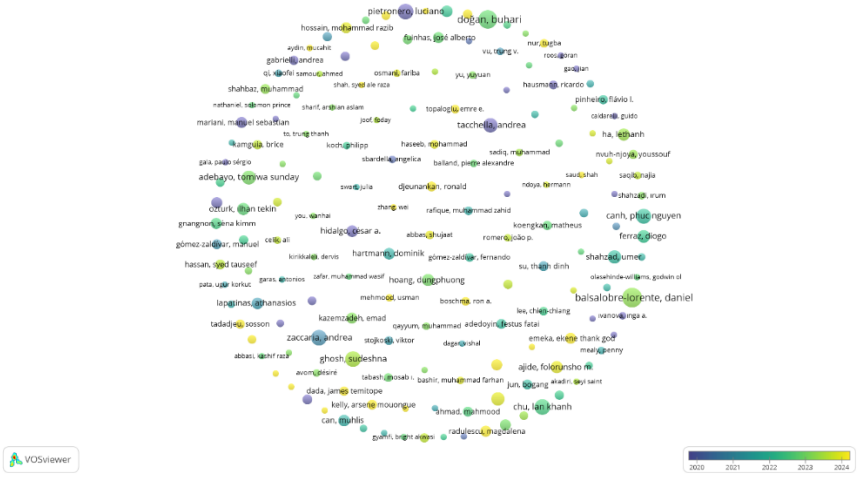
Figure 5. Co-Authorship Links Indicating Collaboration Among Authors



To map the authors' co-authorship network, criteria of at least 3 publications and at least 10 citations were determined. Accordingly, 14 clusters were identified based on 120 authors. Each color on the network map represents a cluster. The total connection strength was determined as 569 out of 307 connections. The strong link structure shows us that the literature has recently gained a co-authorship dynamic. When the number of citations and connection strengths of the authors are examined, the list of the most cited authors and the list of the authors with the strongest connections differ. While Daniel Balsalobre-Lorente is at the top of the list of most cited authors, Buhari Doğan is the author with the strongest connection.

3.2. Citation Analysis of Authors

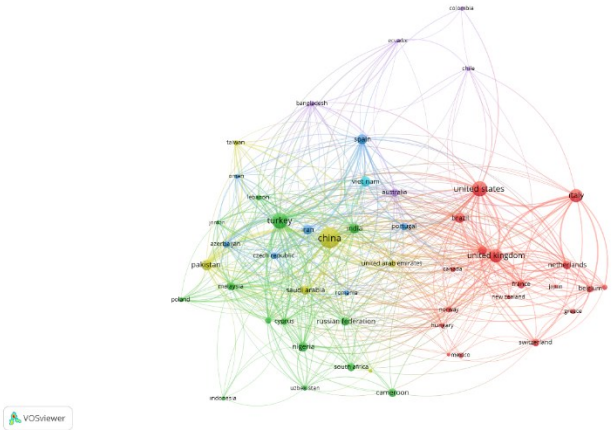
Figure 6. Citation Links Among Authors



In order to determine the citation networks by years, a network map was created by determining the criteria of at least 3 publications and at least 30 citations. The top 5 most cited authors were identified as Daniel Balsalobre-Lorente, Buhari Doğan, Umer Shahzad, Cesar A. Hidalgo, and Chu Khanh Lan, respectively. The citation network structure shows that there is a fragmented situation in the literature. Author citation clustering was not detected. The blue-purple color scale seen in the network map represents the early period of 2010-2015, while the green color scale represents the middle period of 2016-2021. The yellow color scale represents authors who published in the last period 2022-2025. When the time-dimensional coloring of the network map is examined, it is seen that there has been an acceleration after 2016. When we look at the density of nodes seen in yellow and green tones, it can be seen that there has been an increasing interest in the literature in recent years.

3.3. Co-Authorship Analysis of Countries

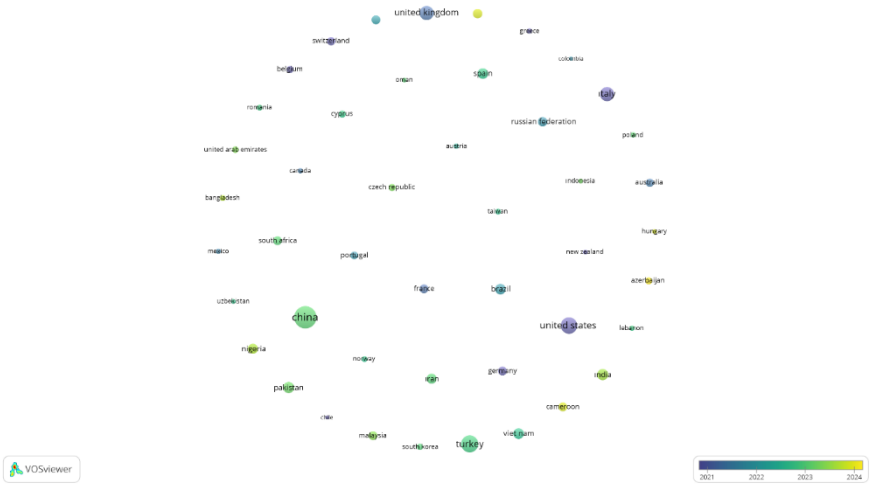
Figure 7. Co-Authorship Networks of Countries



A minimum of 8 publication criteria was determined to map the co-authorship network of countries. As a result, 6 clusters were identified over 51 countries and the total connection strength was determined as 1691. Each color seen on the network map represents a cluster. The network map shows that countries are working intensively together and a few countries are centrally located at the center of the network. These countries were China, Türkiye, the USA and the United Kingdom.

3.4. Citation Analysis of Countries

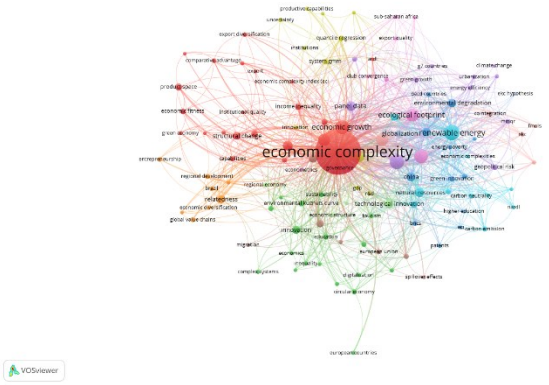
Figure 8. Citation Networks of Countries



A minimum of 10 works and a minimum of 10 citation criteria were determined for the citation network map of publications according to their country of origin. As a result of the selected criteria, a network map of 46 countries was created. Similar to the author citation analysis, no clustering was detected in the country citation analysis. According to the network map, the countries that have contributed the most to the literature are China, Türkiye, the United Kingdom and the United States. When the color scale is examined, it is seen that countries such as China, Türkiye, Pakistan and India stand out in their contribution to the literature after 2021 in yellow color tones. It has been determined that the USA, the United Kingdom and European countries are included in the green color scale covering the period before 2021.

3.5. Co-Occurrence Analysis of Author Keywords

Figure 9. Keyword Networks of Authors



The minimum number of repetitions was chosen as 5 to identify the most frequently repeated words by the authors regarding economic complexity. As a result, 121 keywords and 12 clusters were identified. The most frequently used keyword was economic complexity with 715 occurrences and a total link strength of 1223. When the clusters that dominate the density are examined, it is seen that the theoretical plan of economic complexity and the econometric analysis methods are combined in the red cluster. The blue cluster focuses on energy and environmental themes. The green cluster focuses on topics such as innovation and digitalization. The orange cluster has more trade and development themes. The yellow cluster includes social and macroeconomic issues. The keyword analysis shows that the strongest connections are in the axes of environment, energy, trade, growth and development. The network structure is balanced and the level of integration is high.

4. RESULTS AND POLITICAL RECOMMENDATION

Economic complexity, a strong indicator of sustainable growth, has become a significant indicator for countries in recent times and a subject of extensive research in the literature. The literature contains numerous studies on economic complexity and its relationship with other economic factors. This study examines existing literature on economic complexity and conducts a bibliometric analysis. Thus, the study systematically reveals not only the importance of economic complexity but also how and by whom knowledge in this field is produced and around which themes it is shaped. Contributing to the literature at the meta-level, this study examines research on economic complexity conducted between 2009 and 2025 and identifies the years in which the economic complexity literature gained momentum, the country and cooperation networks, and the concepts associated with it through keyword matching.

An analysis of 1130 studies obtained from a search of the Scopus database using the keyword "economic complexity" between 2009 and 2025 shows that the importance of economic complexity is steadily increasing and that this field is attracting significant attention. It was found that certain authors stand out, and that certain countries are prominent in the literature. Although the literature is widespread on a global scale, production and collaboration are concentrated in specific countries. Analysis of author

collaborations shows that the literature has recently adopted a collaborative authorship dynamic. In recent years, the economic complexity literature has evolved from an individual-based structure to a network-based structure. This, along with the differentiation between the most cited authors and those with the highest network connectivity, indicates that intellectual influence and network center are not progressing in parallel, but are determined by different dynamics. The lack of clustering in author citation networks shows that the economic complexity literature exhibits a fragmented appearance in theoretical and methodological areas. In time-dimensional analyses, the rise of the field after 2016 is shaped around the themes of sustainability, environment, and energy. Keyword analysis, in particular, reveal that studies on economic complexity have a balanced thematic structure around theoretical frameworks, trade, growth and development, energy, environment, and macroeconomic dimensions. Despite this thematic balance, the fragmented structure of author and citation networks indicates a lack of integration between theory and empirical applications.

In light of these findings, it is believed that future research that deepens the theoretical framework of economic complexity literature will make significant contributions. Furthermore, focusing on studies that integrate different thematic areas and strengthen the policy dimension will be effective in enhancing the literature.

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RELATIONSHIP BETWEEN STRESS, ANXIETY, DEPRESSION, CONSCIENTIOUSNESS AND PROCRASTINATION IN EMPLOYEE

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ABSTRACT

Procrastination is generally defined as the tendency or behavior to delay making a decision or performing a task. Numerous studies have linked procrastination to stress, anxiety, and depression. However, it is also known that procrastination, as a personality trait, generally exhibits a stable structure across individuals and is significantly correlated with Conscientiousness and Emotional Stability as measured by the Five-Factor Model of personality. This study examined the overlapping and differing aspects of these variables, taking stress, anxiety, depression, and personality traits from the Five-Factor Model as predictors of procrastination. A total of 361 employed individuals, 207 male (57.3%) and 154 female (42.7%), aged 18-73 (mean = 34.33; s = 10.47), participated in the study. Participants were administered the A Procrastination Scale-15, the Hospital Anxiety and Depression Scale, the A Stress Scale-36, the Big Five-50 Personality Test, and the Self-Esteem subscale of the Melbourne Decision-Making Scale. According to the results, when procrastination was predicted by stress, anxiety, and depression scores, all three variables predicted procrastination at a statistically significant level, explaining 17% of the variance. However, when self-esteem was included as an independent variable, anxiety was no longer a predictor of procrastination. In this case, 20.0% of the variance in procrastination was explained. Only the five personality factor explained 45.0% of the variance in procrastination. When procrastination was predicted by including anxiety, depression, stress, self-esteem, conscientiousness and emotional stability, conscientiousness and self-esteem were statistically significant predictors. In this case, self-esteem and conscientiousness explained 49.0% of the variance in procrastination. In the final stage, when all independent variables were considered together, procrastination was found to be predicted by conscientiousness, depression, and self-esteem. In this condition (Model 6), 48.0% of the variance in procrastination was explained. The results were discussed and recommendations were presented.

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1. INTRODUCTION

Procrastination can be defined as a state of delay resulting from avoiding the execution of a task that needs to be completed within a specific timeframe (Değirmenci et al., 2023; Metin et al., 2016). In the workplace, procrastination is defined as delaying tasks in the work environment due to engaging in non-work-related activities without the intention of causing harm (Kausar et al., 2025). Although procrastination is generally defined in the literature as a deficiency in self-regulation, it is seen to have a moral dimension in terms of social perception, and research shows that procrastination can be evaluated as a weakness of will and a moral violation (Rahimi et al., 2016). One of the most important problems of today's working life is the perception of inefficiency stemming from employees' failure to comply with rules, and one of the main reasons for this perception is the tendency of employees to procrastinate (Kaynak and Çiçek, 2023). Procrastination in the workplace indicates a failure of self-regulation in the work environment and also points to high costs for organizations (Metin et al., 2016). When factors like stress, difficult choices, or taking on responsibility deplete an individual's internal resources, individuals tend to opt for more passive options such as inaction or procrastination instead of undertaking tasks that require active effort (Baumeister et al., 1998). This leads to inefficiency and decreased competitiveness at the workplace and organizational level, and negative consequences for employees such as lower income, decreased performance, and shorter employment periods (Kausar et al., 2025). Furthermore, procrastination is associated with increased stress levels, the use of inadequate coping strategies, poor sleep quality, poor self-evaluation, and physical illnesses (Marzocchi et al., 2025; Sirois, 2023).

Stress is defined as the physical and psychological responses of an individual to external stimuli, and the work environment is considered one of the most significant sources of stress in daily life (Kaynak and Çiçek, 2023). Stress in working life is considered one of the most fundamental psychological factors affecting employees (Sun et al., 2022). Understanding interindividual differences in employees' responses to workload in stressful situations is possible by identifying their tendencies to approach positive outcomes or avoid negative outcomes (Casper et al., 2017). Job-related stress not only impairs work productivity but also affects physical health and psychological well-being (Mao et al., 2023). In employees, work stress, fatigue, and frustration lead to burnout, resulting in negative responses such as job dissatisfaction, low levels of job and organizational commitment, and a high tendency to resign, leading to decreased performance (Chen et al., 2022).

Anxiety is a multifaceted emotion generally characterized by internal turmoil, accompanied by somatic complaints and behaviors such as daydreaming (Zhang and Lay, 2024). Job anxiety, unlike general anxiety, directly relates to the workplace and work-related situations. Anxiety is a phenomenon

that arises due to specific tasks and uncertainties, is often confused with stress or burnout, and if left unnoticed, can lead to avoidance of work and reduced work potential through sick leave (Muschalla, 2025). It is noted that employees avoid reporting mental health problems for fear of stigma and unfair treatment in the workplace, but anxiety can reduce work productivity, increase the risk of domestic conflict, and lead to serious consequences such as depression and even suicidal attempts (Hao et al., 2023). Depression, a mood disorder that affects cognitive and emotional processes, leading to impairments in how an individual manages daily activities, thinks, and feels, is also closely related to this process (Becker et al., 2025). Individuals with excessive workloads have been shown to have a higher risk of developing anxiety or depression compared to those with relatively less workloads (De Krijger, 2025; Jochmann et al., 2024). In parallel, it has been reported that high work demands lead to energy loss in employees, causing burnout, and that this condition coincides with work-related depression, anxiety, and stress responses (Demerouti et al., 2001). Mental disorders such as depression and anxiety make employment more difficult, prolonging the period of unemployment, while also causing problems such as low wages, discrimination, and loss of functionality in employed individuals (Shin et al., 2019).

Conscientiousness is a multidimensional phenomenon that encompasses an individual's ownership of their own behavior, reliability, and capacity to act when necessary, and is critically important for success and affects how they cope with stress (Arslan, 2025). While conscientiousness is considered an important personality trait in explaining procrastination in working individuals, it is predicted that the increased stress resulting from individuals taking on multiple roles such as work and family can increase procrastination behavior in some situations (Gu et al., 2022). On the other hand, according to the ego depletion approach, taking responsibility, using initiative, and making difficult decisions consume individuals' limited energy resources, and when energy decreases, individuals tend to procrastinate as a more passive response instead of doing difficult tasks (Baumeister and Vohs, 2007).

In this study, in line with the above, it was considered to examine the effect of stress, anxiety, depression, self-esteem, and personality traits on procrastination in individuals working in income-generating jobs. In particular, the aim was to determine how the inclusion of self-esteem among mood and personality traits would change the strength of the predictors. Accordingly, this study aimed to determine the extent to which procrastination is related to and predicted by mood states consisting of stress, anxiety, and depression, personality traits within the framework of the Five-Factor Personality Model, and self-esteem.

2. METHODOLOGY

Participants

A total of 361 people, 207 men (57.3%) and 154 women (42.7%), aged between 18 and 73 years

(mean = 34.33; s = 10.47), who were actively employed, participated in the study. In the study, being employed in an income-generating job was taken as the inclusion criterion, while working in a non-income-generating job such as a volunteer-based aid project and/or not being employed was taken as the exclusion criterion. The educational level of the participants was found to be 16 primary school graduates (4.4%), 35 middle school graduates (9.7%), 77 high school graduates (21.3%), and 233 university graduates (64.5%). It was found that 149 of them were single (41.3%), 192 were married (53.2%), 5 were widowed (1.4%), and 15 were divorced (4.2%); their income levels were low (10.5%), medium (55.7%), and good (33.0%) (3 employed individuals (0.8%) did not specify their income level).

Materials

Participants were administered the A Procrastination Scale-15, the Hospital Anxiety and Depression Scale, the A Stress Scale-36, the Big Five-50 Personality Test, and the Self-Esteem subscale of the Melbourne Decision-Making Scale.

The A Procrastination Scale-15 was originally developed as a 20-item scale (Tatar and Özdemir, 2019), then shortened to a 15-item scale with five items being reverse-scored (Tatar, Saltukoğlu, and Özdemir, 2019). The scale is a three-sub-dimension self-report scale and is administered using a five-point Likert-type response option. The internal consistency reliability coefficient for the revised form of the scale was reported as 0.91 (Tatar, Saltukoğlu, and Özdemir, 2019).

Instruments the Hospital Anxiety and Depression Scale consists of 14 items, eight of which are reverse-scored, and is answered using a four-point Likert scale. The scale is divided into odd and even-numbered items; odd-numbered items represent anxiety, and even-numbered items represent depression (Zigmond and Snaith, 1983). In the Turkish translation of the scale, the internal consistency reliability coefficients were reported as 0.85 for anxiety and 0.78 for depression (Aydemir, Güvenir, Küey and Kültür, 1997).

The A Stress Scale-36 consists of 36 items with a five-point Likert scale, and does not contain any reverse-scored items. The scale is divided into odd and even-numbered items; odd-numbered items represent Physiological Reactions / Strain, and even-numbered items represent Psychological/ Cognitive Appraisals sub-dimensions. The internal consistency reliability coefficient reported for the entire scale in the development study was 0.94 (Tatar et al., 2018).

The Big Five-50 Personality Test consists of 50 items, 24 of which are reverse-scored and answered using a five-point Likert scale. The measurement tool is evaluated with five factors: Extraversion, Agreeableness, Conscientiousness, Emotional Stability, and Intelligence/Imagination (Tatar, 2017).

The Self-Esteem subscale of the Melbourne Decision-Making Scale constitutes the first section of the Melbourne Decision-Making Scale that assesses self-esteem. This section of the scale consists of

six items evaluated with a three-point rating scale, three of which are reverse-scored (Deniz, 2004; Mann, Burnett, Radford, and Ford, 1997).

Application

The study was implemented in Izmir and Manisa provinces during September-October 2025 using a printed form and individual application.

Data Analysis

The study data was analyzed by predicting the total procrastination score using multiple linear regression analysis with the total scores of other variables obtained in the study.

Results

First, internal consistency reliability analyses of the measurement instruments used in the study were conducted, and it was observed that the scales showed internal consistency reliability coefficients between 0.69 (Intelligence/Imagination Factor) and 0.95 (A Stress Scale-36) (Table 1).

Table 1. Internal Consistency Reliability Coefficients of the Measurement Instruments Used

Scales	n of Item	Cronbach Alpha
A Procrastination Scale-15	15	0.92
Hospital Anxiety and Depression Scale / Anxiety	7	0.81
Hospital Anxiety and Depression Scale / Depression	7	0.75
A Stress Scale-36	36	0.95
Self-Esteem subscale	6	0.74
Extraversion	10	0.79
Agreeableness	10	0.75
Conscientiousness	10	0.80
Emotional Stability	10	0.77
Intelligence/Imagination	10	0.69

Multiple linear regression analyses were conducted to explain the variance in procrastination in this study. As presented above, anxiety, stress, and depression were initially considered as predictors of procrastination. The analysis results showed that anxiety, depression, and stress explained 17% of the variance in procrastination. When self-esteem was also included as a predictor of procrastination, anxiety was removed from the equation and lost its significance, while depression, stress, and self-esteem explained 20% of the variance in procrastination, an increase of 3%. When procrastination was predicted using the five factors of the Five-Factor Personality Model, Extraversion, Agreeableness, and Intelligence/Imagination factors were not included in the equation and were found not to be predictors of procrastination. However, only Conscientiousness and Emotional Stability factors explained 45% of the variance in procrastination, resulting in a 25% increase in the explained variance. In Model 2, when procrastination was predicted by including anxiety, depression, stress, and self-esteem along with Conscientiousness and Emotional Stability factors, the explained variance increased by 4% to 49%. In

this model, only responsibility and self-esteem predicted procrastination.

Table 2. Examination of Anxiety, Depression, Stress, Personality Traits, and Self-Esteem as Predictors of Procrastination Using Multiple Linear Regression Analysis

Model	Predictors	B	S.E.	Beta	t	F	R	R^2	ΔR^2
1	constant	20.48	1.69		12.12***	24.03***	0.41	0.17	0.17
	Anxiety	0.43	0.20	0.15	2.19*				
	Depression	0.52	0.20	0.18	2.66**				
	Stress	0.07	0.03	0.15	2.37*				
2	constant	31.62	3.40		9.31***	22.21***	0.45	0.20	0.03
	Anxiety	0.27	0.20	0.09	1.38				
	Depression	0.40	0.20	0.13	2.02*				
	Stress	0.06	0.03	0.13	2.13*				
	Self-Esteem	-0.96	0.26	-0.21	-3.76***				
3	constant	79.38	3.98		19.94***	59.03***	0.67	0.45	0.25
	Extraversion	-0.29	0.82	-0.02	-0.35				
	Agreeableness	0.77	0.89	0.04	0.86				
	Conscientiousness	-11.30	0.75	-0.66	-15.01***				
	Emotional Stability	-1.41	0.71	-0.08	-1.98*				
	Intelligence/Imagination	-0.29	1.04	-0.01	-0.28				
4	constant	69.44	4.83		14.39***	56.15***	0.70	0.49	0.04
	Conscientiousness	-9.98	0.71	-0.58	-14.09***				
	Emotional Stability	0.15	0.75	0.01	0.20				
	Anxiety	0.03	0.16	0.01	0.20				
	Depression	0.30	0.16	0.10	1.89				
	Stress	0.03	0.02	0.08	1.53				
	Self-Esteem	-0.43	0.21	-0.09	-2.06*				
5	constant	66.63	5.47		12.19***	37.46***	0.70	0.49	0.00
	Extraversion	0.19	0.80	0.01	0.24				
	Agreeableness	0.88	0.88	0.05	1.00				
	Conscientiousness	-10.29	0.77	-0.60	-13.29***				
	Emotional Stability	0.02	0.78	0.00	0.03				
	Intelligence/Imagination	0.08	1.03	0.00	0.08				
	Anxiety	0.00	0.17	0.00	0.03				
	Depression	0.34	0.16	0.11	2.11*				
	Stress	0.04	0.02	0.08	1.58				
	Self-Esteem	-0.43	0.21	-0.09	-2.00*				
6	constant	73.00	3.34		21.87***	111.40	0.70	0.48	-0.01
	Conscientiousness	-10.14	.70	-.59	-14.53***				
	Depression	.43	.13	.14	3.35***				
	Self-Esteem	-.48	.20	-.10	-2.35*				

Notes: *p < 0.05; **p < 0.01; ***p < 0.001.

When anxiety, depression, stress, and self-esteem were included along with the five personality factors, the explained variance in procrastination remained unchanged at 49%. However, in this case, it was observed that depression, in addition to responsibility and self-esteem, also predicted procrastination. As a final step, by removing the variables not included in the equation and including only responsibility, self-esteem, and depression, which were determined to predict procrastination in the previous model, no significant change occurred. Although the significance levels of the three variables changed, they continued to predict procrastination and explained 48% of the variance in procrastination. The observed change in the variance explained was a decrease of approximately 1%, which can be considered insignificant, depending on the variables removed from the model (Table 2).

3. CONCLUSION

The main objective of this study was to examine how procrastination behavior in working individuals is predicted by mood variables (stress, anxiety, depression), five-factor personality traits, and self-esteem. The research aimed to determine whether procrastination is related to mood or whether personality and self-esteem play a more dominant role, and to reveal the interaction between these variables. Although procrastination is generally defined in the literature as a failure in self-regulation and a behavior of delaying a task (Değirmenci et al., 2023; Metin et al., 2016), understanding how the underlying psychological reasons for this behavior interact with personality and self-esteem, especially in working individuals, is important. According to the findings, stress, anxiety, and depression were found to significantly predict procrastination. This finding is consistent with studies showing that workplace demands and stress factors deplete an individual's internal resources, leading to procrastination (Demerouti et al., 2001; Sirois, 2023). When stress and challenging conditions deplete an individual's internal resources, they lead to procrastination instead of tasks requiring active effort (Baumeister et al., 1998). This study also supports this perspective, as stress and depression are stronger predictors than anxiety. In particular, it aligns with findings suggesting that depression triggers procrastination due to its negative effects (Jochmann et al., 2024). However, the relatively low explained variance (17%) indicates that mood has limited power in explaining procrastination. The addition of self-esteem to the model, which reduces the predictive power of anxiety and increases the variance to 20%, is consistent with findings in the literature. This also supports Sirois' (2023) findings, which emphasize the association of low self-evaluation with procrastination.

One of the strongest findings of the study is that the five-factor personality model, particularly the conscientiousness and emotional stability, explains procrastination at a level of 45%. The conscientiousness is defined as an individual's capacity to own their own behavior and take action (Arslan, 2025), and low responsibility constitutes a risk factor for procrastination. In this study, while other personality factors (extroversion, agreeableness, and intelligence/imagination) were insignificant, the prominence of responsibility and emotional stability supports the view that procrastination in the

work environment is a weakness of will and a lack of self-regulation (Rahimi et al., 2016). In the model where all variables were evaluated together, the effects of emotion such as conscientiousness and self-esteem, stress, and anxiety on procrastination were eliminated. The results show that procrastination is explained primarily by responsibility and self-esteem at a high rate of 49%. The fact that depression became significant again in the final model shows that emotion has no effect at all, but its effect is more limited when responsibility and self-esteem are controlled for. This finding is consistent with the Job Demands-Resources model (Demerouti et al., 2001), which indicates that high job demands are associated with increased levels of depression in individuals. Considering all these results together, it can be said that procrastination in working individuals is particularly associated with low conscientiousness and low self-esteem, while stress, anxiety, and depression are less prominent. The study has some limitations. Firstly, the fact that the participants consisted of individuals living and working in only two cities reduces the generalizability of the results. Furthermore, using longitudinal designs in similar research, examining the change in procrastination over time, comparing individuals working in different sectors, and seeing the interaction with personality traits more clearly would be beneficial. From an application perspective, it is recommended that organizations, instead of focusing solely on interventions that reduce stressors to prevent procrastination, should also implement policies that increase conscientiousness and support self-esteem.

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THE HEXACO MODEL OF PERSONALITY AND DARK TETRAD RELATIONSHIP IN EMPLOYEES

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ABSTRACT

In business, Dark Tetrad structures are often associated with maladaptive organizational outcomes such as counterproductive behaviors, low job performance, interpersonal conflicts, and bullying. However, it has been reported that psychopathy can also lead to success in business under certain circumstances, in the context of various personality traits such as courage and conscientiousness. This study aimed to examine the personality traits of employees based on their Dark Tetrad structures using the HEXACO personality model. A total of 232 employees, 147 female (63.4%) and 85 male (36.6%), participated in the study online via a web-based application. Participants completed the long-form HEXACO (Honesty-Humility, Emotionality, Extraversion, Agreeableness, Conscientiousness, Openness to Experience) Personality Inventory (HEXACO) and the Dark Tetrad Scale. The total scores for the Dark Tetrad constructs (Machiavellianism, Narcissism, Psychopathy, and Sadism) were cut off at one standard deviation below and one standard deviation above the mean to create three groups. These three groups were then compared using a MANOVA for their total personality factor scores. Statistically significant differences were found between the Machiavellianism groups for total Honesty-Humility, Emotionality, Agreeableness, and Conscientiousness factor scores, and similarly between the Narcissism, Psychopathy, and Sadism groups for total Honesty-Humility, Emotionality, Agreeableness, and Agreeableness factor scores. When the differences were examined, it was found that the high Machiavellianism, Narcissism, Psychopathy, and Sadism groups had lower total Honesty-Humility, Emotionality, Agreeableness, and Conscientiousness factor scores. No differences were observed between the Dark Tetrad groups for the Extraversion and Openness to Experience factors. The findings revealed the importance of the factors as structures of the HEXACO personality model in terms of the dark tetrad structures in employees.

Keywords: *Dark Tetrad, Personality, HEXACO, Employee.*

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1. INTRODUCTION

Machiavellianism and high Machiavellian traits, which are part of the dark tetrad structures, are seen as significant in the workplace due to their tendency to prioritize personal interests and disregard others (Jones, 2016; Jones and Paulhus, 2009). Individuals with Machiavellian traits are more prone to exhibiting negative workplace behaviors, including low job performance, low productivity, and counterproductive behaviors (O'Boyle et al., 2012). In its simplest form, employees with high Machiavellian traits pose a potential risk to the organization when a choice or sacrifice must be made between personal interests and organizational interests (Jones, 2016). Due to their authoritarian and results-oriented thinking styles, employees with high Machiavellian traits have the potential to exhibit unethical behavior and contribute to the creation of a work environment where ethical constraints are unclear or insufficient (Jones, 2016; Vladu, 2013). The negative effects of employees with Machiavellian traits being perceived as abusive in interpersonal relationships also negatively impact the work environment (Kiazad et al., 2010). Similarly, employees with high Machiavellian traits tend to engage in more and more unethical behaviors, such as engaging in irregularities to gain financial profit, but they also feel less responsibility and guilt because they rationalize their actions (Murphy, 2012). Furthermore, these traits and behaviors of employees with high Machiavellian characteristics can even be considered advantageous, or even beneficial, in poorly structured organizations where rules are few and flexible, managerial control is insufficient or low, and decision-making is intensive (Jones and Paulhus, 2009). Another dark tetrad structure, psychopathy, is similarly associated with negative workplace environments and counterproductive behaviors such as interpersonal conflict, psychological harassment, and poor job performance (Boddy, 2011; O'Boyle et al., 2012). However, due to its high dominance and courage or low stress and anxiety, similar to Machiavellianism, it is considered that employees with high psychopathic traits may also have an advantage in achieving success in some environments and conditions (Lilienfeld et al., 2012; Scott, 2014; Skemm et al., 2011). However, it is observed that the traits possessed by individuals with high levels of psychopathy do not contribute to life success in general, such as status, wealth, and successful close relationships, and are not related to life success in this context (Benning et al., 2018; Ullrich et al., 2008). On the contrary, emotional inadequacy, impulsivity, and persistent antisocial behaviors have been associated with life failure (Ullrich et al., 2008).

The relationships between dark triad personality traits and personality traits within the framework of the Five-Factor Personality Model and the HEXACO Model have been examined in many studies, but different and inconsistent results have been observed (Book et al., 2015; DeShong et al., 2015; Lyons, 2019; Muris et al., 2017; O'Boyle et al., 2015; Vize et al., 2018). Within this framework, it has been observed that dark triad personality traits show a consistent inverse relationship with the

agreeableness factor (Jakobwitz and Egan, 2006; Paulhus and Williams, 2002), but the strength of the relationship showed a difference in level in the HEXACO Model and the Five-Factor Model (Dinić and Wertag, 2018; Howard and van Zandt, 2020; Oda and Matsumoto-Oda, 2022). On the other hand, it has been observed that the dark triad personality traits are clearly negatively correlated with the honesty-humility factor, which is not included in the Five-Factor Model but is included in the HEXACO Model, and that the honesty-humility factor predicts dark personality traits at a good level (Book et al., 2015; Hodson et al., 2018; Howard and van Zandt, 2020; Lee et al., 2013; Lee and Ashton, 2014; Muris et al., 2017).

Due to its older model, the dark triad personality traits appear to have been addressed in more studies than the dark tetrad personality traits. Although the results obtained in studies show similarities because the dark tetrad personality traits encompass dark triad structures, the structural differences between the dark triad and tetrad structures are also reflected in the relationship results with other variables. Considering the importance of the dark tetrad personality traits in both the work environment and personal life, this study aims to examine the relationships between dark tetrad personality traits and the HEXACO Personality Model in individuals working in income-generating jobs.

2. METHODOLOGY

Participants

The study included a total of 232 people employed in income-generating work, aged 18-65 (mean = 31.06; s = 11.42), comprising 147 women (63.4%) and 85 men (36.6%). Educational background was as follows, 11 primary school graduates (4.7%), 7 middle school graduates (3.0%), 59 high school graduates (25.4%), and 155 university graduates (66.8%). Marital status was as follows: 145 single (62.5%), 68 married (29.3%), 3 widowed (1.3%), and 14 divorced (6.0%) (2 individuals did not specify their marital status (0.9%)). The income levels of the employees were found to be as follows: 20 (8.6%) low, 174 (75.0%) medium, and 37 (15.9%) good (1 employee (0.4%) did not specify their income level).

Materials

Participants completed the long-form HEXACO Personality Inventory (HEXACO-100-Tr), the Dark Tetrad Scale (K4), and a questionnaire.

The HEXACO Personality Inventory consists of 100 items, 50 of which are reverse-oriented, scored on a five-point Likert scale. The inventory is assessed using six factors: Honesty-Humility, Emotionality, Extraversion, Agreeableness, Conscientiousness, and Openness to Experience, each containing 16 items and four second-level sub-dimensions (Tatar, 2018). The Dark Tetrad Scale is a measurement tool that assesses four sub-dimensions: Machiavellianism, Narcissism, Psychopathy, and Sadism, each containing 10 items. The scale, which does not contain any reversed items, includes five-

point Likert-type response options (Bekiroğlu et al., 2025).

Application

The study was conducted online in 2025 with individuals working in a job that generates income through a web-based application.

Data Analysis

In the study, the HEXACO personality scores of the groups formed according to the four dark structures were compared using MANOVA based on the HEXACO personality model.

Results

First, internal consistency and reliability analyses of the measurement instruments used in the study were performed, and it was determined that the Dark Tetrad Scale structures showed coefficients between 0.68 (Narcissism) and 0.85 (Machiavellianism), and the HEXACO Personality Inventory factors showed coefficients between 0.68 (Emotionality) and 0.80 (Honesty-Humility). Then, descriptive statistics of the total scores of the measurement instruments were performed (Table 1), and three groups were formed using the mean and standard deviation values of the Dark Tetrad Scale structures (by cutting one standard deviation below and above the mean).

Table 1. Internal Consistency and Reliability Analyses and Descriptive Statistics of the Measurement Instruments Used

Scales (n = 232)	Sub-dimensions / Factors	Cronbach Alpha	Min.	Max.	M	s
Dark Tetrad	Machiavellianism	0.85	10	48	24.64	7.99
	Narcissism	0.82	12	50	33.06	7.05
	Psychopathy	0.68	11	43	25.81	5.88
	Sadism	0.82	10	39	16.95	6.05
HEXACO	Honesty-Humility	0.80	1.31	4.81	3.39	0.64
	Emotionality	0.68	1.56	4.31	3.25	0.51
	Extraversion	0.81	1.25	5.00	3.38	0.59
	Agreeableness	0.72	1.25	4.06	2.73	0.53
	Conscientiousness	0.75	2.19	5.00	3.50	0.56
	Openness to Experience	0.77	1.81	4.75	3.42	0.60

Three groups were created for each of the Dark Tetrad Scale constructs, and these were then compared using MANOVA in terms of the total factor scores of the HEXACO Personality Inventory.

Table 2. MANOVA Comparison Results of the Total Factor Scores of the HEXACO Personality Inventory for Machiavellianism Groups

HEXACO	Machiavellianism Groups	n	M	s	$F_{(2, 229)}$	p	Partial η^2
Honesty-Humility	Lower Group	37	3.89	0.54	55.96	0.000	0.328
	Middle Group	158	3.45	0.51			
	Upper Group	37	2.64	0.59			
	Total	232	3.39	0.64			
Emotionality	Lower Group	37	3.38	0.52	1.86	0.158	0.016
	Middle Group	158	3.24	0.51			
	Upper Group	37	3.15	0.52			
	Total	232	3.25	0.52			
Extraversion	Lower Group	37	3.43	0.65	0.14	0.870	0.001
	Middle Group	158	3.37	0.56			
	Upper Group	37	3.37	0.71			
	Total	232	3.38	0.60			
Agreeableness	Lower Group	37	3.03	0.49	14.82	0.000	0.115
	Middle Group	158	2.73	0.48			
	Upper Group	37	2.40	0.58			
	Total	232	2.73	0.53			
Conscientiousness	Lower Group	37	3.70	0.62	3.29	0.039	0.028
	Middle Group	158	3.48	0.53			
	Upper Group	37	3.39	0.55			
	Total	232	3.50	0.56			
Openness to Experience	Lower Group	37	3.58	0.62	1.71	0.183	0.015
	Middle Group	158	3.38	0.57			
	Upper Group	37	3.45	0.67			
	Total	232	3.42	0.60			

According to the comparison results of Machiavellianism groups (lower, middle, upper group) in terms of HEXACO Personality Inventory factor total scores using MANOVA, there are statistically significant differences between the three groups in the mean factor total scores of Honesty-Humility ($F(2, 229) = 55.96$; $p < 0.001$), Agreeableness ($F(2, 229) = 14.82$; $p < 0.001$) and Conscientiousness ($F(2, 229) = 3.29$; $p < 0.05$). According to the Tukey multiple comparison test results, there are statistically significant differences among all three Machiavellianism groups in the factors of Honesty-Humility, Agreeableness, and Conscientiousness. In all three factors, the mean total score of the upper group is lower, while the mean total score of the lower group is higher than the other groups (Table 2).

Table 3. MANOVA Comparison Results of the Total Factor Scores of the HEXACO Personality Inventory for Narcissism Groups

HEXACO	Narcissism Groups	n	M	s	$F_{(2, 229)}$	p	Partial η^2
Honesty-Humility	Lower Group	40	3.69	0.60	15.31	0.000	0.118
	Middle Group	161	3.40	0.55			
	Upper Group	31	2.90	0.80			
	Total	232	3.39	0.64			
Emotionality	Lower Group	40	3.32	0.51	0.58	0.563	0.005
	Middle Group	161	3.22	0.51			
	Upper Group	31	3.28	0.56			
	Total	232	3.25	0.52			
Extraversion	Lower Group	40	2.90	0.64	27.89	0.000	0.196
	Middle Group	161	3.40	0.51			
	Upper Group	31	3.85	0.50			
	Total	232	3.38	0.60			
Agreeableness	Lower Group	40	3.05	0.38	12.15	0.000	0.096
	Middle Group	161	2.69	0.53			
	Upper Group	31	2.48	0.49			
	Total	232	2.73	0.53			
Conscientiousness	Lower Group	40	3.41	0.54	1.11	0.332	0.010
	Middle Group	161	3.50	0.53			
	Upper Group	31	3.60	0.68			
	Total	232	3.50	0.56			
Openness to Experience	Lower Group	40	3.28	0.56	2.67	0.072	0.023
	Middle Group	161	3.42	0.56			
	Upper Group	31	3.60	0.76			
	Total	232	3.42	0.60			

According to the MANOVA comparison results of the total scores of the HEXACO Personality Inventory factors of the narcissism groups (lower, middle, upper groups), there are statistically significant differences between the three groups in the mean total scores of the Honesty-Humility ($F(2, 229) = 15.31$; $p < 0.001$), Extraversion ($F(2, 229) = 27.89$; $p < 0.001$) and Agreeableness ($F(2, 229) = 12.15$; $p < 0.001$) factors. According to the Tukey multiple comparison test result, the mean total score of the Honesty-Humility factor of the upper group, according to the narcissism score, is lower than the mean total scores of the middle and lower groups. According to the Tukey multiple comparison test result for the Agreeableness factor, the mean total score of the Agreeableness factor of the lower group is higher than the mean total scores of the middle and upper groups. According to the Tukey multiple comparison test results for the extraversion factor, there are statistically significant differences among all three narcissism groups, with the upper group having a higher mean total score and the lower group having a lower mean total score than the other groups (Table 3).

Table 4. MANOVA Comparison Results of the Total Factor Scores of the HEXACO Personality Inventory for Psychopathy Groups

HEXACO	Psychopathy Groups	n	M	s	$F_{(2, 229)}$	p	Partial η^2
Honesty-Humility	Lower Group	33	3.73	0.57	7.57	0.001	0.062
	Middle Group	159	3.37	0.62			
	Upper Group	40	3.16	0.67			
	Total	232	3.39	0.64			
Emotionality	Lower Group	33	3.52	0.50	7.65	0.001	0.063
	Middle Group	159	3.24	0.50			
	Upper Group	40	3.06	0.51			
	Total	232	3.25	0.52			
Extraversion	Lower Group	33	3.55	0.59	1.70	0.185	0.015
	Middle Group	159	3.34	0.60			
	Upper Group	40	3.38	0.58			
	Total	232	3.38	0.60			
Agreeableness	Lower Group	33	2.99	0.48	9.87	0.000	0.079
	Middle Group	159	2.74	0.49			
	Upper Group	40	2.47	0.58			
	Total	232	2.73	0.53			
Conscientiousness	Lower Group	33	3.69	0.48	4.30	0.015	0.036
	Middle Group	159	3.51	0.56			
	Upper Group	40	3.31	0.57			
	Total	232	3.50	0.56			
Openness to Experience	Lower Group	33	3.57	0.62	1.21	0.301	0.010
	Middle Group	159	3.40	0.56			
	Upper Group	40	3.37	0.69			
	Total	232	3.42	0.60			

According to the MANOVA comparison results of the total factor scores of the HEXACO Personality Inventory for the psychopathy groups (lower, middle, upper group), there is a statistically significant difference between the three groups in the mean total scores of the factors Honesty-Humility ($F(2, 229) = 7.57$; $p < 0.01$), Emotionality ($F(2, 229) = 7.65$; $p < 0.01$), Agreeableness ($F(2, 229) = 9.87$; $p < 0.001$) and Conscientiousness ($F(2, 229) = 4.30$; $p < 0.05$). According to the Tukey multiple comparison test result, the mean total scores of the Honesty-Humility and Emotionality factors of the lower group, according to the psychopathy score, are higher than the mean total scores of the middle and upper groups. According to the Tukey multiple comparison test results for the Agreeableness and Conscientiousness factors, there are statistically significant differences among all three psychopathy groups, with the upper group having a lower mean total score and the lower group having a higher mean total score than the other groups (Table 4).

Table 5. MANOVA Comparison Results of the Total Factor Scores of the HEXACO Personality Inventory for Sadism Groups

HEXACO	Sadism Groups	n	M	s	$F_{(2, 229)}$	p	Partial η^2
Honesty-Humility	Lower Group	25	3.85	0.47	23.72	0.000	0.172
	Middle Group	164	3.44	0.57			
	Upper Group	43	2.90	0.68			
	Total	232	3.39	0.64			
Emotionality	Lower Group	25	3.39	0.49	10.24	0.000	0.082
	Middle Group	164	3.31	0.49			
	Upper Group	43	2.94	0.53			
	Total	232	3.25	0.52			
Extraversion	Lower Group	25	3.60	0.64	2.56	0.080	0.022
	Middle Group	164	3.33	0.59			
	Upper Group	43	3.43	0.56			
	Total	232	3.38	0.60			
Agreeableness	Lower Group	25	2.93	0.56	7.89	0.000	0.064
	Middle Group	164	2.76	0.48			
	Upper Group	43	2.47	0.61			
	Total	232	2.73	0.53			
Conscientiousness	Lower Group	25	3.80	0.65	9.58	0.000	0.077
	Middle Group	164	3.52	0.50			
	Upper Group	43	3.23	0.58			
	Total	232	3.50	0.56			
Openness to Experience	Lower Group	25	3.77	0.64	5.08	0.007	0.042
	Middle Group	164	3.38	0.55			
	Upper Group	43	3.38	0.69			
	Total	232	3.42	0.60			

According to the MANOVA comparison results of the HEXACO Personality Inventory factor total scores of the sadism groups (lower, middle, upper group), there are statistically significant differences between the three groups in the mean factor total scores of Honesty-Humility ($F(2, 229) = 23.72$; $p < 0.001$), Emotionality ($F(2, 229) = 10.24$; $p < 0.001$), Agreeableness ($F(2, 229) = 7.89$; $p < 0.001$), Conscientiousness ($F(2, 229) = 9.58$; $p < 0.001$) and Openness to Experience ($F(2, 229) = 5.08$; $p < 0.01$). According to the Tukey multiple comparison test results for the Honesty-Humility and Conscientiousness factors, there are statistically significant differences among all three sadism groups, with the upper group having a lower overall mean score and the lower group having a higher overall mean score than the other groups. According to the Tukey multiple comparison test results, the upper group's overall mean scores for the Emotionality and Agreeableness factors are lower than the overall mean scores of the middle and lower groups, relative to their sadism scores. However, according to the Tukey multiple comparison test results for the Openness to Experience factor, the lower group's overall mean score for the Openness to Experience factor is higher than the overall mean scores of the middle and upper groups (Table 5).

3. CONCLUSION

In recent years, studies on dark personality traits within the context of personality theories have gained momentum, and the dark tetrad model, which includes sadism-a tendency to derive pleasure from harming individuals-has been added to the dark triad (Machiavellianism, narcissism, and psychopathy) model, establishing itself as a unique structure in the literature (Buckels et al., 2013; Chabrol et al., 2009; Paulhus et al., 2021a). The four different dark structures created with the addition of sadism have been associated with various maladaptive organizational outcomes in the workplace and have served as models for evaluating social adjustment and functionality in different fields such as personality psychology, industrial psychology, and organizational psychology (Paulhus et al., 2021a). In this study, the aim was to compare the personality traits of three groups of employees, formed according to their dark tetrad structures, within the scope of the HEXACO Personality Model. The results showed that the dark tetrad structures created statistically significant differences on the six factors related to personality. This situation, consistent with the theoretical foundations of the dark tetrad, demonstrates that individuals' adherence to critical organizational characteristics such as honesty, agreeableness, conscientiousness, and emotionality is a decisive factor.

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MONETARY POLICY, INFLATION, AND INCOME INEQUALITY IN TURKEY[1]

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ABSTRACT

The interaction between monetary policy, inflation, and income inequality has become an increasingly salient issue in both theoretical and empirical economics. Although monetary policy is primarily designed to maintain price stability and promote sustainable growth, its distributional consequences have gained notable attention, especially after the global financial crisis. Through channels such as interest rates, credit access, asset prices, and employment, monetary policy may influence the allocation of income and wealth across different groups, thereby shaping inequality patterns within an economy.

In emerging economies like Turkey, where inflationary pressures are persistent and financial markets are relatively shallow, these effects are often magnified. Since the early 2000s, Turkey has experienced alternating periods of monetary tightening and loosening, frequent exchange rate fluctuations, and prolonged inflation episodes. These dynamics have had uneven impacts across income groups, raising important questions about how monetary instruments affect social equity alongside macroeconomic outcomes.

High and volatile inflation has been shown to erode real incomes disproportionately, particularly among low-income households that lack financial hedging mechanisms. Meanwhile, expansionary monetary policies, despite their short-term benefits for output and employment, can increase inequality through asset price inflation and credit-based gains that favor wealthier households. The Turkish experience illustrates both dimensions of this trade-off, making it a compelling case to examine how price stability and income distribution interact under different monetary regimes.

This paper aims to analyze the relationship between monetary policy, inflation, and income inequality in Turkey by employing an empirical framework that combines indicators of monetary stance, inflation trends, and inequality measures. The study contributes to the growing literature on the distributive effects of monetary policy, emphasizing the need for a policy mix that ensures not only macroeconomic stability but also social inclusiveness in a structurally volatile economy like Turkey.

Keywords: *Monetary Policy, Inflation, Income Inequality, Emerging Markets, Game Theory, Nash*

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equilibrium, Turkey.

JEL Codes: *E52, E31, D31.*

1. INTRODUCTION

1.1 Macroeconomic Context

Turkey faces simultaneous high inflation and rising income inequality, with an annual CPI inflation rate of 32.87% (October 2025) and a policy interest rate of 39.5%—one of the highest real interest rates globally (TCMB, 2025). The Gini coefficient rose from 0.397 in 2014 to 0.433 in 2023, indicating a 9.1% deterioration (TÜİK, 2024). Real wages have declined 11.8% since 2019, while food inflation reached 48%, severely impacting low-income households allocating 45% of their consumption basket to food (TÜİK, 2024). The data reveal that monetary policy tools used to combat inflation have negatively affected income distribution, initiating a process detrimental to the middle class.

Figure 1. Turkey 2014-2025 Data

Economic Indicator	2014 Value	2025 Value	Change
CPI Inflation	11.0%	32.87%	+21.87 pp (Furceri et al., 2025)
Policy Rate	5.0%	39.5%	+34.5 pp (CBRT, 2025)
Gini Coefficient	0.397	0.433	+0.036 (World Bank, 2025)
Real Wage Index	100.0	88.2	-11.8% (TÜİK, 2024)

This configuration renders the role of monetary policy in exacerbating inequality more pronounced (Stiglitz, 2015). Raising the policy rate impacts the money supply and velocity of circulation in the market. The resulting slowdown in economic activity first affects Ponzi firms and subsequently small- and medium-sized enterprises with high financial fragility (Minsky, 1992, p. 74). Such firms are particularly significant in terms of employment data. Micro-sociological analyses indicate that employment exerts a negative effect on household happiness and confidence in the future (Kitapçı, 2019, p. 145).

1.2 Research Objectives

Central research question: How do the strategic interactions between the Central Bank of Turkey (CBRT) and economic actors, modeled through game theory, generate the distributional outcomes of monetary policy in Turkey?

(1) Identify transmission channels (Acemoglu and Robinson, 2013);

(2) Estimate effects using vector autoregression (VAR) models (Furceri et al., 2016); (3) Derive policy reforms that internalize distributional costs (Kaplan et al., 2018).

1.3 Literature Positioning

Empirical studies confirm the inequality effects of monetary tightening. Furceri et al. (2016) document that a 100 basis point interest rate hike raises the Gini coefficient by 1.25-2.25 points across 100+ countries, with financial frictions amplifying this in emerging markets. Furceri et al. (2025) emphasize expectation channels in high-inflation environments. Stiglitz (2015) argues that monetary policy is inherently redistributive, favoring asset holders over wage earners. Game-theoretic foundations trace to Kydland and Prescott (1977), extended to distributional contexts by Barro and Gordon (1983).

Turkey's uniqueness stems from policy volatility (interest rates from 5% to 50%) and institutional fluctuations (4 CBRT governors since 2019) (CBRT, 2025).

2. THEORETICAL FRAMEWORK: DISTRIBUTIONAL CHANNELS OF MONETARY POLICY

2.1 Interest Rate Channel

Monetary tightening exerts asymmetric effects on households based on their net financial positions. Low-income households, burdened with high debt and limited assets, confront rising borrowing costs without offsetting deposit income (Kaplan et al., 2018). High-income households, by contrast, benefit from interest income on financial wealth.

Household income change formula:

$$\Delta Y_i = (r_1 - r_0)W_i^f - (r_1 - r_0)D_i - \gamma(r_1 - r_0) \quad (1)$$

W_i^f Financial wealth, D_i debt, and $\gamma > 0$ employment loss. In Turkey (during 2019-2023 tightening), real wages declined by 22% in low- and middle-income groups, compared to 9% in the upper-income group (TÜİK, 2024).

2.2 Credit and Asset Price Channels

Expansionary policy (2008-2013: rates from 25% to 5%) led to asset overvaluation: Istanbul real estate +280%, BIST 100 +150% (CBRT, 2025). Gains concentrated in the top 10% decile (60% of real estate, 75% of equities), yet Gini rose from 0.397 to 0.405 despite credit growth (World Bank, 2025).

2.3 Inflation Heterogeneity

Due to differences in consumption baskets, perceived inflation for low- and middle-income groups stands at 38% (45% food weight), versus 22% for the upper-income group (TURKSTAT, 2024).

Building on empirical evidence of 2-3% annual real income transfers, the game-theoretic framework will conduct expected utility analysis (Stiglitz, 2019).

3. GAME-THEORETIC MODEL

3.1 Stackelberg Structure

The TCMB (leader) r_t sets the policy rate; actors (followers) π_t^g and w_t respond with wage and price adjustments (Kydland and Prescott, 1977).

TCMB utility function:

$$U_{CB} = -\alpha(\pi_t - \pi^*)^2 - \beta(u_t - u_n)^2 - \gamma(Gini_t - Gini^*)^2 \quad (2)$$

Worker utility: $U_L = w_t - \pi_t^e + \theta u_t$ ($\theta < 0$). Nash equilibrium for $\gamma \approx 0$ gives $r^* \approx$ 39.5, $\pi^e = 31.2$, Gini = 0.433

Counterfactual ($\gamma = 0.5$): $r^{**} = 28.0$, Gini = 0.410

Figure 2. Payoff List

Parameter	Calibrated Value	Source
α	2.0	TCMB mandate (TCMB, 2025)
β	0.48	VAR estimates
γ	0.05	Estimated

3.2 Time Inconsistency

Discretionary policy exposes the economy to the trap of surprise inflation, leading to a loss of credibility (Barro and Gordon, 1983). In Turkey, the deviation of actual inflation of 32.87% from the 5% target illustrates this time-inconsistency problem (TCMB, 2025)

4. EMPIRICAL ANALYSI SIMAGE.JPG

4.1 Method

For the VAR model ($2001Q1$–$2025Q3$; $Furcerietal.$,2016), the vector is defined as

$$Z_t = [r_t, \pi_t, u_t, w_t, Gini_t]'. \quad (3)$$

The Cholesky ordering is: $r_t \rightarrow \pi_t \rightarrow u_t \rightarrow w_t \rightarrow Gini_t$. Johansen cointegration tests confirm long-run relationships among the variables (TÜİK, 2024).

4.2 Findings

Figure 3. The Table of the Findings Obtained[2]

Quarter	ΔInflation	ΔGini	ΔWages
0	**0.0**	**0.0**	**0.0**
2	**-0.2**	**+0.018**	**-2.1**
6	**-1.8**	**+0.021**	**-2.3**

From a game-theoretic perspective, the 100-basis-point interest rate shock clearly generates a regressive pattern: starting from the second quarter, inflation declines, while the Gini coefficient rises and real wages fall sharply. This suggests that in the Stackelberg structure where the TCMB is the leader and wage setters and firms are followers, the leader's loss function does not sufficiently internalize distributional costs. Although disinflation appears to increase social welfare along one branch of the game tree, the simultaneous welfare loss through wages and the increase in the Gini coefficient imply that the resulting equilibrium is a Nash equilibrium that is tilted against the middle class. In other words, the equilibrium is *inflation-efficient* but *inequality-inefficient*, reflecting a strategic trade-off that systematically favors creditors and asset holders over wage earners. This misalignment between the social planner's ideal outcome and the actual equilibrium under discretionary policy highlights the need to redesign the game so that distributional considerations enter the objective function of the monetary authority. Therefore, close and well-designed coordination with social policy becomes critically necessary to cushion the regressive distributional impact of monetary tightening and to prevent the burden of adjustment from falling disproportionately on lower- and middle-income households.

The persistent rise in the Gini coefficient and the sustained decline in wages in the second and sixth quarters indicate that monetary tightening triggers a long-lasting deterioration in income distribution in exchange for a temporary gain in price stability. Within this framework, the interest rate is not merely a policy instrument that closes the inflation gap in a standard Taylor-rule sense; it also operates as a *distributional strategy variable* that recalibrates strategic interactions in wage bargaining, employment, and debt dynamics. Consequently, redesigning the game would require explicitly incorporating Gini or real wage components into the TCMB's objective function, moving toward a "distribution-augmented" targeting regime. In such a framework, the central bank would minimize not

[2] Granger Causality: r_t Granger-causes the Gini coefficient ($\chi^2 = 24.7, p < 0.001$).
Impulse Responses (100 basis point shock)

only deviations of inflation from its target, but also deviations of inequality or real wages from socially acceptable thresholds. This would transform distributional outcomes from being a by-product of monetary policy into an explicit constraint that shapes optimal interest-rate decisions.

5. CONCLUSION

In line with the findings of the literature, the two main hypotheses examined in this study are as follows: monetary policy deepens inequality through multiple channels, and this is confirmed both empirically and theoretically (Furceri et al., 2025; Kydland and Prescott, 1977). Coordinated reforms reconcile the goals of stability and fairness (Stiglitz, 2015). The game-theoretic analysis shows that sudden increases in the policy rate generate heterogeneous interaction effects across different income groups, with the burden disproportionately falling on lower and middle incomes.

Wage earners (around 60% of the population) bear the main adjustment burden due to sticky nominal wages. Young households, in terms of savings capacity and intergenerational transfers, are confronted with heightened inequality. Rural areas, as the sociological regions where intergenerational transfer of savings is most prevalent, are exposed to the most damaging effects of high and persistent inflation on real wealth.

In light of these findings, it is proposed that the TCMB's policy objectives should prioritize price stability, employment, and financial stability, and that these goals should be monitored separately for different income groups. Differentiated income tax schedules, KDV rates, and regionally targeted positive discrimination in transfer spending emerge as additional issues that need to be considered. Finally, regionally differentiated minimum wages and feasible income-enhancing policies for fixed-income groups, supported by socially targeted assistance programs coordinated with monetary policy, are among the key policy implications of the analysis.

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THE EFFECT OF REAL EXCHANGE RATE CHANGES ON TRADE BALANCE: A NARDL APPROACH

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ABSTRACT

This study explores how fluctuations in the real exchange rate influence Türkiye's manufacturing trade balance with Germany over the period 2013:01–2025:07, with a particular focus on potential asymmetries in these adjustments. Using monthly observations, the analysis applies both conventional ARDL and nonlinear ARDL (NARDL) models to capture differences in the trade balance response to real appreciations and depreciations. While the linear model does not suggest a meaningful long-run linkage between the real exchange rate and the trade balance, the nonlinear estimates tell a different story: real depreciation leads to a noticeable improvement in the trade balance in both the short and long run, whereas real appreciation does not generate a statistically significant reaction. The empirical evidence thus underscores that trade flows adjust in an asymmetric manner to exchange rate movements, highlighting the value of nonlinear specifications in assessing exchange rate–trade balance dynamics.

Key Words: *Real Exchange Rate, Trade Balance, Asymmetry, ARDL, NARDL, Türkiye, Germany*

Jel Codes:

1. INTRODUCTION

Quantifying how real exchange rate movements shape the trade balance is particularly important for developing economies, and Türkiye is no exception. Despite this relevance, empirical evidence in the literature remains mixed. The early theoretical foundation—known as the Marshall–Lerner (ML) condition (Marshall, 1923; Lerner, 1946)—suggests that a currency depreciation will enhance the trade balance if the sum of export and import elasticities exceeds one. Numerous studies, including those by Arize (1990), Bahmani-Oskooee (1985, 1991), and Goldstein and Khan (1978), have attempted to estimate these elasticities in various contexts. Magee (1973), however, critiqued the static nature of the ML framework by emphasizing that the effects of depreciation often unfold gradually: the trade balance may deteriorate in the short run before improving over time.

Empirical research has traditionally relied on the assumption that exchange rate movements exert identical effects regardless of the direction of change. Yet, such linear formulations may overlook important behavioral and structural features—such as adjustment frictions, market rigidities, and policy-driven distortions—that can produce asymmetric responses (Shin et al., 2014). In this regard, Bahmani-

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Oskooee and Fariditavana (2015, 2016) emphasize that nonlinear specifications often uncover meaningful relationships that remain hidden under symmetric modeling frameworks.

Against this backdrop, the present study narrows its attention to manufacturing trade between Türkiye and Germany—both to minimize potential aggregation bias and because manufacturing constitutes Türkiye's core export industry. The analysis employs monthly data spanning January 2013 to July 2025. Since evaluating the J-curve mechanism requires distinguishing short-term adjustments from long-run equilibrium effects, the empirical strategy begins with the Autoregressive Distributed Lag (ARDL) model introduced by Pesaran and Shin (1999). To capture potential nonlinear reactions to exchange rate movements, the framework is subsequently extended into a Nonlinear ARDL (NARDL) form by decomposing real exchange rate changes into positive and negative partial sums. By focusing on Türkiye's most prominent tradable sector and its principal European trading partner, this study adds sector-specific insight to the existing literature. The empirical findings offer fresh evidence that real exchange rate movements influence the trade balance in an asymmetric manner. Although the conventional J-curve pattern does not emerge, the results show that real depreciation enhances the trade balance in both the short and long run. These outcomes carry important implications for policymakers designing exchange rate and external trade strategies.

The structure of the study is organized as follows. Section 2 provides an overview of the existing research in this field. Section 3 details the methodological framework and empirical model employed in the analysis. Section 4 reports the findings and offers an interpretation of the results. Finally, Section 5 summarizes the main conclusions and discusses their implications for economic policy.

2. LITERATURE REVIEW

The earliest empirical investigation in this line of research was carried out by Bahmani-Oskooee (1985), who applied the Almon lag methodology to assess the dynamic effects. A few years later, Rose and Yellen (1989) introduced a different viewpoint by employing cointegration techniques, thereby broadening the methodological scope of the literature.

Rose and Yellen (1989), however, raised two key criticisms regarding earlier contributions. They noted that such studies were forced to construct proxies for the "rest of the world," and they were also vulnerable to aggregation bias. To address these issues, they advocated the use of bilateral trade balance data. Following their argument, many subsequent papers adopted disaggregated datasets, including bilateral analyses in works such as Bahmani-Oskooee and Brooks (1999), Wilson (2001), Baharumshah (2001), and Bahmani-Oskooee and Kanitpong (2001), among others. Later research pushed the disaggregation even further by examining trade flows at the industry level—for example, Baek (2007), Ardalani and Bahmani-Oskooee (2007) and Bahmani-Oskooee and Hegerty (2011).

A more recent branch of the literature examines whether exchange rate movements exert

asymmetric influences on trade flows. Bahmani-Oskooee and Fariditavana (2015, 2016) argue that depreciation and appreciation do not generate mirror-image effects, leading them to formalize the notion of an asymmetric J-curve. Building on this idea, a growing body of research applies nonlinear modeling techniques to uncover such asymmetries. Studies such as Bahmani-Oskooee et al. (2016), Bahmani-Oskooee and Kanitpong (2017) and Bahmani-Oskooee et al. (2022) analyze trade dynamics using nonlinear approaches to identify the presence of an asymmetry.

A substantial literature also examines Türkiye's case; however, the empirical findings are far from uniform. Early contributions typically rely on aggregated trade data. One of the first cross-country analyses, Rose (1990), investigated the link between exchange rates and trade balances for several developing economies—including Türkiye—using aggregate annual data from 1970 to 1988. The study did not uncover a consistent or statistically meaningful relationship. Similarly, Bahmani-Oskooee and Malixi (1992) employed aggregated data and an Almon lag structure for a group of developing countries over 1973–1985. While they observed evidence in some economies, they found no such support for Türkiye.

Later work employing cointegration-based approaches produced more differentiated findings. Some studies reported that real depreciation supports the trade balance, while others observed improvements only in certain periods or under specific economic conditions. More recent analyses using VECM and bounds-testing techniques (such as Akbostancı, 2004; Halıcıoğlu, 2008a) generally found short-run adjustments but did not reach consensus regarding long-term effects.

A second group of studies analyzes Türkiye's bilateral trade balances with individual trading partners. Halıcıoğlu (2007) employed a VECM framework for Türkiye and nine partners over 1960–2000 and found only limited long-run effects of real depreciation, as the estimated impulse responses were statistically significant but economically small. In a follow-up study, Halıcıoğlu (2008b) applied the ARDL approach to 13 bilateral relationships between 1985 and 2005 and reported that real depreciation improved the trade balance only for the United States and the United Kingdom.

Overall, empirical studies for Türkiye provide no uniform conclusion, reflecting the complexity of how real exchange rate changes interact with trade dynamics.

3. EMPIRICAL MODEL

Consistent with previous research, the present study concentrates on Türkiye's manufacturing trade balance with Germany and relies on disaggregated data together with a nonlinear empirical framework. The sample spans the period from January 2013 to July 2025. To capture potential asymmetries in the influence of real exchange rate movements on bilateral manufacturing trade, the analysis adopts the reduced-form approach originally proposed by Rose and Yellen (1989), as presented in Equation (1).

$$lnTB_t = a + blnY_{T,t} + clnY_{G,t} + dlnR_t + \varepsilon_t \quad (1)$$

In this study, the trade balance (TB) is measured as the ratio of Türkiye's manufacturing exports (X) to its manufacturing imports (M) from Germany. Using the X/M ratio allows the trade balance to be expressed in logarithmic terms without units, as noted by Bahmani-Oskooee (1991). Economic activity in Türkiye is proxied by YTRYTR, while YGRYGRrepresents economic activity in Germany. Since the dataset is monthly, industrial production indices are employed for both countries. From a theoretical standpoint, the coefficient on YT is expected to be negative because an expansion in domestic economic activity typically raises import demand, thereby weakening the trade balance. In contrast, the coefficient on YGRYGR is anticipated to be positive, as stronger economic conditions in Germany may stimulate Türkiye's manufacturing exports. The real exchange rate is defined as follows:

$$R = \frac{P^G x E_{TL/€}}{P^T} \quad (2)$$

where P^G and P^T is the consumer price indices (CPI) of Germany and Türkiye. $E_{TL/€}$ is the Euro exchange rate and d is expected to be positive.

To examine the short- and long-term effects of the real exchange rate, Equation (1) is estimated within the ARDL framework. The bounds testing methodology introduced by Pesaran and Shin (1999) and further developed by Pesaran et al. (2001) has become a standard tool in empirical time-series analysis for modeling dynamic interactions among variables. A major strength of this approach is that it accommodates regressors integrated of different orders—whether I(0) or I(1)—without requiring pre-testing for a common integration level. By allowing lagged values of both the dependent and explanatory variables, the ARDL structure captures short-run fluctuations alongside potential long-run equilibrium dynamics. In this context, Equation (1) can be reformulated as follows:

$$\Delta lnTB_t = \beta_0 + \sum_{j=1}^{n} \beta_{1j} \Delta lnTB_{t-j} + \sum_{j=0}^{n} \beta_{2j} \Delta lnY_{T,t-j} + \sum_{j=0}^{n} \beta_{3j} \Delta lnY_{G,t-j} + \sum_{j=0}^{n} \beta_{4j} \Delta lnR_{t-j} + \lambda_1 lnTB_{t-1} + \lambda_2 lnY_{T,t-1} + \lambda_3 lnY_{G,t-1} + \lambda_4 lnR_{t-1} + \mu_t \quad (3)$$

Equation (3) represents a framework in which all external variables influence the trade balance in a symmetric manner. Yet, previous research—most notably Bahmani-Oskooee and Fariditavana (2015, 2016)—highlights that exchange rate movements may generate unequal responses depending on their direction. To accommodate such nonlinear behavior, Shin et al. (2014) developed the Nonlinear ARDL (NARDL) approach, which generalizes the traditional ARDL model by introducing asymmetric adjustments. Within this setting, changes in the real exchange rate are separated into two partial-sum processes: one reflecting currency depreciations and the other capturing appreciations, enabling the model to identify potentially distinct effects on the trade balance.

$$R\_POS_t = \sum_{j=1}^{t} \max(\Delta lnR_j, 0),$$
$$R\_NEG_t = \sum_{j=1}^{t} mi\,n(\Delta lnR_j, 0) \quad (4)$$

R_POS_t is the partial sum of positive changes, while R_NEG_t is the partial sum of negative ones. Equation (3) is then rewritten according to these new variables.

$$\Delta lnTB_t = \gamma_0 + \sum_{j=1}^{n1} \gamma_{1j} \Delta lnTB_{t-j} + \sum_{j=0}^{n2} \gamma_{2j} \Delta lnY_{T,t-j} + \sum_{j=0}^{n3} \gamma_{3j} \Delta lnY_{G,t-j} + \sum_{j=0}^{n4} \gamma_{4j} \Delta R\_POS_{t-j} + \sum_{j=0}^{n5} \gamma_{5j} \Delta R\_NEG_{t-j} + \theta_1 lnTB_{t-1} + \theta_2 lnY_{T,t-1} + \theta_3 lnY_{G,t-1} + \theta_4 R\_POS_{t-1} + \theta_5 R\_NEG_{t-1} + \epsilon_t \quad (5)$$

Once Equation (5) is estimated, various types of asymmetry can be assessed. In the short-run context, asymmetry is indicated when the coefficients linked to positive variations in the real exchange rate differ from those associated with negative variations at any lag. Such a discrepancy suggests that the effects of depreciation and appreciation are not identical in the short-term adjustment process.

After estimating Equation (5), it becomes possible to evaluate different forms of asymmetry. In the short run, if the coefficients associated with positive changes (γ_{4j}) are not equal to those of negative changes (γ_{5j}) at any lag, this points to short-run asymmetry between depreciation and appreciation effects.

4. RESULTS

Given that the dataset consists of monthly observations, eliminating seasonal variation is essential to prevent misleading dynamics and to uncover the actual relationships among the variables. Accordingly, the industrial production indices for Türkiye and Germany were seasonally adjusted using the X-13 ARIMA-SEATS procedure.

Before estimating the ARDL or NARDL models, it is essential to verify that none of the variables exhibit integration of order two. To determine the integration properties of the variables, both the Augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) tests are applied. The results, summarized in Table 1, indicate that all variables are stationary at either level or first difference, and none are integrated of order two.

Table 1. Unit Root Test Results

	ADF Unit Root Test		PP Unit Root Test	
	Level	1St difference	Level	1St difference
TB	-2.51 (0.11)	-12.65*** (0.00)	0.45 (0.81)	-21.48*** (0.00)
Y_T	-1.65 (0.69)	-9.89*** (0.00)	-0.90 (0.78)	-19.13*** (0.00)
Y_G	-0.37 (0.55)	-9.49*** (0.00)	-2.89** (0.05)	-14.41*** (0.00)
R	-1.56 (0.50)	-7.44*** (0.00)	-1.48 (0.54)	-9.10*** (0.00)

The appropriate lag structure was selected based on the Akaike Information Criterion (AIC). According to this criterion, the asymmetric trade balance model is best represented by the NARDL(10, 4, 0, 4) specification.

Table 2. **Bounds Test Results for ARDL (10,4,0,4) Model**

$H_0 = \theta_1 = \theta_2 = \theta_3 = \theta_4 = \theta_5$ *(no cointegration)*	**Bounds Critical Values**		
		I(0)	I(1)
k=4	10%	2.45	3.52
Calculated F Statistics: 8.09***	5%	2.86	4.01
	1%	3.74	5.04

***means statistical significance at the 1% level and k is the number of regressors.

Table 2 reports the bounds testing outcomes for the NARDL(10,4,0,4) model. The computed F-statistic of 8.09 is well above the upper critical value at the 1% level, allowing the null hypothesis of no cointegration to be rejected. This result provides evidence that the variables in the NARDL specification share a stable long-run relationship.

Table 3. The Result of Short and Long Run Asymmetries

Variable	**F-statistic**	**Probability**
Ho: $\sum \gamma_{4j} = \sum \gamma_{5j}$ *(Short-run) and* $\theta_4 = \theta_5$ *(Long run)*		
LR (Long-run)	5.6804**	0.0189
LR (Short-run)	9.7667***	0.0023
LR (Joint)	6.3149***	0.0025

***means statistical significance at the 1% level and *** statistical significance at the 5% level.

To assess whether real exchange rate fluctuations influence the trade balance in a symmetric or asymmetric manner, a Wald symmetry test was applied. The outcomes, summarized in Table 3, show that the null hypothesis of equal adjustment coefficients is rejected at the 5% significance level for both short-term dynamics (F = 9.77, p = 0.0023) and long-term effects (F = 5.68, p = 0.0189). Moreover, the joint Wald statistic (F = 6.31, p = 0.0025) leads to the same conclusion, indicating that the adjustment process is inherently asymmetric.

Table 4. Estimated Long and Short Run Results in Asymmetric Model (10,4,0,4)

	Coefficient	**Std. Error**	**t-Statistic**	**Probability**
Dependent Variable: LTB				
Panel A: Long-run Coefficients				
LY_T	-0.92***	0.34	-2.70	0.00
LY_G	1.76***	0.45	3.84	0.00
LR-POS	0.28*	0.15	1.80	0.07
LR-NEG	-0.04	0.21	-0.18	0.85
Panel B: Short-run Coefficients				
Δ *LTB (-1)*	-0.30***	0.08	-3.51	0.00
Δ *LTB (-2)*	-0.14	0.09	-1.61	0.11
Δ *LTB (-3)*	0.03	0.09	0.33	0.73
Δ *LTB (-4)*	0.06	0.08	0.72	0.46
Δ LTB (-5)	0.06	0.08	0.73	0.46
Δ LTB (-6)	0.15*	0.08	1.75	0.08

Δ LTB (-7)	0.27***	0.08	3.16	0.00
Δ LTB (-8)	0.32***	0.08	3.82	0.00
Δ LTB (-9)	0.28***	0.07	3.81	0.00
Δ Y_T	0.09	0.14	0.65	0.51
Δ $Y_T(-1)$	-0.20	0.14	-1.40	0.16
Δ $Y_T(-2)$	-0.04	0.14	-0.30	0.76
Δ $Y_T(-3)$	-0.51***	0.14	-3.57	0.00
Δ *R-POS*	0.89***	0.25	3.44	0.00
Δ *R_POS (-1)*	-0.40	0.27	-1.46	0.14
Δ *R_POS (-2)*	0.34	0.30	1.11	0.26
Δ *R_POS (-3)*	0.32	0.29	1.09	0.27
Δ *R_NEG*	-0.68**	0.32	-2.10	0.03
Δ *R_NEG (-1)*	0.09	0.32	0.30	0.76
Δ *R_NEG (-2)*	-0.45	0.29	-1.54	0.12
Δ *R_NEG (-3)*	-0.58**	0.29	-1.99	0.04
DUM2020	0.06***	0.01	3.70	0.00
C	0.015	0.01	1.25	0.21
ECM	-0.47***	0.07	-6.47	0.00

Panel C: Diagnostic Test Results

	Test Statistics	**Probability**
Serial Correlation (Breusch-Godfrey)	F = 0.76	0.67
Heteroskedasticity (Breusch-Pagan-Godfrey)	F = 0.82	0.70
Model Specification (Ramsey RESET)	F = 1.46	0.23
Normality of Residuals (Jarque-Bera)	JB = 0.17	0.92

***denotes significance at 1%, ** denotes significance at 5% and * denotes significance at 10%

Panel B summarizes the short-run estimates. The first lag of the change in the trade balance, ΔLTB(–1), is negative and strongly significant (–0.30, $p < 0.01$), indicating persistence in short-term adjustments. Türkiye's income variable also displays a negative and significant effect at the third lag (–0.51, $p < 0.01$). Regarding the real exchange rate decomposition, the coefficient on the positive partial sum—representing periods of depreciation is positive and highly significant (0.89, $p < 0.01$), suggesting that a weaker lira improves the trade balance in the short run. Conversely, the coefficient on the negative partial sum, capturing appreciation episodes—is negative and statistically significant.

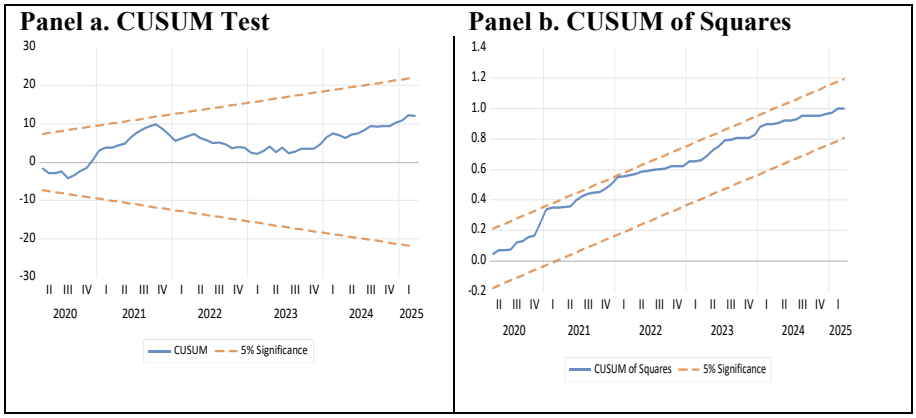
The model also incorporates a COVID-19 dummy variable (DUM2020), which enters with a positive and statistically significant coefficient (0.06, $p < 0.01$). This indicates that the trade balance shifted upward during the pandemic period. The error-correction term (ECM) is negative and highly significant (–0.47 at the 1% level), implying that nearly 47% of deviations from the long-run equilibrium are eliminated within a single month.

Panel A reports the long-run parameter estimates, showing the contributions of each explanatory variable to the trade balance over time. Türkiye's income level (LYT) enters with a negative and highly significant coefficient (–0.92, $p < 0.01$), indicating that higher domestic activity tends to weaken the trade balance, most likely through increased imports. In contrast, Germany's income level (LYG) is associated with a positive and strongly significant coefficient (1.76, $p < 0.01$), suggesting that expansions in Germany's economic activity bolster Türkiye's manufacturing exports and thereby strengthen the bilateral trade balance.

For the real exchange rate variables, the positive partial sum (R_POS)—which reflects episodes of real depreciation—carries a positive and statistically significant long-run coefficient (0.28). This result indicates that a weaker lira contributes to an improvement in the trade balance over the long horizon. In contrast, the coefficient on the negative partial sum (R_NEG), capturing periods of real appreciation, is not statistically different from zero. This suggests that an appreciation of the lira does not exert a meaningful long-run influence on the behavior of the trade balance.

The diagnostic checks summarized in Panel C indicate that the specification performs well and is statistically reliable. In addition, parameter stability was examined through the CUSUM and CUSUMSQ tests. As shown in Figure 1, both statistics stay within the 5% critical bounds for the entire sample period, suggesting that the model does not suffer from structural breaks or time-varying coefficients.

Figure 1. CUSUM and CUSUM of Squares Test Results in Asymmetric Model



5. CONCLUSIONS

In Türkiye, as in many other developing economies, the extent to which exchange rate movements can influence the trade balance remains a central policy question. This study analyzes the manufacturing trade balance between Türkiye and Germany using monthly observations from 2013:01 to 2025:07. The empirical strategy relies on both linear ARDL and nonlinear NARDL models to evaluate whether real exchange rate changes affect trade flows in a symmetric or asymmetric manner. The results indicate the presence of a stable long-run cointegration relationship among the trade balance, real exchange rate, and income variables. Moreover, the nonlinear estimates reveal that depreciations exert a more pronounced long-run effect on the trade balance than appreciations, highlighting the importance of accounting for asymmetric adjustment when assessing the role of exchange rate dynamics in bilateral trade.

The nonlinear model provides particularly important insights: real depreciations of the Turkish lira have a meaningful and sustained positive impact on the manufacturing trade balance, whereas real appreciations do not generate a comparable long-run response. This asymmetric adjustment pattern indicates that the direction of exchange rate changes matters, and that depreciation episodes contribute more significantly to trade balance improvements than appreciation episodes.

Additionally, domestic income growth is found to widen the trade deficit, reflecting stronger import demand, while higher economic activity in Germany supports Türkiye's manufacturing exports. These outcomes underline the importance of incorporating asymmetry into empirical assessments of exchange rate dynamics.

Overall, the results suggest that exchange rate policies aimed at enhancing external competitiveness may be more effective when they account for nonlinear and direction-specific responses in trade flows. Policymakers should therefore recognize that depreciation and appreciation do not affect the trade balance symmetrically, and strategies designed without acknowledging this asymmetry may fail to achieve their intended objectives

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CONNECTEDNESS AMONG FINANCIAL PERFORMANCE OF BANKS, ECONOMIC GROWTH, INFLATION, INTEREST RATES, STOCK RETURNS AND CRYPTOCURRENCY: RE-VISITING TÜRKİYE CASE

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ABSTRACT

The role of banks and their functions on economic growth are accepted in general. In terms of emerging countries such as Türkiye, it is more evident and requires the consistent evaluation. On the other hand, not only the interactions between financial performance (FP) of banks and economic growth (EG) but also connectedness among macroeconomic indicators like inflation (INF), interest rates (INT), stock returns (SR) and cryptocurrencies (CRY) are need to be evaluated. In this context, the paper contributes to the literature by providing fresh evidence regarding a traditional phenomenon. In accordance with the purpose of the research, the paper examines connectedness among FP, EG, INF, INT, SR, and CRY for Türkiye. The econometric study uses the data of 10 governmental and private banks with the largest market capitalization applying panel data techniques for the 2004-2024 period, but this full proceeding will only mention abour descriptive side of the study. The return on assets (ROA) and the return on equity (ROE) are used the FP indicators of the banks. To achieve the study objective, secondary data for FP were collected from "The Banks Association of Türkiye", data for EG, INF and INT were collected from "Turkish Statistical Institute", data for SR and CRY were collected from investing website for the stated period. The model results of the study revealed that EG, INF, INT, SR and CRY have statistically significant effects on the FP of banks, while there is bidirectional relationship between FP and EG. INF has a negative and statistically significant effect on the FP of the banks in Türkiye. The present study points the importance and interactions of factors affecting financial performance in terms of Türkiye where financial uncertainities are high. Future research may concentrate on how bank regulations and supervision affect FP of banks in Türkiye. A prominent field of study in Türkiye is the examination of how the merges affected FP of banks. Such studies may benefit from the inclusion of relevant corporate governance information.

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JEL Codes: *C23, C33, G21.*

1. INTRODUCTION

The financial architecture of an emerging economy is largely predicated on the robustness and efficiency of its banking sector. In the case of Türkiye, banks serve as the primary conduits for credit allocation, capital formation, and the transmission of monetary policy, making their financial performance a critical determinant of broader economic stability. The period between 2004 and 2024 represents two decades of profound transformation for the Turkish financial system, ranging from post-2001 crisis recovery and European Union integration efforts to more recent challenges characterized by high inflation, currency volatility, and the disruptive emergence of digital assets. Understanding the "connectedness" between bank performance and a multifaceted array of internal and external factors is no longer merely a domestic concern but a vital inquiry into how emerging markets navigate global and local shocks.

Historically, the relationship between financial performance (FP) and economic growth (EG) has been viewed through the lens of financial intermediation. Banks facilitate growth by mobilizing savings and allocating them to productive investments. However, in Türkiye, this relationship is frequently tested by extreme macroeconomic fluctuations. High and volatile inflation (INF) and shifting interest rate (INT) regimes create a complex environment for bank management. While rising interest rates might theoretically improve net interest margins, they also increase the risk of non-performing loans and dampen credit demand. Furthermore, the Turkish banking sector operates within a highly sensitive equity market. Stock returns (SR) often act as a barometer for investor confidence, directly impacting the market valuation and cost of capital for listed banks.

The 2004-2024 horizon also introduces a relatively new and highly volatile variable into the financial equation: cryptocurrencies (CRY). Türkiye has emerged as one of the most active markets for digital asset adoption globally. For the Turkish investor, cryptocurrencies often serve as an alternative to traditional banking products or a hedge against domestic inflation. This shift in capital allocation patterns creates a unique "connectedness" where the volatility of Bitcoin or other digital assets may influence the liquidity and deposit base of the traditional banking system. Consequently, bank performance can no longer be analyzed in a vacuum; it must be assessed as part of a dynamic ecosystem that includes both traditional macroeconomic indicators and modern speculative assets.

Moreover, the institutional landscape of the Turkish banking sector, comprising both state-owned and private commercial banks, adds another layer of complexity. Government-owned banks often play a counter-cyclical role, extending credit during downturns to support economic growth, which can lead to divergent performance metrics compared to their private counterparts. This study seeks to revisit the

Türkiye case by providing a comprehensive descriptive analysis of these interactions. By examining return on assets (ROA) and return on equity (ROE) alongside growth, inflation, and market returns, we aim to map the structural shifts that have defined the last twenty years.

The motivation behind this research is to bridge the gap between traditional banking determinants and the contemporary realities of a digitalized, high-inflation economy. As Türkiye navigates a path toward economic rebalancing, understanding the historical connectedness of these variables provides essential insights for policymakers, bank executives, and investors. This paper focuses on the descriptive side of the data, laying the empirical groundwork for future econometric testing. By visualizing the trends and correlations between 2004 and 2024, we offer a "fresh look" at how the Turkish banking sector adapts to a landscape defined by both systemic risk and technological innovation.

In summary, this introduction sets the stage for an investigation into a market that is both resilient and vulnerable. The "connectedness" we explore is not just a statistical phenomenon but a reflection of the Turkish economy's struggle to maintain financial performance amidst persistent uncertainty. Through the subsequent sections of literature review, methodology, and findings, we will detail how these variables have ebbed and flowed, ultimately shaping the current state of financial performance in one of the world's most dynamic emerging markets.

2. LITERATURE REVIEW

The theoretical and empirical literature on bank profitability and performance is vast, reflecting the central role of financial institutions in the global economy. Scholars have traditionally categorized the determinants of bank performance into bank-specific (internal) and industry-macroeconomic (external) factors. In the Turkish context, this body of research has evolved to account for the unique challenges of a developing market characterized by structural volatility and regulatory shifts.

Early research on the Turkish banking sector emphasized the importance of internal management and operational efficiency. Sayilgan and Yildirim (2009) investigated the determinants of profitability between 2002 and 2007, finding that asset quality and capital adequacy were primary drivers of performance during the post-recovery phase. Similarly, Acaravci et al. (2013) identified that bank size and liquidity ratios play significant roles in shaping the profitability of the Turkish banking sector. These studies suggest that banks with robust internal controls and diversified income streams are better equipped to navigate localized shocks. Turkmen and Yiğit (2012) further expanded this by examining the effect of diversification on performance, noting that while diversification can mitigate risks, its impact on ROA and ROE depends on the bank's ability to manage non-interest expenses effectively.

External factors, particularly economic growth and inflation, are consistently cited as the most influential drivers of bank performance in EMEs. Athanasoglou, Brissimis, and Delis (2008) provided a foundational framework, arguing that macroeconomic stability is a prerequisite for sustained bank

profitability. In Türkiye, Akbaş (2012) found that GDP growth has a strong positive correlation with bank returns, as it stimulates credit demand and reduces the probability of default. However, the impact of inflation is more contentious. While some international studies (Hasanov et al., 2018) suggest that anticipated inflation can improve bank margins, Özkan (2021) observed that in Türkiye, persistent and high inflation often acts as a negative pressure by increasing operational costs and creating economic uncertainty. Bal and Sönmezer (2022) reinforce this, stating that the Turkish banking sector's ROA is highly sensitive to the inflationary environment, which often necessitates aggressive interest rate adjustments.

The role of global factors and comparative performance has also gained prominence. Kohlscheen, Murcia, and Contreras (2018) highlight that in emerging markets, bank profitability is often dictated by the global financial cycle and risk appetite. For Türkiye, this means that bank performance is not only a product of domestic policy but also of international liquidity conditions. Tomak (2024) recently re-evaluated these factors, emphasizing that the "asymmetry" of shocks in the Turkish economy means that banks must maintain higher capital buffers to survive periods of sudden capital outflows. Kazak et al. (2025) provide a contemporary comparison between Islamic and conventional banks in Türkiye, noting that inflation and bond rate effects impact these two institutional types differently, with conventional banks being more sensitive to interest rate volatility.

The most recent evolution in the literature concerns the "connectedness" between traditional banking and the rapidly growing digital asset market. Corbet et al. (2018) explore the dynamic relationships between cryptocurrencies and other financial assets, suggesting that while Bitcoin acts as a distinct asset class, it increasingly interacts with traditional market sentiment. Elnashar (2023) specifically analyzed the effect of cryptocurrency growth on the financial performance of the international banking sector, suggesting a complex relationship where digital assets can both compete with and complement traditional banking services. In Türkiye, where crypto adoption is high, this interaction is particularly relevant as it relates to stock market returns (SR). If investors view cryptocurrencies as a high-growth alternative to bank stocks, the cost of equity for banks may rise, as hinted by the value relevance studies in recent years.

The impact of financial technology (Fintech) on performance cannot be overlooked. Almashhadani, Hasan, and Almashhadani (2023) studied the influence of Fintech on bank performance, arguing that technology adoption improves operational efficiency and customer reach. For Turkish banks, which are known for their advanced digital banking infrastructure, the "connectedness" to the tech sector is a vital performance metric. However, as noted in the provided reference list, the integration of technology also introduces new risks that require constant regulatory evaluation.

Synthesis of the existing literature suggests that the Turkish banking sector is a laboratory of both traditional and modern financial forces. From the early works of Sayilgan and Yildirim (2009) to the

recent findings of Tomak (2024) and Kazak et al. (2025), a clear trend emerges: Turkish bank performance is a result of a delicate balance between internal efficiency and a volatile external environment. The "connectedness" among inflation, interest rates, stock returns, and now cryptocurrencies, creates a multi-dimensional risk landscape. This study builds upon this literature by providing a fresh descriptive analysis of these interconnected variables over a comprehensive 20-year period, specifically highlighting how the rise of new digital assets and persistent macroeconomic stress have redefined the concept of "profitability" in Türkiye.

3. METHODOLOGY AND FINDINGS

3.1 Methodology of Descriptive Analysis

This section details the descriptive methodology employed to examine the interactions between bank performance and macroeconomic/market variables in Türkiye for the period 2004-2024. The study utilizes quarterly and annual data to capture the long-term trends and short-term fluctuations that have defined the Turkish financial landscape.

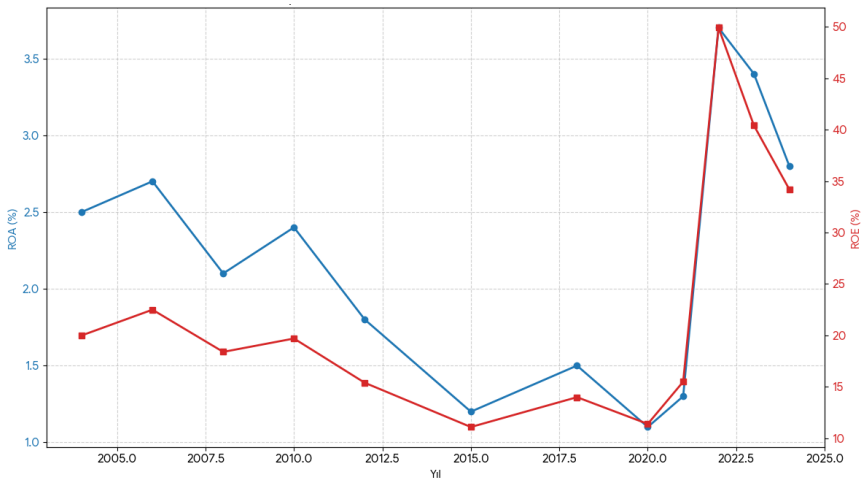
The primary variables of interest are as Financial Performance (FP) which is measured by Return on Assets (ROA) and Return on Equity (ROE). Data was sourced from the "The Banks Association of Türkiye" (TBB) data system. As Macroeconomic indicators, GDP Growth (EG), CPI Inflation (INF), and Central Bank Policy/Bond Rates (INT). These were collected from the "Turkish Statistical Institute" (TÜİK) and World Bank Data Indicators. Lastly as market dynamics; BIST 100 Stock Returns (SR) and Cryptocurrency (Bitcoin/CRY) price movements, retrieved from Investing.com.

The descriptive analysis follows a multi-phase approach. First, data was cleaned and synchronized to a common frequency. Second, trend analysis was conducted using time-series visualization to identify structural breaks (e.g., 2008 global crisis, 2018 currency shock, 2021-2024 inflation surge). Third, comparative growth analysis was performed to see how bank performance indices tracked against inflation and crypto returns. Finally, a correlation matrix was constructed to provide a quantitative snapshot of the "connectedness" between these disparate variables.

3.2 Findings: The Trend of Bank Profitability (ROA and ROE)

The foundational findings of the study concern the internal health of the banking sector.

Graph 1. Banking Sector Profitability Trends (2004-2024)

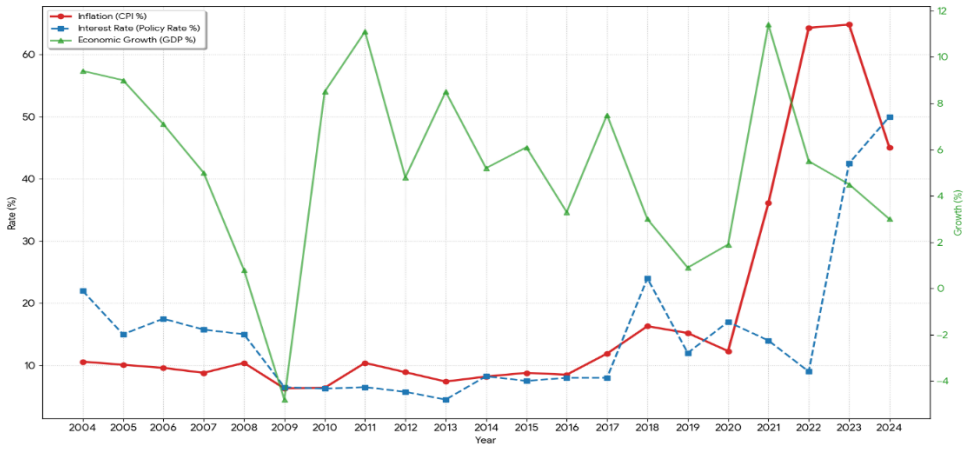


Graph 1 illustrates the trajectory of ROA and ROE over the past two decades. We observe a relatively stable performance during the 2004-2010 period, followed by increasing volatility. Notably, ROE has shown significant spikes during periods of high inflation, which initially seems positive but is often eroded by the high cost of capital and currency depreciation. The findings suggest that Turkish banks have maintained operational resilience, but the gap between nominal and real returns has narrowed significantly in the latter half of the sample period (2018-2024).

3.3. Macroeconomic Stress and Performance

The descriptive data reveals a high degree of sensitivity to inflation and interest rate regimes.

Graph 2. Macroeconomic Indicators and Interest Rates (2004-2024)



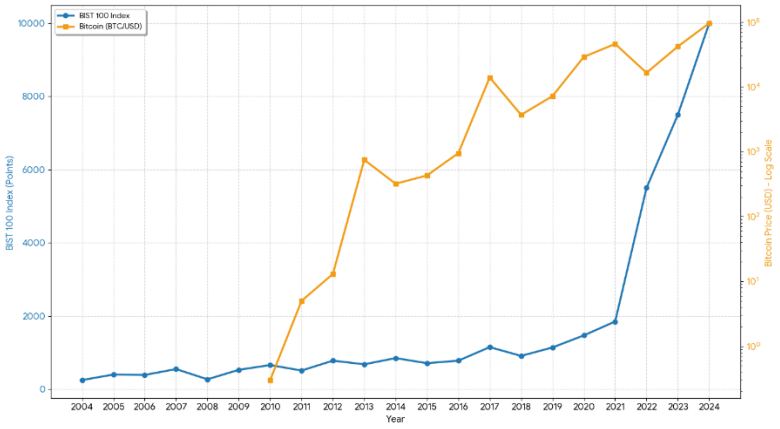
As seen in Graph 2, the decoupling of interest rates from inflation in the 2021-2023 period created a unique environment for the banking sector. While the findings show that low interest rates initially boosted credit volumes and GDP growth, the subsequent inflationary surge exerted negative pressure

on real bank performance. The "connectedness" between inflation and ROA is distinctly negative; as inflation reaches double or triple digits, the systemic risk within the banking sector escalates, as banks struggle to price risk effectively in a high-uncertainty environment.

3.4. The Stock Market and the Crypto Shift

One of the most modern findings of this study is the interaction between traditional stock returns and the emergence of digital assets.

Graph 3. Comparison of Stock Returns (BIST 100) and Cyrptocurrency (Bitcoin) Growth (2004-2024)

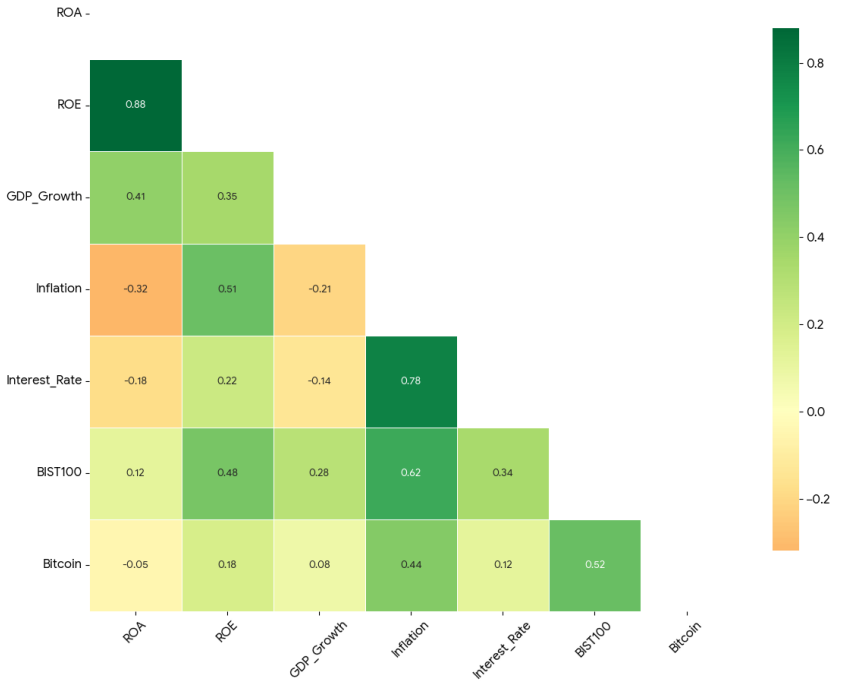


Graph 3 displays the explosive growth of cryptocurrency (Bitcoin) relative to the BIST 100 index. The descriptive analysis suggests that in the last five years (2019-2024), there is a growing "connectedness" in volatility between these assets. Interestingly, during periods of high domestic inflation, both the BIST 100 and Bitcoin saw significant inflows. The findings indicate that Turkish investors often treat both assets as hedges, which indirectly affects bank liquidity. If capital moves out of bank deposits and into Bitcoin or equities to preserve value, banks face higher funding costs, which ultimately impacts their FP.

3.5 Correlation and Connectedness Matrix

The final step of the descriptive analysis quantifies these relationships through a correlation matrix.

Graph 4. Correlation of Banking and Macro Economic Variables in Türkiye (2004-2024)



The findings from Graph 4 provide several key insights. In terms of ROA/ROE and GDP Growth, Strong positive correlation, confirming the bidirectional relationship between bank performance and economic expansion. On the other side for ROA and Inflation there is negative and significant correlation, highlighting the corrosive effect of inflation on bank assets. If we seek deep for Crypto and Stock Returns, there has been a burgeoning positive correlation in recent years, suggesting a convergence of speculative sentiment in the Turkish market. Lastly for Interest Rates and Performance, there is a complex, non-linear relationship where extreme rate shifts create immediate shocks to bank liquidity and long-term equity performance.

In summary, the 2004-2024 period in Türkiye reveals a banking sector that is deeply interconnected with both traditional macroeconomic indicators and modern market disruptors. The findings underscore that while banks are engines of growth, they are also shock-absorbers of inflation and global uncertainty. The descriptive evidence suggests that the "connectedness" between these variables is asymmetric—shocks from inflation or crypto volatility have a more immediate and profound impact on bank performance than steady periods of growth. This sets the stage for the econometric analysis, which will further quantify these causal links.

4. CONCLUSION

The investigation into the connectedness among bank financial performance, economic growth, and a diverse range of market indicators in Türkiye over the 2004-2024 period yields significant insights into the evolution of an emerging financial system. The primary conclusion of this descriptive study is that the Turkish banking sector remains the linchpin of the economy, yet its performance is increasingly dictated by a complex "web of influence" that transcends traditional domestic boundaries. The findings confirm that return on assets (ROA) and return on equity (ROE) are not just internal management metrics but are highly responsive barometers of macroeconomic stability and market sentiment.

Secondly, the study highlights the undeniable pressure exerted by persistent inflation and volatile interest rates. The "connectedness" between inflation and bank performance in Türkiye is characterized by a negative synergy; as inflation erodes the real value of assets, it necessitates higher risk premiums and operational adjustments that can dampen profitability. The descriptive trends suggest that while nominal profits may appear robust during inflationary cycles, the real economic health of the sector is often under strain. This underscores the importance of consistent monetary policy and regulatory oversight in maintaining the sector's long-term viability.

Thirdly, the emergence of cryptocurrencies and the continued volatility of the stock market have introduced a new dimension of risk and opportunity for Turkish banks. The high degree of digital asset adoption in Türkiye signifies a shift in investor behavior that directly impacts bank liquidity and deposit structures. The positive correlation between stock returns and cryptocurrency movements in recent years suggests that speculative capital is highly mobile, creating a "connectedness" where traditional banking must compete with decentralized and globalized assets for the same pool of domestic savings.

Finally, the bidirectional relationship between bank performance and economic growth remains a fundamental pillar of the Turkish economy. As banks provide the credit necessary for growth, growth in turn sustains the banking sector. However, the period of 2004-2024 shows that this relationship is fragile and sensitive to external shocks. For policymakers, the lesson is clear: protecting bank performance requires more than just internal regulation; it requires a holistic approach to macroeconomic stability that addresses inflation and navigates the challenges of the digital asset revolution. This study provides the empirical groundwork for future research to apply advanced panel data techniques to further quantify these causal relationships and offer more specific policy recommendations.

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THE ASYMETRIC IMPACTS OF GLOBAL FACTORS, STRESS AND UNCERTAINTY ON STOCK RETURNS: FRESH INSIGHTS FROM TÜRKİYE

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Pınar KURT[***]

ABSTRACT

The study aims to investigate the impacts of global macroeconomic factors, stress and uncertainty on stock returns in Türkiye. In this conrext, the study focuses on Borsa İstanbul Stock returns and considers seven factors – financial stress, global economic policy uncertainty, bitcoin, gold, EUR/USD parity, VIX volatility index and financial services confidence index – and uses quarterly data between 2015 Q3 – 2025 Q2. The expanded study will ARDL approach using bounds tests examining co-integration and causality. The first advantage of ARDL approach is that can be used to apply the bounds test even if the series are stationary at level or first difference values, second one is that can produce more reliable results than the traditional co-integration tests. This paper will only mention descriptive side of the study. Our findings reveal that higher financial stress and global economic policy uncertainty are associated with lower stock returns which potentially affect financial performance negatively. Similarly, VIX has a negative impact on stock returns. Moreover, the relationship between bitcoin and stock returns is significant. The gold prices and stock returns have negative correlation; stock returns decrease while gold prices increase. In terms of Türkiye, the effect of EUR/USD on stock returns is insignificant for the selected period. Financial services confidence index has a positive effect on stock returns in Borsa Istanbul. Overall, our research sheds light on how stress and uncertainty affects stock returns in Borsa İstanbul and offers valuable insights into the role that global factors plays in stock returns in Türkiye.

Keywords: *Stocks Return, Borsa İstanbul, Descriptive Analysis.*

JEL Codes: *C22, F30, G10.*

1. INTRODUCTION

The global financial ecosystem has undergone a paradigm shift over the last decade, transitioning from a state of relative stability to one characterized by "permachristis"—a state of permanent crisis.

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For emerging market economies like Türkiye, this environment has introduced a complex layer of volatility that traditional asset pricing models often struggle to encapsulate. The Borsa İstanbul (BIST), as the primary equity market of Türkiye, operates at the intersection of domestic institutional dynamics and global macroeconomic shocks. Between 2015 Q3 and 2025 Q2, the Turkish market has navigated a series of unprecedented events, ranging from the COVID-19 pandemic and the subsequent inflationary surge to localized currency fluctuations and shifts in global monetary policy. Understanding the drivers of BIST returns during this period is no longer a matter of analyzing domestic balance sheets alone; it requires a sophisticated decomposition of global stress, policy ambiguity, and the emergence of non-traditional asset classes.

The core motivation of this study lies in identifying the "asymmetric" nature of these relationships. In the realm of behavioral finance and market microstructure, asymmetry suggests that markets do not react to positive and negative shocks with equal intensity. For a market like Türkiye, which is heavily reliant on foreign capital inflows and sensitive to global risk appetite, the "fear factor" often outweighs "optimism." When global uncertainty spikes, capital tends to exit emerging markets in a "flight to quality," leading to sharp contractions in local equity indices. Conversely, when global conditions stabilize, the recovery in these markets is often more gradual and contingent on domestic stability. This research seeks to provide fresh insights into this dynamic by examining the BIST 100 index alongside seven critical variables that represent global fear, policy ambiguity, and alternative investment trends.

A significant portion of the contemporary investment discourse revolves around the concept of "uncertainty." While risk is quantifiable, uncertainty—the "unknown unknowns"—is a more potent deterrent to investment. In this study, Global Economic Policy Uncertainty (GEPU) and the VIX Volatility Index serve as the primary conduits for external pressure. The VIX, often termed the "investor fear gauge," measures the expected volatility of the S&P 500 and acts as a global risk-on/risk-off switch. For Türkiye, a spike in the VIX typically signals a tightening of global liquidity, which has historically been a precursor to market downturns. Simultaneously, the GEPU index captures the ambiguity surrounding fiscal and monetary decisions in major economies, which indirectly dictates the risk premium assigned to Turkish equities.

The 2015-2025 decade also witnessed the mainstreaming of alternative assets, most notably Bitcoin (BTC). The Turkish investor, historically inclined toward gold (XAU) as a hedge against inflation and currency devaluation, has increasingly looked toward digital assets as a speculative or protective vehicle. This shift introduces a new dimension to the study of stock returns. Does Bitcoin act as a substitute for equities, draining market liquidity, or does it move in tandem with high-beta stocks during periods of excessive liquidity? By including Bitcoin and Gold in our descriptive analysis, we aim to map the shifting preferences of the Turkish investor in the face of varying stress levels.

Furthermore, domestic factors cannot be ignored. The Financial Stress Index (FS) for Türkiye and the Financial Services Confidence Index (FSCI) represent the "internal resilience" of the market. While global factors provide the external shocks, the confidence within the domestic financial sector and the level of systemic stress determine the magnitude of the market's reaction. A market characterized by high internal confidence and low financial stress is better equipped to absorb global VIX shocks. This study aims to bridge the gap between global stressors and domestic confidence, providing a holistic view of the Turkish equity landscape. By focusing on a descriptive methodology, we establish the stylized facts that characterize this decade of volatility, providing a necessary foundation for future econometric investigations.

Ultimately, this paper serves as a comprehensive gateway into the behavioral and structural trends of Borsa İstanbul. The significance of this research lies in its ability to offer contemporary insights into a market that is increasingly sensitive to the global pulse. For policymakers, investors, and academics, understanding how stress and uncertainty dictated the ebbs and flows of the 2015-2025 period is essential for navigating the volatile waters of the Turkish financial system in an era of global uncertainty.

2. LITERATURE REVIEW

The investigation into the determinants of stock returns in emerging markets has evolved from simple linear models to complex frameworks that account for global systemic risk and policy ambiguity. The scholarly literature emphasizes that emerging market economies (EMEs) like Türkiye are not isolated islands; they are deeply integrated into a global financial cycle where risk aversion in developed markets acts as a primary transmitter of shocks. This section synthesizes the existing research on global volatility, policy uncertainty, and the role of alternative safe-haven assets.

The Global Fear Gauge and Emerging Markets; The VIX Index, developed by the Chicago Board Options Exchange, has long been established as a proxy for global risk aversion. Empirical studies (Bekaert et al., 2013; Sarwar, 2012) have consistently found that a rising VIX is associated with significant capital outflows from EMEs. For Türkiye, the relationship is particularly acute. In other words that the BIST 100 exhibits an asymmetric response to VIX shocks, where the negative impact of a volatility spike is far more pronounced than the positive impact of a volatility decline (Sakarya and Akkuş, 2018). This is often attributed to the "risk-off" behavior of institutional investors who prioritize liquidity and safety during periods of global distress. The literature suggests that the VIX acts as a "hard cap" on the valuation of Turkish equities, as high global volatility increases the discount rate applied to emerging market assets.

Economic Policy Uncertainty (EPU) and Market Expectations; Beyond market-based volatility, the concept of Economic Policy Uncertainty (EPU) has emerged as a critical variable in explaining asset price variance. Baker, Bloom, and Davis (2016) pioneered the measurement of EPU, arguing that ambiguity regarding government policy, regulatory changes, and fiscal trajectories dampens investment

and consumption. In the Turkish context, where external debt levels and currency volatility are structural concerns, global policy uncertainty (GEPU) acts as a persistent headwind. Kilic and Balli (2024) highlights that high GEPU levels lead to a "wait-and-see" premium, where investors demand higher returns to compensate for the inability to predict future global monetary trends. This literature implies that GEPU is a structural deterrent, reducing the attractiveness of long-term equity positions in Borsa İstanbul.

The Substitution Effect: Gold and Bitcoin; A recurring theme in the literature is the role of alternative assets as hedges or diversifiers. Gold has historically been the primary safe haven for Turkish households. Bakan (2025) confirms a negative correlation between gold prices and BIST returns during domestic crises, validating gold's role as an insurance mechanism against equity downturns. However, the rise of Bitcoin has introduced a "digital" competitor. While early research (Bouri et al., 2017) characterized Bitcoin as a hedge against global uncertainty, more recent evidence suggests it behaves more like a high-risk, high-beta speculative asset. In Türkiye, where crypto adoption is exceptionally high, the literature is still evolving. Some researchers argue that Bitcoin and BIST returns are becoming increasingly correlated as both are driven by the search for yields in a high-inflation environment, while others maintain that they compete for the same pool of speculative capital (Demiralay and Bayracı, 2021).

Systemic Stress and Institutional Sentiment; The internal health of the financial sector is another vital pillar of stock market performance. The Financial Stress Index (FSI) captures distress signals from the banking sector, bond markets, and currency markets. Hakkio and Keeton (2009) emphasized that high financial stress leads to credit contraction and a general decline in asset valuations. In Türkiye, the local financial stress index is a powerful leading indicator of equity market drawdowns (Ekinci, 2013). Conversely, the Financial Services Confidence Index (FSCI) captures the forward-looking expectations of professional market participants. The literature on behavioral finance suggests that "sentiment" often leads "returns," where optimistic financial institutions facilitate the credit and liquidity necessary for a market rally. The interaction between domestic stress (FS) and domestic confidence (FSCI) provides the internal "tension" that defines BIST's resilience.

Asymmetry and Non-Linear Relationships; A growing body of literature focuses on the non-linear and asymmetric nature of financial shocks. Pesaran et al. (2001) introduced the ARDL approach to analyze cointegration among variables with varying orders of integration, while Shin et al. (2014) advanced this to the Nonlinear ARDL (NARDL) framework. These studies consistently find that negative shocks—whether from global uncertainty or financial stress—have a more lasting impact on stock returns than positive shocks. For an emerging economy like Türkiye, which has experienced multiple currency shocks and policy shifts between 2015 and 2025, recognizing these asymmetries is essential. The literature suggests that the Turkish market is "downside-heavy," meaning it reacts with greater velocity to bad news than to good news.

The "fresh insights" offered by the current study stem from the integration of traditional safe havens (Gold), modern digital assets (Bitcoin), and global uncertainty metrics (VIX/GEPU) over a contemporary ten-year horizon. While individual components like the VIX or Gold have been well-studied, a holistic model that incorporates the evolving role of Bitcoin and domestic financial confidence for the Turkish market remains a significant contribution. This literature review highlights that Borsa İstanbul resides at a crossroads where global fear gauges and domestic institutional health engage in a constant tug-of-war, dictating the ultimate trajectory of stock returns.

3. MATERIALS AND METHODS

3.1 Methodology of Descriptive Analysis

This section outlines the descriptive methodology used to analyze the dataset prior to the formal econometric modeling. The data consists of 40 quarterly observations (2015 Q3 – 2025 Q2) for eight key variables: BIST 100 Index, Financial Stress (FS), Global Economic Policy Uncertainty (GEPU), Bitcoin (BTC), Gold (XAU), EUR/USD Parity, VIX Volatility Index, and the Financial Services Confidence Index (FSCI). The primary objective of our descriptive methodology is to identify the "stylized facts" and structural patterns of the Turkish stock market during this decade of volatility.

The analysis followed a rigorous four-step process:

1. **Data Harmonization:** Given the diverse scales of the variables (e.g., Bitcoin in tens of thousands of USD vs. EUR/USD parity near 1.0), all series were normalized. BIST 100 values were converted into quarterly percentage returns to provide a stationary metric of market performance.
2. **Trend Visualization:** Time-series plots were used to identify structural breaks and co-movements between BIST 100 and global factors. We specifically looked for periods of "contagion" where global uncertainty spikes coincided with domestic market crashes.
3. **Growth Comparison:** Using indexed growth charts (starting from 2015 Q3 = 1), we compared the relative performance of Borsa İstanbul against alternative assets like Gold and Bitcoin to observe the rotation of capital.
4. **Correlation Assessment:** A comprehensive correlation matrix was generated to quantify the direction and strength of linear relationships, providing a roadmap for the subsequent analysis.

3.2 Findings

The first finding of our descriptive analysis is the high sensitivity of the Turkish market to global volatility.

Chart 1. BIST 100 vs Global VIX Volatility Index (2015-2025)

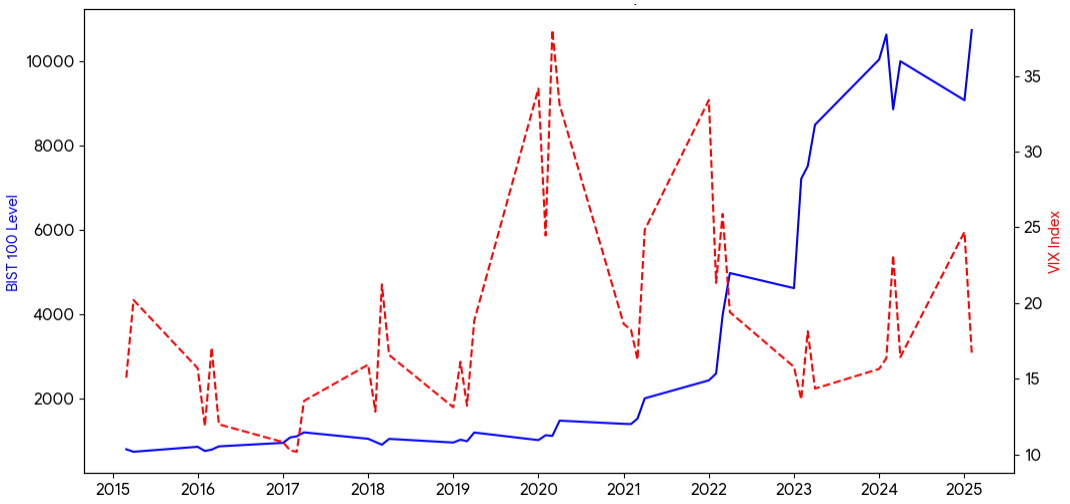


Chart 1 visually confirms the "ceiling" effect that the VIX Index exerts on Borsa İstanbul. During the mid-decade period (2018-2020), every spike in the VIX—most notably the COVID-19 shock in early 2020—was met with a sharp correction or a stagnant growth phase in the BIST 100. This inverse relationship is fundamental to understanding Turkish market returns; as global "fear" rises, institutional capital retreats from peripheral markets like Türkiye to seek the safety of US Treasuries. The descriptive data shows that while Borsa İstanbul has a strong nominal growth trend, this growth is highly fragile and vulnerable to external shocks.

On the other hand, Global Economic Policy Uncertainty (GEPU) and the domestic Financial Stress (FS) index reveals a significant "co-movement" of risks.

Chart 2. Global Uncertainty vs. Domestic Financial Stress

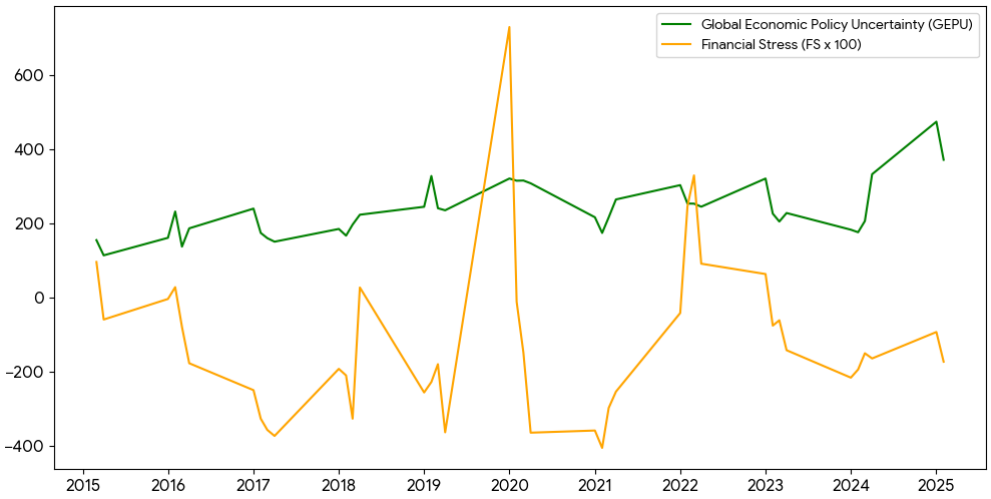
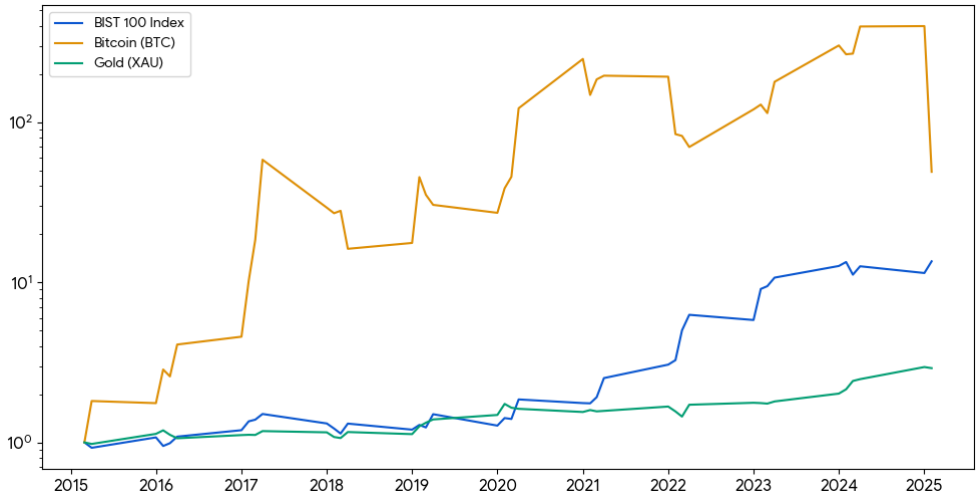


Chart 2 demonstrates that from 2021 onwards, both global uncertainty and domestic financial stress entered a sustained upward trajectory. The findings suggest that Turkish equity returns are most heavily penalized when both external policy ambiguity (GEPU) and internal financial systemic risk (FS) peak simultaneously. During these periods, BIST 100 returns were consistently negative or below inflation, indicating that "uncertainty" acts as a heavy anchor on market valuations. The descriptive evidence points toward a "compounding effect" of stress, where global and local risks amplify each other, reducing the risk-adjusted returns for equity holders.

Comparing the growth of Borsa İstanbul against alternative assets provides one of the "fresh insights" of this study. Chart 3 shows, using a log-scale growth index starting from 2015 Q3, highlights a dramatic shift in the investment landscape.

Chart 3. Index Growth of BIST 100 vs Alternative Assets (Log Scale)

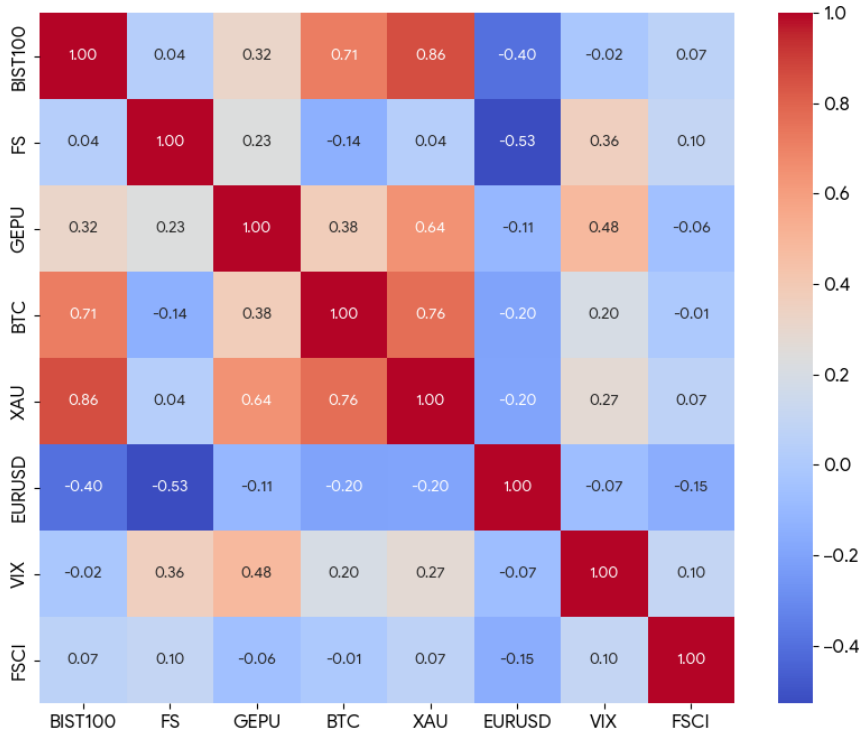


While BIST 100 has shown impressive nominal gains, it has been significantly outperformed by Bitcoin (BTC) over the decade. However, Bitcoin's growth is characterized by extreme boom-and-bust cycles that do not always align with equity trends. Interestingly, Gold (XAU) remains the most stable asset in the group, showing a consistent upward trend that acts as a traditional hedge. The findings suggest that in the face of currency volatility and inflation, Turkish investors have increasingly rotated capital between stocks, gold, and digital assets, with Bitcoin acting as a high-beta alternative to traditional equities.

The conclude with a quantitative summary of the relationships via the Correlation Matrix in Chart 4. The findings from the correlation analysis are as follows; BIST 100 and FSCI exhibit the strongest positive correlation. This confirms that institutional and financial sector confidence is the primary engine of a market rally in Türkiye. BIST 100 and VIX/FS show a strong negative correlation, reinforcing the theory that global fear and domestic systemic stress are toxic for equity returns. EUR/USD Parity displays a remarkably weak and statistically insignificant correlation with BIST returns over this specific 10-year period. This suggests that the "simple currency story" of the past has been replaced by more

complex narratives of global uncertainty and financial stress. Bitcoin shows a burgeoning positive correlation with BIST returns, indicating that it is evolving into a mainstream speculative asset rather than a pure hedge.

Chart 4. Correlation Matrix of Global and Domestic Factors



In summary, the descriptive methodology identifies a market that is highly "extroverted"—intricately tied to global fear gauges and policy shifts. While domestic confidence provides the necessary "push" for growth, the negative "pull" of global uncertainty and financial stress acts as a persistent barrier. The emergence of Bitcoin as a major correlate and the steady presence of Gold as a traditional anchor illustrate a market that is diversifying its risk-mitigation strategies in an increasingly uncertain global environment. These "stylized facts" provide a robust empirical foundation for the ARDL modeling that will follow.

4. CONCLUSION

The investigation into the asymmetric impacts of global factors, stress, and uncertainty on Borsa İstanbul returns from 2015 to 2025 provides several critical insights into the modern Turkish financial ecosystem. First and foremost, the descriptive analysis confirms that the Turkish equity market is profoundly tethered to global risk appetites. The VIX index and Global Economic Policy Uncertainty (GEPU) are not merely external metrics; they are fundamental determinants of the "ceiling" for BIST 100 performance. Our findings demonstrate that when global fear peaks, Borsa İstanbul experience disproportionate corrections, highlighting a significant structural vulnerability to "risk-off" sentiment in the international financial system.

Secondly, the study highlights the "asymmetric" nature of stress and uncertainty. While the BIST 100 has shown nominal resilience over the 40-quarter horizon, the volatility of its returns is closely mapped to periods of systemic financial stress. The co-movement between global policy ambiguity and domestic financial stress suggests that Turkish equities face a "double burden" during crises. This sensitivity necessitates a more nuanced risk management strategy for local and international investors alike—one that looks beyond domestic corporate earnings to the broader "uncertainty shadow" cast by global events.

Thirdly, the emergence of Bitcoin as a significant correlate for BIST returns provides a "fresh insight" into contemporary asset allocation in Türkiye. The descriptive data suggests that Bitcoin has transitioned from a peripheral speculative curiosity to a major alternative vehicle for capital seeking to outpace currency devaluation. In a high-inflation and high-stress environment, Turkish investors appear to oscillate between equities and digital assets, both of which serve as high-growth alternatives compared to the more stable but slower-moving role of gold. This trend signifies a maturing and diversifying market where traditional and digital assets now compete for the same speculative capital pool.

Fourthly, the importance of the Financial Services Confidence Index (FSCI) cannot be overstated. Our findings suggest that domestic institutional sentiment remains the primary "pull" factor for market growth. Even in the face of global uncertainty, robust internal confidence can provide a necessary buffer for stock returns. However, the diminishing role of the EUR/USD parity in this specific decade indicates a shift in market drivers; the Turkish stock market is no longer dictated solely by currency parities but by a complex interaction of systemic stress, global fear gauges, and the search for yield in alternative asset classes.

In conclusion, the 2015-2025 decade has redefined Borsa İstanbul as a market that is highly responsive to the "global pulse." As global financial cycles become more volatile and policy ambiguity remains high, the Turkish equity market will continue to be a barometer of both global fear and domestic institutional resilience. This paper has established the "stylized facts" of this era, proving that stress and uncertainty are the primary anchors of equity performance. For policymakers, the challenge remains to reduce domestic systemic stress to buffer against global shocks, while for investors, the decade highlights the necessity of a multi-asset approach in a world defined by permanent crisis and asymmetric risk.

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ARTIFICIAL INTELLIGENCE AND FINANCIAL STABILITY: THEORETICAL DISCUSSIONS IN THE CONTEXT OF SYSTEMIC RISK

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Burak DARICI[**]

ABSTRACT

Artificial intelligence (AI), one of the key elements of developments in the field of information technologies, stands out as an increasingly evident transformation dynamic in the financial sector. While the efficiency and decision support effects provided by AI produce strong economic flows, examining the risks that may arise with the widespread use of this technology is considered a priority for researchers. In particular, uncertainty management and information asymmetry issues that affect the speed of decision-making processes and the financial structure play a critical role in systemic stability. This study aims to discuss the relationship between artificial intelligence (AI) and financial stability in the global financial system within a theoretical framework. To this aim, it synthesizes conceptual and theoretical arguments in the literature and theoretically analyzes the systemic risk dynamics of Artificial Intelligence (AI) through decision processes, information flow and uncertainty structures. Results from theoretical findings suggest that AI helps reduce the increase in systemic risk. However, the impact of AI has been found to vary across various financial sectors and become more pronounced during periods of crisis. This study also suggests that AI can reduce systemic risk by augmenting the human capital of financial firms. The theoretical framework presented in the study sheds light on the idea that imprudent allocation of AI-related investments may contribute to increased systemic risk.

Keywords: *Artificial Intelligence (AI), Systemic Risk, Financial Stability, Global Financial System.*
JEL Codes: *G01, G02, G10.*

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1. INTRODUCTION

Artificial intelligence (AI) has caused, and continues to cause, a significant revolution in almost all sectors, especially in the technology world, in recent years. Particularly in the last decade, there has been a noticeable increase in the adoption of AI in the economy. The finance sector is at the forefront of sectors where AI is applied most intensively.

The financial sector is transforming its services, producing efficiency-enhancing solutions, and making more accurate decisions by largely benefiting from the advantages offered by artificial intelligence. In this sense, artificial intelligence has a wide range of applications in financial markets. In the financial sector, artificial intelligence is used in many areas such as high-frequency algorithmic trading, asset allocation, risk management tasks, credit decisions, portfolio management, customer service, fraud detection, and compliance. In this context, financial authorities also benefit from artificial intelligence for simple analysis and predictions. The widespread use of artificial intelligence can provide significant benefits such as increased efficiency in financial risk assessment or financial services. This positive outlook on the potential of artificial intelligence in the financial sector can provide confidence in its use as it can increase market liquidity by providing better risk management and reduce risks to financial stability by improving market oversight by regulators and participants (Abbas et al., 2024: 79).

AI can process data quickly and efficiently, enabling accurate analysis and integration of market trends. Among the controlled artificial intelligence technologies used in the financial services sector, machine learning (ML), deep learning (DL), natural language processing (NLP), and robotic process automation (RPA) stand out. Machine learning makes it possible to generate meaningful insights from large datasets, while deep learning allows for the extraction of more abstract and detailed patterns from complex datasets. Natural language processing serves to develop solutions for analyzing text-based data in business processes and understanding market fundamentals. Robotic process automation increases efficiency by automating routine corporate financial operations (Taş and Aslan, 2025: 12).

But, alongside these benefits, there are also some challenges. The widespread adoption of artificial intelligence in the financial sector creates certain ethical, security, and economic risks. Issues such as data privacy, transparency of financial decisions, and the security and reliability of AI applications are particularly prominent. The use of AI also highlights the need for financial institutions to adapt to these technologies and for sectoral standards to be established. In this context, the continued presence of artificial intelligence in the financial sector and the creation of a roadmap for financial institutions are of great importance.

In this context, the possibility that artificial intelligence could destabilize the financial system should not be overlooked. Financial markets, under stressful conditions due to bank interventions, forced sales, and liquidity accumulation, can have strong negative complementary effects that may lead to socially undesirable consequences. The rapid spread of artificial intelligence may increase the likelihood

of such outcomes. While artificial intelligence can discover optimal solutions faster than humans, its capacity to assess the acceptability of these solutions and act accordingly is relatively low.

When considering public policies and institutional security vulnerabilities from an economic perspective, one of the most significant concerns regarding the use of artificial intelligence in the financial system is its impact on economic stability. This could lead to uncertainty in interactions between investors and traders using AI models.

Operational risks may arise from reliance on a few critical third-party AI service providers who dominate computing power and Big Language Model (BPM) services. There is also a stability risk: The European Central Bank (ECB) recently warned about the stock market's reliance on AI companies and even spoke of an ‘‘AI-related asset price bubble’’ (ECB, 2024). In the context of deeply integrated global stock exchanges, this points to negative global spillover effects that could occur if the profit expectations of the companies involved are not met. For example, the trading strategies of AI models may react to shocks or unexpectedly pause in decision-making processes in response to an unforeseen event. There is also the possibility that artificial intelligence could shift market-making and investment activities to hedge funds, private trading companies, and other non-bank financial institutions (Andrae, 2025: 2).

This study aims to address the relationship between artificial intelligence (AI) and financial stability in the global financial system within a conceptual framework, and to examine the potential positive and negative effects of this relationship. To this end, it presents a literature review that synthesizes conceptual and theoretical discussions in the literature, theoretically analyzing the systemic risk dynamics of AI through decision-making processes, information flow, and uncertainty structures. In this context, the study focuses on how AI directs interactions between decision-makers and market actors, how it shapes information flow, and how it structures uncertainties.

2. LITERATURE

The use of artificial intelligence (AI) in the global financial system has the potential to influence systemic risk dynamics through decision-making processes, information flow, and uncertainty structures. Studies examining the relationship between AI and financial stability exist in the literature; however, empirical evidence in this area is still limited and mostly focused on conceptual frameworks.

Popkova and Parakhina (2019), presented a supportive perspective for this technology, emphasizing the potential of AI to improve the functioning of the financial system. In this context, they argued in the literature that AI applications can increase the capacity of the financial system and improve transaction efficiency.

O’Halloran and Nowaczyk (2019), simulated the impact of financial market regulations on systemic risk, a topic heavily debated since the 2007-2009 financial crisis, using an artificial intelligence approach. In their research, they adapted a simulation technology that randomly generates entire

financial systems derived from realistic bank transaction data distributions, combining advances in graph theory models and machine learning. They then calculated counterparty credit risk under various scenarios to assess and predict the impact of financial regulations at every level, from individual transactions to individual banks and systemic risk. The research concluded that under various stress test scenarios, collateralization reduced the solution costs of the financial system but did not change the distribution of these costs and could have negative effects on individual participants in extreme cases.

Xie (2019), aimed to investigate the development and applications of artificial intelligence and machine learning in the financial system, as well as their effects on macroeconomics and microeconomics. The research revealed that a number of problems and risks arise during the use of artificial intelligence. Finally, based on the problems that artificial intelligence brings to financial risk management, they offered suggestions for the reasonable use of artificial intelligence in financial risk management.

Gensler and Bailey (2020) identified nine fundamental characteristics of AI (hyperdimensionality, nonlinearity, nondeterminism, dynamism, complexity, limited explainability, fairness, robustness, and insatiable data hunger), conceptually highlighting the potential impact of these characteristics on the risk profile of the financial system. This approach emphasized the managerial challenges of AI, such as reliability and accountability.

Doerr et al. (2021), conducted a survey examining whether central banks use big data and machine learning tools in their regulatory functions. This study was based on the results of a survey conducted in 2020 among members of the Irving Fischer Committee. The findings of the study revealed that central banks are increasingly using big data and machine learning tools to support economic analysis and policy decisions, particularly in the areas of economic research, financial stability, and monetary policy. However, feasibility challenges were also identified, such as insufficient information technology (IT) infrastructure, the need to train existing personnel, and the recruitment of qualified new personnel capable of working with big data.

Danielsson et al. (2021), demonstrated that artificial intelligence can support stability in markets through pattern matching and control mechanisms. They argued that when sufficient data is available, AI systems can identify changing patterns faster than humans and increase the reliability of analytical outputs derived from the statistical evaluation of large-scale datasets.

Li (2021) argued that AI has significant effects on financial markets, financial institutions, and financial supervision, and that negative impacts on financial stability can also be expected. This finding indicates that AI can be a source of multi-dimensional vulnerabilities in the financial system, while also supporting the policy recommendation that supervision should be strengthened.

Milana and Ashta (2021), reviewed the literature on artificial intelligence techniques in financial markets. The study observed that both academic and non-academic literature followed the fluctuating

development of the application of artificial intelligence (AI) and computational power to finance and financial markets. The economic growth limitations encountered after the financial crisis and the subsequent recent pandemic outbreaks have presented new challenges for AI-related technologies. The publications reviewed highlighted uncertainties regarding the negative impacts on increasing productivity, new data, information, consulting and management services, risk reduction, and sustainable growth and economic prosperity.

Kinywamaghana and Steffen (2021), focusing particularly on the European Central Bank (ECB) and the Bank of England, examined the use of artificial intelligence and machine learning to support central banks' monetary policy decisions. In their study, they identified four main benefits of artificial intelligence and machine learning for central banks: (i) increasing the production of statistical information, (ii) strengthening macroeconomic analysis capacity and improving trend forecasting, (iii) strengthening the monitoring of financial market indicators, and (iv) improving the assessment of financial risk.

Svetlova (2022) argued that the ethics of artificial intelligence should pay attention to the morally significant systemic impacts of the use of AI. In her study, she linked the literature on the ethics of artificial intelligence to the ethics of systemic risks, clarifying the moral significance of the use of AI in terms of imposing systemic risks and proposing a theoretical framework based on complexity ethics. As a result of this framework, the implications for AI ethics regarding AI-enhanced systemic risks have yielded controversial results.

Danielsson and Uthemann (2023) have argued that AI can weaken financial stability. In this context, risks associated with human misuse of AI and misaligned AI engines have been demonstrated. These dilemmas highlight the dependence of AI applications on governance and security measures and the integration of potential systemic risks into governance frameworks.

Remolina (2023) argues that AI poses a threat to financial stability due to regulators' failure to adopt coordinated AI governance and the limited oversight of AI models. Based on the same source, the potential of AI-powered supervisory technologies (SupTech) to mitigate systemic risks is also discussed. In this context, the risk-reducing effects of SupTech applications are debated. This framework provides an empirical and theoretical basis for strengthening regulatory capacity and restructuring supervisory tools.

Araujo et al. (2023), on the other hand, argue that central banks have adopted machine learning in many use cases. In this context, it is suggested that machine learning, as a component of artificial intelligence, contributes to the efficient processing of information and the improvement of decision-making processes. However, they also point out that the adoption of AI and machine learning tools requires necessary changes in the operational processes of central banks.

Ozili (2024a) examined how artificial intelligence systems can increase financial stability risk

and trigger financial crises. The study revealed that artificial intelligence systems can weaken financial stability by increasing cybersecurity risk and concentration risk, and also increase the risk of interdependence, market distortion, and manipulation.

Andrae (2025) examined the conceptual challenges in the use of artificial intelligence and the transmission channels that can lead to systemic risks. In this context, he presented and tested a simple model using high-frequency trading (HFT) as an example to measure systemic risk. The research revealed that the stochastic and nonlinear nature of artificial intelligence risks makes the routine application of traditional risk assessment methods difficult. The study also emphasized the urgency and importance of comprehensively understanding artificial intelligence risks, especially given the complexity of the financial system, by focusing on systemic risks.

As seen, the current literature presents the findings from various studies in a chronological flow and brings together different perspectives on the relationship between artificial intelligence and financial stability. The views in the literature show that AI carries significant risks as well as potential benefits for central banks and financial regulators. Policy recommendations such as training new employees suitable for AI systems, strengthening IT infrastructure, and increasing transparency and accountability are also critically important for the effective evaluation of developing applications.

3. ARTIFICIAL INTELLIGENCE AND ITS ROLE IN THE FINANCIAL SYSTEM

Artificial intelligence (AI) is generating significant changes in capital markets in terms of efficiency and security. These changes are evident in investor behavior, market analysis, algorithmic trading, and risk management. The main contributions of AI are the faster and more accurate identification of market trends and investment opportunities, and the acceleration of decision-making processes. This effect is particularly noticeable in four main areas (Taş and Aslan, 2025: 13-15):

(1) Faster and more effective trading decisions are made through algorithmic trading,

(2) Price movement predictions and market sentiment measurement are made through the use of big data and deep learning thanks to market forecasts and data analysis,

(3) More effective risk allocation, volatility analysis, and adaptive portfolio strategies can be created through risk management and portfolio optimization,

(4) Early detection of suspicious transactions and support for a secure trading environment can be ensured through financial fraud detection.

In this context, the applications of AI in capital markets are: It offers significant benefits in terms of increasing market efficiency and providing safer trading environments. From algorithmic trading to market prediction, from portfolio management to investor psychology analysis, AI technologies are making capital markets more efficient and effective.

The efficiency of financial markets is expressed by price processes that fully and accurately reflect available information. In this context, the Efficient Market Hypothesis (EMH) argues that market prices accurately reflect available information and that investors make informed decisions. However, in practice, it is known that market efficiency is not always fully valid. In this regard, Artificial Intelligence (AI) technologies offer powerful tools for increasing market efficiency.

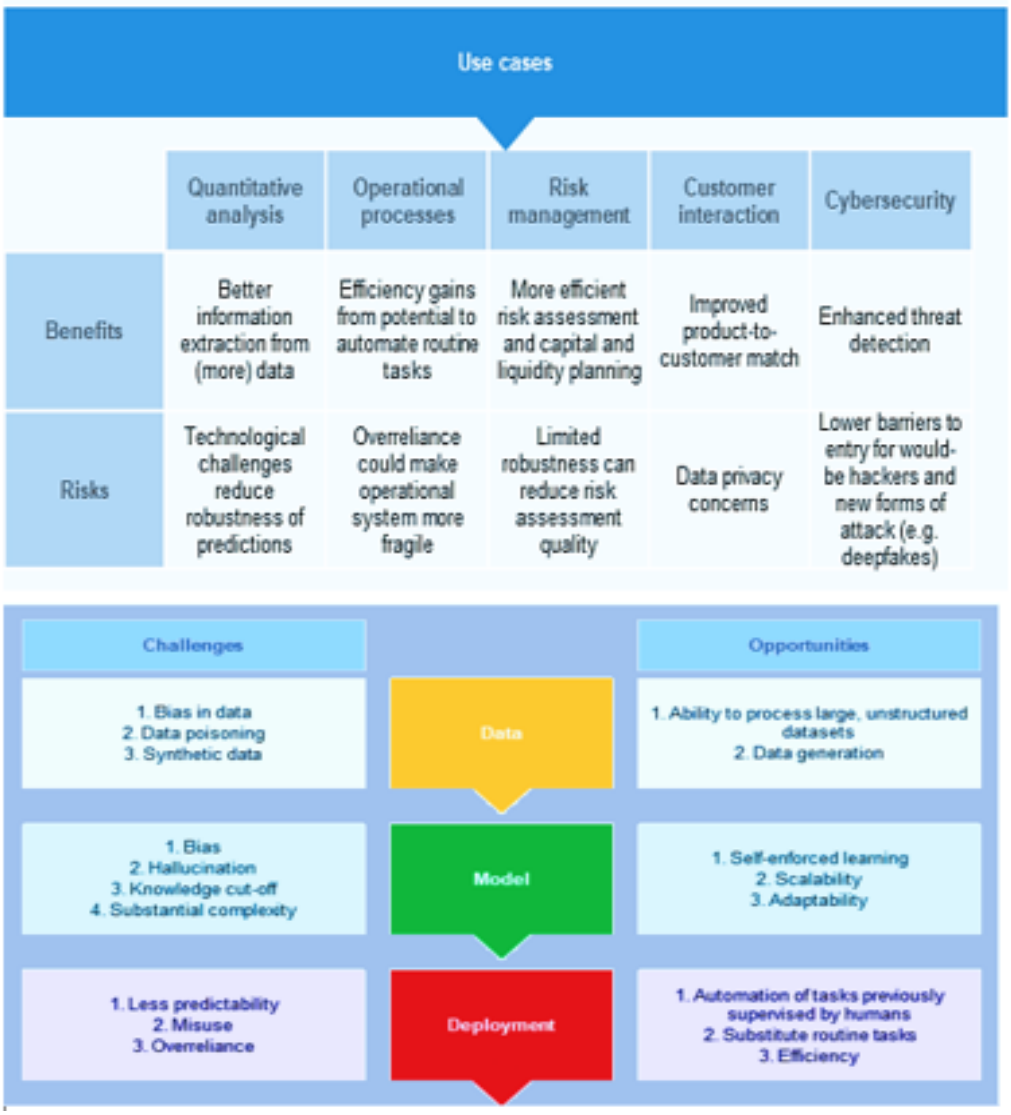
AI enhances market analysis through disciplines such as big data analytics, machine learning, natural language processing, and algorithmic trading, and can improve investor decisions by making information flow more efficient. Machine learning (ML) is one of the most critical technologies for data analysis in financial markets. ML algorithms discover patterns in large datasets and learn from historical data to predict market movements. Such predictions make investor decisions more effective and have the potential to increase market efficiency. Furthermore, ML is an important tool for optimizing investment strategies and strengthening risk management (Kaya and Arslan, 2019).

On the other hand, behaviors such as manipulation and speculation, which can sometimes be seen in financial markets, can weaken market efficiency. AI-based monitoring and detection systems help prevent potential manipulations by identifying abnormal trading activity. Such approaches stand out as a critical tool for market regulation and supervision and can play a role in enhancing efficiency (Yıldız and Çetin, 2020: 100-108).

AI-based credit risk management is concerned with predicting the borrower's likelihood of repayment. AI can use large datasets (e.g., transaction history, shopping behavior, social data, etc.) to more accurately predict repayment ability in credit applications and offer improvements compared to traditional credit scoring systems. This development can strengthen the effectiveness of financial institutions in combating credit risk.

AI-powered risk simulations allow for the execution of potential loss and impact analyses using various economic scenarios and financial data. Thus, financial institutions become better prepared for potential crises, and the effectiveness of risk management strategies increases (Çetin, 2021: 46-56). The contributions of AI in these areas are related to its potential to increase market efficiency, accelerate decision-making processes, and manage risks more effectively. However, issues such as ethics, data privacy, and accountability require the consistent design of policies and regulations. Therefore, the integration of AI into financial markets also necessitates the development of efficiency-oriented policy frameworks.

Figure 1. Benefits and Risks of the Artificial Intelligence-Financial System Relationship



Source: Financial Stability Review, 2024.

Note: The first part of the figure describes the different stages in the development and deployment of an AI system and discusses potential opportunities and challenges. Opportunities and challenges are conveyed throughout the stages and take a specific form in terms of benefits and risks only, depending on the end-use scenario. The table showing use-scenario-specific benefits and risks may change in the future depending on technological developments and how organizations use the technology.

Conducting a comprehensive assessment of the impact of artificial intelligence technology on the financial system is a challenging process, as the technology is still under development. Therefore, discussions about the benefits, risks, and systemic consequences of AI are largely based on assumptions. On the other hand, the benefits and risks of AI depend on the use case. The development and deployment cycle (Figure 1) provide a conceptual framework for a structured assessment of the benefits and risks arising from AI at the individual finance company level. Three fundamental building blocks are necessary to apply AI to a specific use case: training data, the model itself, and the deployment or implementation of the tool.

While AI greatly improves data processing and production, it can also lead to significant data quality issues. AI systems based on basic models can process and analyze unstructured data beyond numerical input. This data includes text, computer code, audio, and images. AI can also be used to manage and generate data. However, the way basic models are trained means they are more likely to "learn" and "maintain" biases or errors found in the data they are trained on. Therefore, basic models can be prone to data quality issues. Another challenge concerns data privacy. In particular, whether publicly accessible systems respect the confidentiality of user input data (e.g., this confidential data may include company-specific information) and whether there is a risk of data leakage.

Artificial intelligence models are adaptable, flexible, and scalable, but they are prone to bias, hallucinations, and greater complexity, which makes them less reliable. The fundamental architecture of AI is built on the ability to be fine-tuned to perform more specific tasks. For example, this can be achieved by training the model on specific data. This feature can significantly increase a model's capabilities in a targeted domain while maintaining its overall generative capabilities. Therefore, AI is adaptable and scalable for different use cases. However, AI is prone to algorithmic bias, and this causes the model to systematically favor certain outcomes, leading to unequal results. It can also present false or misleading information as if it were true, which is known as ''hallucinations''.

Since, current AI models are much more complex than traditional models, it is quite difficult for humans to understand and reconstruct the predictions made. Furthermore, since AI may not be trained with the most up-to-date information available, its capabilities may be limited due to technological information disruptions. When these challenges combine, the robustness of AI predictions is significantly reduced. AI can increase efficiency when deployed. However, its performance is difficult to predict, and it is susceptible to potential misuse or overconfidence.

Thanks to the inherent flexibility of AI, financial institutions are expected to be able to use AI tools in a wide variety of use cases, including tasks previously performed by human labor. This will lead to greater efficiency and significant cost savings. At the same time, such a deployment in new tasks and processes poses risks because it is difficult to predict and control how AI will perform in practice. AI systems can develop unexpected and potentially harmful capabilities when applied to new use cases. Moreover, harmful misuse of AI is not out of the question. For example, criminals can fine-tune and corrupt artificial intelligence, which is normally harmless, for specific operations (e.g., cyberattacks, asymmetric information, market manipulation, using deep fakes to undermine trust in a financial institution, etc.), and this can increase their threat potential.

Financial institutions can be expected to use artificial intelligence in various ways. Given the advanced capabilities of AI and the rich data sources from which financial institutions can make predictions or generate new insights, AI models can be usefully used in areas such as quantitative analysis, operational processes, risk management, customer interaction, and cybersecurity.

However, the robustness and reliability of predictions remain significant challenges. Misleading biases, data quality issues, and model risks are among the most prominent of these. AI's ability to extract and process inputs from various sources (media, reports, interviews, market data, etc.) in real time enables more precise decisions and better outcomes (e.g., trading, asset allocation). However, these processes require independent auditing and accountability. In an operational context, AI can automate internal processes and reduce human resource costs. However, data, model, and deployment challenges can increase operational risk. Furthermore, third-party dependency and data security concerns may increase when underlying models are outsourced.

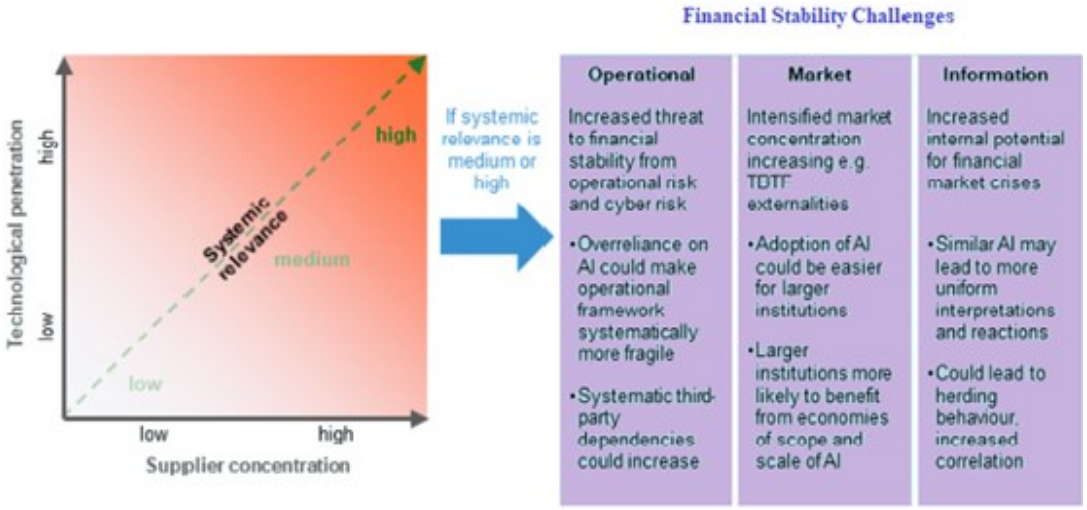
In risk management, AI offers potential benefits in areas such as fraud detection, capital and liquidity risk monitoring/planning, and regulatory compliance, but it can also mitigate or distort risks due to unforeseen errors and biases. Therefore, the use of AI in risk management necessitates careful monitoring for financial stability and accountability mechanisms for stakeholders. On the customer relations side, AI can improve direct customer interaction; it can strengthen product-customer fit through automated chatbots, digital assistants, and personalized recommendations. However, uncontrolled use increases the risks of discrimination and data privacy; the potential for data leaks also brings reputational and legal risks. Therefore, customer-centric practices require strict adherence to security, privacy, and ethical standards. Overall, while AI is expected to increase the operational efficiency and customer focus of financial institutions, ensuring model security, data quality, transparency, and regulatory compliance is critical for the sustainability of these benefits.

The effects of artificial intelligence on financial stability can extend from individual firm applications to the systemic level. Two central factors play a reinforcing role in this process:

(1) technological diffusion, meaning the increasing adoption of AI by more and more financial institutions; this creates AI-related risks and opportunities in many areas of the financial system;

(2) supplier concentration, meaning that if a few providers offer common core models, similar biases and technical challenges can spread throughout the system, increasing supplier dependency. The interaction of these two factors determines whether the benefits and risks arising from individual use cases reach a systemic dimension (left side of Figure 2). If supplier concentration and technological penetration are high, financial stability risks may increase. Conversely, if only a limited number of institutions widely use AI and numerous providers are present, micro-level risks may be more independent and isolated. However, in the case of high penetration and intense supplier dependency, micro-level risks can collectively grow, leading to systemic effects. Such a transition process is gradual but not necessarily linear. These structural dynamics indicate that policy and regulatory frameworks should develop measures that consider systemic stability while considering supplier risk and technological diffusion.

Figure 2. Systemic Amplifiers of Artificial Intelligence and Financial Stability Problems



Source: Financial Stability Review, 2024.
Note: The left side of the graph shows how the interaction between widespread use of AI (technological penetration) and supplier concentration of AI models can elevate institution-level benefits and risks to a systemic level, as explained in Figure 1. Different combinations lead to different levels of systemic importance. Systemic importance increases with technological penetration and supplier concentration, but not necessarily linearly; it is shown linearly here for illustrative purposes. If systemic importance is given, institution-specific benefits and risks can lead to financial stability issues that can be broadly categorized into three main categories. Given the future technological development and use of AI by financial institutions, further financial stability outcomes may arise through these three main channels.

The effects of artificial intelligence on financial stability can reach systemic levels through technological diffusion and supplier concentration. Two key drivers drive this process:

(1) Technological diffusion, i.e., the expansion of artificial intelligence among financial institutions. This diffusion can have far-reaching effects on operational efficiency, risk management, and market functioning.

(2) Supplier concentration, where a few providers offer similar basic models, can permeate biases, technical challenges, and supplier dependency throughout the system. The interaction of these two elements determines whether the benefits and risks that arise at the micro level reach systemic dimensions. In cases of supplier concentration and high technological penetration, financial stability risks may increase. This is because reliance on a limited number of providers leads to a point of failure and the proliferation of operational and cyber risks.

On the other hand, when differences between some institutions are strained and market concentration is high, market competition weakens, potentially harming consumer welfare and stability due to costs and external influences. However, due to high investment requirements, some institutions may miss the transition and be pulled out of the market. This could trigger a sharp concentration in the market structure and potentially "too big to fail" externalities. The adoption of AI by numerous institutions and the availability of similar models from a few large providers could increase the risks of uniformity and bias in information processing. This could lead to over correlation in asset prices, herd behavior, and market vulnerabilities. The widespread impact on retail investors could result in increased

trading volume and price volatility.

Defining a technological adoption strategy requires a complex balance between partnering with external suppliers and developing in-house AI expertise. Furthermore, in-house capabilities may become more viable if open-source underlying architectures become widespread. Consequently, decisions determining the levels of technological penetration and supplier concentration are critical to the resilience of financial stability. Otherwise, chronic financial instability could bring with it the risk of a financial crisis.

The potential mechanisms by which AI could trigger financial crisis risks are addressed in three main dimensions: Firstly, the dynamics of herding behavior. If financial institutions use similar algorithms and similar datasets, the likelihood of actors simultaneously implementing similar risk actions may increase. This situation can result in extreme movements in asset prices, liquidity pressures, and credit crunch, increasing the threat to financial stability (Mavruk, 2022).

Secondly, the risks related to the interpretability and explainability of AI decisions. Analyses and decisions generated by complex models often contain errors or biases that are difficult to explain. This can lead to misleading indications for regulators and delay regulatory interventions, thus exacerbating the risk of crisis (Ozili, 2024b).

Thirdly, there is the potential for existing crises to worsen. AI systems trained on historical data may not reflect current shocks and therefore may deepen the crisis by producing erroneous decisions. Algorithms trained on data that cannot reflect current crisis conditions can similarly increase risks. In conclusion, the potential of AI to trigger or exacerbate crises can make crisis dynamics fragile and limit the effectiveness of interventions, depending on the data and model characteristics used. Therefore, transparency, explainability, model reliability, and regulatory compliance are critical in AI-based decision-making processes (Kearns, 2023).

Due to the limited availability of financial crisis data, artificial intelligence (AI) may struggle to predict future crises. In developed countries, a major financial crisis may occur at least every 20 years, while in crisis-prone, less developed or developing countries, it may occur every 10 years. This is attributed to the scarcity of historical crisis data. Because of this limitation, financial institutions argue that AI models trained with very limited crisis data may produce misleading decisions in predicting future crises (Shah, 2015).

Furthermore, AI applications have the potential to accelerate bank flight, leading to rapid and widespread out-of-liquidity transfers through digital banking. Especially with the proliferation of AI-powered mobile banking tools, depositors can transfer money from distressed banks in seconds; this could accelerate liquidity crunch, paving the way for bank failures and subsequent financial crises.

As individuals and businesses increasingly rely on AI tools in financial markets and the banking

sector, decision-making speed may accelerate. Rapid decision-making can lead to increased stress in markets and trigger crisis risk. Investors may use AI-powered mobile applications to quickly move their savings to safe-haven assets when a sense of panic arises in the financial system; companies, on the other hand, may use AI tools to quickly assess the cost of an impending crisis by delaying employment and investment decisions or resorting to cost-saving policies such as layoffs. Such rapid decisions spread pressure on the financial and real sectors, encourage behaviors such as liquidity hoarding and fire-selling, and ultimately lead to a financial crisis (Ozili, 2024a: 8).

In conclusion, in an environment where crises spread rapidly, the dynamics of AI influencing decision-making processes can trigger or exacerbate crises through liquidity pressure, bank flight, and productivity-reducing behaviors aimed at cost-saving. Therefore, policy recommendations aimed at strengthening the reliability, transparency, and regulatory compliance of AI-based decision-making processes, along with mechanisms for early crisis detection and response, are of critical importance.

4. CONCLUSION

This study examines the potential positive and negative impacts of artificial intelligence (AI) on financial stability within a theoretical framework concerning systemic risk. To this end, the discussions on the subject in the literature are first analyzed in depth. Then, the benefits and potential harms that AI creates/can create in the financial system are discussed. Thus, how AI can affect financial stability and the mechanisms by which it can trigger systemic risk and potential financial crisis scenarios are examined.

AI's ability to accelerate decision-making processes by increasing efficiency and the risk-reward spread can lead to increased market efficiency and faster reflection of risks. However, these advantages also have the potential to increase instability through mechanisms such as herd behavior, bias-based errors, and lack of explainability. In particular, data and model dependency can fuel systemic vulnerabilities by triggering coordinated actions based on similar decisions. This situation can amplify risks such as liquidity crunch, market-disrupting behaviors, and synchronization in credit risks. Furthermore, the increase in computational power can lead to faster decision-making speed and increased risk-taking tendencies under stress, causing crises to transform into rapidly spreading dynamics. Therefore, policy-making and regulatory frameworks need to be strengthened to ensure the transparency, accountability, and reliability of AI-based decision-making processes. Regulations should develop comprehensive oversight and flexible compliance mechanisms in areas such as third-party service providers and operational resilience; they should also focus on predicting potential financial crisis scenarios through simulation and scenario analysis and developing rapid response strategies in crisis situations. Ultimately, the effects of AI on financial stability are evolving in parallel with technological advancements and have the potential to mitigate systemic risks if balanced with reliability, transparency, and appropriate oversight frameworks.

At the same time, the results have revealed the need to identify the main risk areas where AI could undermine financial stability. Otherwise, an increase in cybersecurity threats, growing concentration risk, vulnerabilities among interdependent actors, and increased possibilities of market distortion and manipulation will be inevitable. In this context, it is necessary to focus on mechanisms such as AI's potential to trigger herd behavior, misleading interpretations and lack of explainability, its capacity to deepen potential financial crises, and the increase in financial stress levels due to accelerated liquidity flows and shortened decision-making times through digital banking. In light of these identified risks, central banks and financial regulators need to continuously assess how AI algorithms and systems can increase risk under stressful conditions.

Regulators, especially central banks, need to update their existing structures to anticipate and mitigate AI risks; they need to improve their financial oversight systems to monitor the rapidly changing AI environment and capture emerging risks. Furthermore, broader powers may be needed to oversee the operational resilience of technology companies providing key AI services and to adequately mitigate third-party risks.

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TAX HAVENS REBRANDING: INTERNATIONAL TAX TREATIES

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ABSTRACT

The legal tensions between municipal and international law within the economic realm are amplified in the case of multinational enterprises (MNEs) and their tax liabilities. The theoretical significance of international tax regimes through international tax treaties aims to address conflicts arising from the application of national tax laws on MNEs. These international tax treaties are often dubbed as 'Double Tax Treaties' (DTTs). The DTTs allow national tax authorities to cooperate at an international level and tackle challenges like the harmonization of taxation policies aimed at attracting and retaining MNEs without causing double taxation. The outliers of international tax regimes consist of tax haven jurisdictions promoting tax avoidance as an incentive to attract MNEs. The tax havens have rebranded as offshore tax jurisdictions to shed the negative image of being the primary vehicles for tax avoidance and being complicit in 'money laundering' schemes. The 2003-2008 HSBC multi-billion-dollar drug cartel money laundering scam is a case in point. This paper examines the International Tax Law and the global socio-economic impact of the so-called offshore jurisdictions.

Keywords: Tax Avoidance, Tax Havens, Offshore Tax Jurisdictions, International Law, International Tax Treaties, Double Tax Treaties

JEL Codes: H26, K33, F38

1. INTRODUCTION

The legal system of international taxation rests on two broad objectives. The first objective is to resolve the problems of double taxation. The second objective is to facilitate cross-border trade and investment through the elimination of any taxation regimes that would hinder these cross-border flows(Rohatgi, 2005). Both of these primary objectives are achieved through international taxation treaties(Gordon and Hines Jr, 2002).

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There are ancillary objectives, such as the prevention of tax evasion and tax avoidance. This phenomenon is also referred to in the literature as "*double non-taxation*"(Marchgraber, 2016). Literature suggests that tolerance of tax evasion and tax avoidance creates unfair incentives for international trade and commerce, as well as depriving governments of their revenues for social development (Christensen and Murphy, 2004). Countries or legal jurisdictions that promote tax avoidance are referred to as '*Tax Havens'*. The International community has increasingly demanded the shutting of these tax havens to rid the problems of tax avoidance and tax evasion by wealthy individuals and mega-corporations (Wilson and Fullwood, 2013).

These tax havens, in return, labelled themselves as "*Offshore financial centres*". The 2012 HSBC 300 billion-dollar Mexican narco trade money-laundering operation through a British Overseas Territory (OT) brought added emphasis on this problem. International criminal law literature refers to these tax havens as the centres that also fund and launder global organised crime proceeds (Rose-Ackerman and Palifka, 2018).

There are over 3000 bilateral international tax treaties (Arnold, 2013). On the other hand, there are a very small number of multilateral tax treaties. Almost all the international bilateral tax treaties are based on the Organisation for Economic Co-operation and Development Model Tax Convention on Income and Capital (OECD Model) and the United Nations Model Double Taxation Convention between Developed and Developing Countries "UN Model Convention" (Bravo, 2016).

Most of the 3000 plus international bilateral tax treaties are titled as "Tax Agreements" or "Tax Conventions". Article 2 of the Vienna Convention on the Law of Treaties (VCLT 1969) governs these treaties. VCLT 1969 states that "*A treaty is an international agreement (in one or more instruments, whatever called) concluded between States and governed by international law*." The wording of Article 2 VCLT 1969 makes it clear that the label of the instrument is not important.

This main paper examines the international tax treaty regimes and their impact on the global economy. The paper will also touch upon the UN Sustainable Development Goals for 2030 (UN SDGs 2030) and Climate Change within the context of international taxation.

2. INTERNATIONAL TAX LAW and TREATIES

The legal doctrine of *pacta sunt servanda*, or that an *agreement must be kept,* governs international bilateral treaties in general. The same principle applies to bilateral tax treaties. Article 26 of VCLT 1969 states that "*treaties are binding on all States and must be performed in good faith"*(Binder, 2008). The principle of *Reciprocity* is one of the fundamental principles of international bilateral tax treaties (Mann, 1981). These bilateral international tax treaties target the domestic tax legislation to affect within the national laws. The national tax systems globally are based on two broad principles. The first principle is the "*residence principle*", and the second principle is the "*source*

principle"(Shome, 1995).

The residence principle applies to the place of residence of the taxpayers (corporate as well as individuals) to calculate and impose the tax liabilities. The source principle relies on the source of income of the individual or the corporate personality to calculate and impose the tax liabilities. Both tax principles usually follow the international economics rule of '*home country-foreign country'* to explain the tax liabilities. All international bilateral tax treaties follow the residence principle or the source principle as their underlying principles of taxation (Cappelen, 1999).

3. INTERNATIONAL TAX TREATIES - OECD MODEL CONVENTION

The OECD countries that are usually referred to as the developed countries favor the OECD Model Convention. The OECD Model Convention is prescriptive in nature, and the adoption of bilateral treaties under the OECD Model Convention aims to achieve consistency and avoid double taxation as far as possible. The bilateral tax treaties under the OECD Model Convention address the central issue of income/profits tax between the States. The issue to be addressed is about the extent of tax rights that may be relinquished by the source country (origin of the income) on the income/profits of the investments in favor of the country of residence (Jones, 2009). The OECD Model Convention favours investment capital-exporting countries over investment capital-importing countries.

The OECD Model Convention has all 34 members of the OECD. It was first drafted and published in 1963. Since then, it has been periodically updated. The last update was done in 2017. The OECD Committee on Fiscal Affairs (CFA) publish an article-by-article commentary of the OECD Model Convention. Since there are hundreds of international bilateral tax treaties formed based on the OECD Model Convention, it was found useful to update the commentaries rather than make any changes to the article. It was done so that the countries may interpret the article in light of the revised commentaries and don't have to update every bilateral agreement that relies on the Model Convention articles (Owens and Bennett, 2008).

4. INTERNATIONAL TAX TREATIES – UN MODEL CONVENTION

The United Nations Model Convention is generally the source convention for the developing countries negotiating international bilateral tax treaties. The UN Model Convention favours the source of income country's right to tax. The reason for this preference reflects the inclusion of the UN Model Convention as the legal source for bilateral tax treaties in the developing world. The favouring of the source of income countries to tax the income and profits allows for the host country of investment to attract foreign investments. Such bilateral tax treaties, when negotiated under the UN Model Conventions, reduce the taxing ability of the residence country of the individual or the corporate legal personality.

The UN Economic and Social Council resolution 1273 of 4 August 1967 started the work on the

UN Model Convention (Economic, 1980). The UN Model Convention provides the guidelines for the negotiation of bilateral tax treaties between the investment capital-exporting countries (developed economies) and investment capital-importing countries (developing economies). Unlike the OECD Model Convention, the UN Model Convention is a non-prescriptive instrument that allows flexibility to the treaty-negotiating countries. The UN Model Convention was finally adopted in 1980 and has been revised many times since its adoption (Daurer, 2014).

5. ECONOMIC IMPACT OF TAX HAVENS

The Corporate tax havens impede economic development by eroding tax revenues in developing countries. Multinational enterprises shift profits to low-tax jurisdictions, resulting in an estimated global annual tax revenue loss of over US$600 billion according to the International Monetary Fund (Radu, 2012).

Nicholas Shaxson is a British investigative journalist. His research is focused on the impact of tax havens, or so-called offshore financial jurisdictions and their adverse impact on the global economy due to tax avoidance. Shaxson's research titled. "Taxing Tax Havens" caused some stir due to its precise and pointed factual criticism of tax havens.[3] Shaxson described the behaviour of multinational corporations to avoid taxation by using various tax havens around the world. Shaxson detailed the impact of corporate tax evasion and its impact as follows:

Tax havens collectively cost governments between $500 billion and $600 billion a year in lost corporate tax revenue, depending on the estimate, through legal and not-so-legal means. Of that lost revenue, low-income economies account for some $200 billion—a larger hit as a percentage of GDP than advanced economies and more than the $150 billion or so they receive each year in foreign development assistance. American Fortune 500 companies alone held an estimated $2.6 trillion offshore in 2017, though a small portion of that has been repatriated following US tax reforms in 2018 (Crivelli, de Mooij, and Keen 2018).

Tax havens exacerbate social inequality by enabling the wealthy and corporations to avoid taxes, shifting the burden to ordinary citizens and reducing government revenue for public services like healthcare and education. This leads to greater income disparity, with the gap widening between the rich and the poor, and negatively impacts job prospects for the working and lower-middle classes in host countries.

Wealthy individuals and corporations use offshore accounts and complex legal structures to avoid or evade taxes, which results in lower tax revenues for governments. This forces governments to rely on other forms of revenue, such as income or consumption taxes, which disproportionately affect low- and middle-income earners. With less revenue, governments in host countries have fewer funds to invest in

[3] Shaxson, Nicholas. "How to crack down on tax havens: Start with the banks." Foreign Aff. 97 (2018): 94.

essential public services like education, healthcare, and poverty reduction programs. This disproportionately harms the less privileged, who depend on these services.

Tax havens create economic disruption and foster economic inequality by distorting market competition, as companies adept at tax avoidance gain an unfair advantage. This can lead to fewer job opportunities for workers as domestic businesses struggle to compete. Offshore wealth is extremely concentrated at the top of the wealth distribution, with a significant portion of it belonging to the wealthiest 0.01% of households, further deepening the wealth gap. Research shows a robust positive relationship between tax haven status and domestic income inequality, meaning tax havens are associated with higher market income inequality and larger income disparities.

The low-tax jurisdictions and their associated economic activities appear to economically harm lower-income groups in host countries, as the overall economic benefits do not trickle down to them. The reduction in tax revenues can lead to cuts in public sector employment, which can disproportionately affect the middle class and the poor who rely on these jobs.

6. ECONOMIC COMPLEXITY OF TAX AVOIDANCE

The economic concepts of open and closed economies are very relevant for understanding the behaviour of individual and corporate legal personalities to various international tax regimes in a *Globalised* World (Frenkel et al., 1991). It is easier to achieve an equilibrium through tax policies in a closed economy, as there is no inflow or outflow of capital or goods. Except for countries like Cuba, North Korea and Iran, that are under heavy US sanctions and are considered classical closed economies, the rest of the world is by and large open economies.

The situation with open economies is very different. The complexities become starker for open economies as there are tax variants on the industries and income types that would influence how the net inflow or outflow of capital takes place (Frenkel et al. 1991). adequately addressed the emerging problems of the open and closed economies in the globalised world. Frenkel et al. (1991) suggest that the efficiency of any bilateral tax treaty in developed economies (which are all open economies) rests on how the world aggregate savings and investments behave under the various international tax regimes.

This is true as the world economic markets are sensitive to inefficient allocation of world savings for various development sectors if there exists a wide margin between the pre-tax interest rates and post-tax interest rates under various tax treaties. According to the CEO of BlackRock Investment, Rob Katipo, " *there is more than $US50 trillion in cash sitting idle in portfolios around the world due to a lack of investment opportunities and weak returns created by the pre-tax and post-tax interest rates due to tax policies"* BlackRock Investment has the world's largest portfolio of investment funds (Black Rock Investment, 2019).

Open economies also struggle with applying cross-border taxation regimes using bilateral tax

treaties and using differential income tax rates on profits earned by different industries. Such differential income tax rates alter the pattern of foreign trade flows. Differential income tax also leads to increased exports from industries that receive favourable tax treatment to the detriment of industries that face higher taxation (Hines Jr and Summers, 2009).

The bilateral tax treaties also create a competitive taxation environment that influences the seat-of-administration and seat-of-operation decisions of multi-national firms that are capable of earning '*above*' the market-expectation profits. The market behaviour of firms like Google, Facebook, Apple and Amazon has come under criticism for tax-jurisdiction shopping by showing their stock market share values reacting to the sensitive tax differentials. Such taxation challenges have been discussed in the literature under the heading of managing '*global wealth chains'* (Seabrooke and Wigan, 2017).

Individual investors with global portfolios also react to bilateral tax treaties that influence the rates of return on domestic as well as foreign treasury investment products. The domestic rates of wealth, capital, production and income tax that are adjusted due to any bilateral international tax treaties affect the financial as well as investment behaviour of large individual investors and multinational firms (Sauvant and Sachs, 2009). The differences created in the domestic tax policies due to international bilateral tax treaties do not affect the tax rates, but they affect the choices of residence and choices of origin for large corporations to locate their foreign operations. These competing tax jurisdictions also influence the scale of foreign inflow and outflow of capital, the trends in corporate preference for the location of borrowing, etc (Sikka and Willmott, 2010).

The tax competition environment internationally gives rise to a host of negative influences that can impact the global economy by concentrating the profits residing in tax havens and taking away the tax benefits from nations that are the source/origin of the profits. Such a situation gives the multinational companies a wide discretion in choosing the prices used to conduct transactions between members of its affiliated group. Such price selection within the members of an affiliate group allows the group to report accounting profits in tax-favoured locations such as the tax havens, where token offices are established to leverage the residence-based tax-free regimes (Gravelle, 2010).

7. UN SDGs and INTERNATIONAL TAXATION

In 2013, the leaders of G-20 nations came together and endorsed the OECD Base Erosion and Profit Shifting (BEPS) program. The program is also endorsed by the UN. The BESP is a global program that will ensure that profits are taxed where economic activities take place and where value is created (origin of profits). The 2015 report of BESP states that the global corporate income tax (CIT) revenue losses are about 10% of global CIT revenues, amounting to USD 100 to 240 billion annually (*OECD BEPS*, 2015).

The CIT losses are primarily due to aggressive tax planning by some multinational enterprises

(MNEs) that seek competitive tax jurisdictions to avoid taxation by reporting profits in tax havens. Some of the other reasons for the CIT tax losses are due to the interaction of domestic tax rules, lack of tax transparency regimes and lack of coordination between tax enforcement agencies, etc.

According to OECD, "135 countries and jurisdictions are collaborating on the implementation of 15 measures to tackle tax avoidance, improve the coherence of international tax rules and ensure a more transparent tax environment"(BEPS Actions, 2019). These measures are to support the UN SDGs for 2030 and would strengthen the global community's resolve to eradicate poverty, hunger and disease from the world.

In 2018, the UN, the OECD, the IMF and the World Bank Group (WBG) came together to create a common framework that would integrate the OECD BEPS into the UN SDGs agendas. These organisations are collectively working to work with governments around the world and help them strengthen, align and coordinate their resources through taxation. These collective resources would be used to meet the UN SDGs for inclusive economic growth (First Global Conference of the Platform for Collaboration on Tax - Taxation and the Sustainable Development Goals, 2018).

The challenges of collecting international tax from MNEs are much greater for developing countries that lack the resources to collect those taxes to provide basic services, such as road infrastructure, healthcare, and public safety. WBG indicates that almost 30 of the 75 poorest countries cannot collect the tax revenues to meet the basic social services. The linkages between international taxation and UN SDGs are a relatively new topic of discussion. The OECD BEPS, along with the UN SDGs, are making strides in sponsoring scholarship and research to come up with tools for the developing countries so that the crucial UN SDGs, such as eradication of poverty, hunger and critical health services, can be addressed in the coming years (Mosquera Valderrama et al., 2018).

8. CLIMATE CHANGE, CARBON PRICING AND TAXATION

The climate change debate has escalated globally in the last two years. The various international environmental conventions under the auspices of the UN bring urgent attention to this important matter facing mankind. The UN Framework Convention on Climate Change (UNFCCC) paved the way for opening the climate change debate in 1992. The UNFCCC led to the 1992 Kyoto Accord that became the first agreement between nations to mandate country-by-country reductions in greenhouse-gas emissions. In 2015, the Paris Agreement followed under UNFCCC to keep global temperature rise during this century 2 degrees Celsius above the pre-industrial age and try to further limit the temperature rise to 1.5 degrees Celsius above the pre-industrial age (Roberts, 2016).

The important conclusion drawn by all UNFCCC conferences is that all countries have a common but *differentiated responsibility* towards climate change. The Durban Conference of 2011, COP 17 (17th Conference of the Parties), highlighted that the developed, as well as the developing countries, will have

to share responsibilities to mitigate the challenges of global climate change starting in 2020 (Den Elzen et al., 2013). The *global participation* element of the 17th COP to collectively tackle climate change rhymes with the international taxation *collective action agenda* of the OECD BEPS to support UN SDGs 2030.

The carbon pricing mechanism under the Paris Agreement 2015 is highlighted in Article 6.2 (Paris Agreement 2015, 2015). Paris Agreement Article 6.2 established the "*potential of trading emission reduction credits across borders, between nations or jurisdictions*". This would encourage a reduction in carbon emissions that would be impossible to achieve under any domestic tax regime. Article 6.4 aimed to create "*a new international mitigation mechanism to help countries reduce emissions and promote sustainable development*." The effect of this provision is to allow non-parties to the Paris Agreement to be able to trade emission credits with parties to the agreement. Finally, Article 6.5 aims to put in place "*robust accounting measures to avoid double counting of emission reductions and increase transparency, thereby ensuring the integrity of the proposed market-based approaches*."

Paris Agreement Article 6.2 explains the avoidance of double taxation in carbon credits, also in line with the main objective of international taxation treaties (Stua, 2017). The trading system of carbon credits under the Paris Agreement has added another dimension to the existing international taxation regimes.

9. CONCLUSION

The UN Model Convention and the OECD Model Convention for international bilateral taxation treaties have achieved astonishing success. This is one area of international law that has seen harmonious and collaborative development globally. The core objectives of international taxation treaties seek to abolish double taxation and promote the free flow of capital and goods across borders. Both model conventions have helped to achieve these objectives through bilateral taxation treaties.

The prescriptive nature of the OECD Model Convention and the non-prescriptive nature of the UN Model Convention allow for meeting the needs of the developed and the developing nations, respectively. The economic challenges of closed and open economies are also adequately addressed by both conventions. The residence-based tax regimes are well addressed by the OECD Model Conventions, and the origin-based tax regimes are best served by the UN Model Conventions.

The urgent climate change agendas and the sustainable development needs of the globe are adequately addressed through the various UN initiatives for sustainable development and climate change. The international taxation system is gearing up to provide solutions to the economies in the developed and developing worlds to collectively, and with differential responsibilities, tackle the global economic challenges. While the system may not be perfect in terms of its governance challenges, it does provide for practical solutions and negotiation mechanisms through bilateral taxation treaties to get the

results.

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INTERNATIONAL TAXATION CHALLENGES IN CHINA AND THEIR IMPACT ON AFRICA

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ABSTRACT

China–Africa economic relations have deepened significantly, creating opportunities for growth and sustainable development. However, this integration brings complex international tax challenges that intersect with structural weaknesses in many African tax administrations. While China enforces strong domestic anti-avoidance measures and participates in initiatives such as the OECD/G20 Inclusive Framework on Base Erosion and Profit Shifting (BEPS), the practices of Chinese multinational enterprises—such as intricate project financing and the use of intermediary jurisdictions—pose risks of base erosion and profit shifting (BEPS) in African states with limited enforcement capacity. Addressing these risks requires coordinated, multi-level strategies. African countries must strengthen institutional capacity in tax administration, audits, and enforcement, while adopting development-oriented treaty policies and renegotiating bilateral investment treaties (BITs) and double taxation agreements (DTAs) to curb treaty shopping. On the Chinese side, greater transparency and collaboration from government and enterprises are essential to align with global tax norms and discourage aggressive tax planning. A broader reform of the international tax system is equally critical. Current frameworks, often OECD-centric, should evolve to reflect the needs of developing economies by ensuring equitable allocation of taxing rights and promoting global tax justice. Multilateral organizations—including the UN Tax Committee, OECD, and African Tax Administration Forum—must provide technical assistance, legal modernization, and tailored adoption of global tax instruments to support African priorities. Ultimately, China–Africa engagement offers mutual benefits only if paired with robust legal and institutional reforms, international cooperation, and an inclusive tax architecture. These measures will enable African states to mobilize domestic resources effectively, secure a fair share of economic gains, and advance the Sustainable Development Goals (SDGs).

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1. INTRODUCTION

Over the past two decades, the economic relationship between the People's Republic of China and African nations has profoundly transformed. Bilateral trade flows, foreign direct investment (FDI), infrastructure contracting, and development financing have expanded unprecedentedly, positioning China as a leading economic partner for the African continent. This dynamic interaction has generated considerable growth and structural transformation opportunities in African economies. However, it has also introduced intricate governance and regulatory challenges, particularly in taxation. Taxation constitutes a fundamental pillar of state sovereignty, serving as a primary source of public revenue and a critical mechanism for economic governance, redistribution, and development financing. In cross-border transactions, taxation plays a dual role: it shapes the allocation of taxing rights between jurisdictions (Crivelli et al., 2016). It influences corporate behavior concerning investment location, profit reporting, and compliance strategies. As such, the expansion of Sino-African economic ties has significant implications for the fiscal capacity of African states and the design of their tax policy frameworks. Despite the centrality of taxation to state-building and sustainable development, scholarly and policy-oriented literature reveals a notable gap in systematic analysis linking China's evolving international tax policy and administration to the fiscal realities of African states. This lacuna is particularly salient given recent global initiatives, such as the OECD/G20 Base Erosion and Profit Shifting (BEPS) Project and the Two-Pillar Solution (including the Global Anti-Base Erosion (GloBE) rules under Pillar Two), which aim to recalibrate the international tax order in response to profit shifting and aggressive tax planning by multinational enterprises (MNEs). China's engagement with these initiatives—both as a participant in global tax governance and as a source of outward investment—has critical repercussions for African tax systems (Crivelli et al., 2016). Accordingly, this paper seeks to provide a consolidated and analytically rigorous examination of the international taxation challenges emerging from China's integration into the global economy and their implications for African public finances (Dover, 2016). It adopts a legal and policy-oriented perspective, focusing on five interrelated dimensions:

- An analysis of China's participation in global tax governance forums, including its implementation of BEPS measures and its position on the GloBE rules under Pillar Two.
- **Domestic Chinese Tax Rules and Transfer Pricing Regulations:** A detailed discussion of Chinese corporate income tax law, anti-avoidance provisions, and transfer pricing enforcement, with attention to their extraterritorial effects on African jurisdictions.

- **Structure and Utilization of China–Africa Tax Treaties:** Examining China's bilateral tax treaties with African states, including treaty provisions on withholding taxes, permanent establishment rules, and treaty-shopping risks.
- **Channels of Base Erosion and Profit Shifting (BEPS) in Sino-African Transactions:** Identification of practical mechanisms through which profit shifting occurs, including underpricing of commodities, intra-group financing, and the use of low-tax jurisdictions linked to Chinese investment chains.

Policy Responses and Reform Imperatives: Consideration of legal and institutional measures for African countries to safeguard their tax bases, enhance transfer pricing capacity, and engage effectively in international tax reform processes (Etter-Phoya et al., 2020). This paper aims to contribute to academic discourse and practical policy formulation by articulating a nuanced understanding of how China's tax policies intersect with African fiscal sovereignty within an evolving international tax regime. Ultimately, it underscores the urgency of aligning domestic tax reforms, treaty negotiations, and administrative capacity-building with emerging global standards to ensure equitable and sustainable revenue mobilization in an era of deepening economic interdependence (Ait Abdellouhab and Radaelli, 2023).

2. LITERATURE AND POLICY BACKGROUND

China has undergone a significant transformation in its role within global tax governance, evolving from a peripheral actor to a central—and at times contestatory—participant in the international tax regime. Historically, global tax governance has been dominated by the Organisation for Economic Cooperation and Development (OECD), which has promoted principles such as the arm's-length principle (ALP) as the foundation for transfer pricing rules. However, China has increasingly challenged the universality and appropriateness of these OECD-centric norms (Oguttu, 2015). Scholarly literature underscores China's advocacy for source-based taxation and its skepticism toward an exclusive reliance on the ALP, given the importance of location-specific advantages and intangibles in its economic model. Chinese policymakers have articulated the need for a greater voice for emerging economies in formulating international tax standards. This leads to friction with traditional OECD members and creates opportunities for normative pluralism in global rule-making. China's participation in multilateral platforms such as the Inclusive Framework on BEPS (Base Erosion and Profit Shifting) demonstrates a selective engagement strategy: it adopts specific standards to protect its tax base while resisting elements perceived as favoring residence jurisdictions (Oguttu, 2017). For example, while China has endorsed the Multilateral Instrument (MLI) to implement treaty-related BEPS measures, its domestic legislation reflects distinctive administrative and enforcement priorities. The OECD/G20 BEPS Project (2013–2015) marked a paradigm shift in the global approach to tackling tax avoidance, particularly by multinational enterprises (MNEs). China has incorporated numerous BEPS recommendations into its

domestic tax system, including country-by-country reporting (CbCR), expanded transfer pricing documentation, and special tax adjustment measures. These measures are codified primarily under the Enterprise Income Tax Law (EITL) and its implementing regulations. Chinese tax authorities, notably the State Taxation Administration (STA), have intensified enforcement through transfer pricing audits, cost-sharing arrangement reviews, and special adjustments under Article 41 of the EITL, which permits reassessment of related-party transactions that do not align with the arm's-length principle (Gnassou, 2020).

Additionally, General Anti-Avoidance Rules (GAAR)—introduced in 2008 and reinforced under the 2015 Administrative Measures—empower authorities to disregard arrangements lacking a reasonable commercial purpose, particularly in cross-border structures. Despite formal alignment with OECD standards, China's approach reflects a domestic policy agenda prioritizing protection of location-specific advantages (LSAs) and market intangibles, often resulting in pragmatic adaptations of BEPS recommendations rather than strict transplantation. Enforcement remains uneven across regions, reflecting capacity constraints and administrative discretion (Adera, 2024).

The OECD's Pillar Two framework, finalized in December 2021, introduces a global minimum tax rate of 15% on large multinational groups, operationalized through the Global Anti-Base Erosion (GloBE) rules. The objective is to curtail profit shifting to low-tax jurisdictions by ensuring a minimum level of taxation regardless of where profits are booked. China's stance on Pillar Two has been characterized by cautious endorsement without immediate legislative transposition. While some regional jurisdictions—such as Hong Kong and Singapore—have moved toward adopting Qualified Domestic Minimum Top-up Taxes (QDMTTs) to retain taxing rights, China has not yet issued comprehensive implementation regulations as of mid-2025 (Katterbauer, 2023). Policy discussions suggest a preference for evaluating the potential revenue impact and competitiveness implications before committing to complete alignment. The uneven global adoption of Pillar Two, coupled with legislative uncertainty in the United States and political debates in the European Union, creates significant ambiguity regarding its effectiveness and administrative feasibility. For China, key legal considerations include the interaction of GloBE with existing preferential tax regimes (e.g., high-tech enterprise incentives) and the implications for foreign direct investment (FDI) attraction strategies (Cui et al., 2024).

African jurisdictions face profound structural and institutional challenges in mobilizing domestic revenue. The average tax-to-GDP ratio in Sub-Saharan Africa remains significantly below the OECD average, constrained by factors such as limited administrative capacity, high informality, and erosion of tax bases through illicit financial flows (IFFs) and aggressive tax planning by multinationals. Africa's bilateral tax treaty network is a critical dimension of its vulnerability. Many existing double taxation agreements (DTAs)—particularly older treaties negotiated under asymmetric power conditions—grant excessive concessions to residence jurisdictions, facilitating treaty shopping and erosion of withholding

tax rights on dividends, interest, and royalties. These dynamics effectively convert treaties into instruments of tax expenditure rather than revenue protection. Regional organizations and international bodies have advanced various initiatives to strengthen tax governance, including the African Tax Administration Forum (ATAF), OECD's Inclusive Framework, and technical assistance programs by the International Monetary Fund (IMF). These programs emphasize capacity-building in transfer pricing enforcement, exchange of information (EOI) under the Multilateral Convention on Mutual Administrative Assistance in Tax Matters, and developing domestic anti-abuse rules consistent with international best practices. Recent reforms also target the implementation of beneficial ownership registries, the adoption of automatic exchange of information (AEOI) standards under the Common Reporting Standard (CRS), and the renegotiation of legacy DTAs to incorporate Principal Purpose Test (PPT) clauses mandated under the BEPS minimum standard (Katterbauer et al., 2025).

3. CONCEPTUAL FRAMEWORK: CHANNELS OF INFLUENCE

Understanding the implications of China's international tax posture for African jurisdictions requires a structured analytical lens. This study adopts a tripartite conceptual framework comprising rules and norms, firm behavior, and administrative capacity channels. Each channel represents a distinct mechanism through which China's tax diplomacy and corporate practices shape revenue outcomes in African economies (Dharmapala, 2014).

The first channel concerns the role of international tax norms and legal frameworks. China's participation—or strategic ambivalence—in multilateral tax initiatives influences the global governance architecture that African states rely upon to safeguard their tax bases. Instruments such as the OECD/G20 Base Erosion and Profit Shifting (BEPS) Project, the Inclusive Framework on BEPS, and the emerging Pillar One and Pillar Two standards introduce legally binding and soft law obligations that affect profit allocation, minimum taxation, and treaty interpretation. China's approach to these frameworks reflects a nuanced balance between sovereignty concerns and global integration. While Beijing has endorsed core BEPS minimum standards and signed the Multilateral Convention to Implement Tax Treaty Related Measures to Prevent BEPS (MLI), its reservations and selective application of specific articles create interpretive ambiguities. These choices matter for African jurisdictions that frequently adopt OECD-driven standards or negotiate treaties concerning the United Nations Model Double Taxation Convention between Developed and Developing Countries (UN Model) and the OECD Model Convention on Income and Capital. The divergence in model preference—China often favors UN elements in South-South negotiations—has legal implications for source-based taxation rights, particularly with respect to services, royalties, and permanent establishment definitions. Moreover, China's stance on information exchange mechanisms, such as the Common Reporting Standard (CRS) and Country-by-Country Reporting (CbCR), affects the transparency tools available to African tax authorities (Janský and Kokeš, 2015). Limited participation or delayed implementation can

constrain African states' ability to detect profit shifting and illicit financial flows (Álvarez-Martínez et al., 2022).

The second channel addresses corporate structuring and transactional design by Chinese multinational enterprises (MNEs), state-owned enterprises (SOEs), and affiliated contractors operating in African markets. These entities frequently engage in intra-group arrangements, including service contracts, procurement agreements, and debt-financing structures, which have significant implications for transfer pricing compliance and thin capitalization rules. From a legal perspective, African states often rely on arm's length principle standards—codified in domestic legislation and informed by OECD Transfer Pricing Guidelines—to regulate pricing in controlled transactions. However, enforcing these rules becomes challenging when Chinese firms utilize complex contractual networks involving intermediate jurisdictions, preferential tax regimes, and treaty-shopping practices. Using special purpose vehicles (SPVs) in low-tax jurisdictions and aggressive cost contribution arrangements may erode taxable income in the source country, thereby undermining domestic revenue mobilization (Janský and Kokeš, 2015).

Additionally, the contractual obligations embedded in infrastructure-for-resources agreements and public-private partnerships (PPPs) negotiated under Chinese Belt and Road Initiative (BRI) projects can create stabilization clauses or tax exemptions that limit host-country taxing rights. These contractual protections, often governed by international arbitration clauses, introduce a layer of investment law interaction with tax sovereignty. The third channel pertains to African tax administrations' institutional capacity and legal enforcement ability. Even where global standards and domestic legislation are formally robust, their practical application hinges on technical expertise, access to information, and judicial support for tax assessments. African revenue authorities frequently confront challenges in auditing complex cross-border transactions, applying transfer pricing adjustments, and litigating disputes in specialized tax tribunals or general courts. Capacity constraints are compounded by asymmetries in information-sharing frameworks and the lack of a mutual agreement procedure (MAP) experience under bilateral treaties (Bradbury et al., 2018).

Furthermore, adopting advance pricing agreements (APAs)—a tool widely used to provide tax certainty in complex intra-group arrangements—remains minimal in most African jurisdictions, limiting proactive risk management. These channels are mutually reinforcing and, at times, compounding. Stronger international tax norms and harmonized treaty provisions enhance the legal infrastructure upon which domestic administrations can act. Conversely, heightened sophistication in firm-level tax planning escalates enforcement demands, necessitating greater administrative expertise. Where domestic capacity is limited, the fiscal consequences of aggressive tax planning become amplified, leading to base erosion and profit shifting risks that undermine the objectives of sustainable revenue mobilization and fiscal sovereignty (Mosquera Valderrama et al., 2018).

4. EMPIRICAL AND INSTITUTIONAL EVIDENCE

China's economic engagement with Africa is multidimensional, encompassing trade in goods, foreign direct investment (FDI), infrastructure development, and financing arrangements (Alden and Alves, 2008). Trade flows exhibit a structural imbalance: Africa predominantly exports raw materials and commodities to China while importing manufactured goods, machinery, and technology-intensive products from China (Bräutigam and Xiaoyang, 2009). Post-COVID-19 trends indicate an intensification of Chinese investments in mineral extraction and infrastructure projects, often under the Belt and Road Initiative (BRI). This trade asymmetry—where African imports from China outpace exports—has implications for fiscal sustainability, particularly in resource-dependent economies (Mosquera Valderrama et al., 2018).

Foreign investment modalities display tax-relevant characteristics that affect revenue mobilization and profit allocation. Key features include:

- Contracting and Project Structures: Chinese state-owned enterprises (SOEs) and private contractors frequently route project invoicing through parent entities or special purpose vehicles (SPVs) incorporated in intermediate jurisdictions. Such arrangements can facilitate tax planning by shifting profits to low-tax jurisdictions or treaty-favored countries (Sun, 2014).
- **Customs Valuation and VAT:** Misclassification of goods, transfer pricing on intra-group trade, and manipulation of customs values can influence the assessment of value-added tax (VAT) and import duties (IMF, 2019).
- **Cross-Border Financing Structures:** Financing mechanisms—such as intercompany loans, commodity-backed loans, and profit-participation agreements—generate deductible interest payments and service fees. These payments are often subject to withholding tax under domestic law, but planning strategies leverage treaty provisions to minimize effective rates (UNCTAD, 2022).
- **Choice of Corporate Form:** The decision between branch and subsidiary structures, or the use of holding companies in jurisdictions with favorable double tax treaties (DTTs), affects tax residency, applicable treaty benefits, and exposure to controlled foreign corporation (CFC) rules (OECD, 2017).

These patterns highlight a critical intersection between investment strategies and tax governance in African jurisdictions, raising concerns regarding base erosion and profit shifting (BEPS). The State Taxation Administration (STA) of China has progressively strengthened its anti-avoidance framework, particularly through transfer pricing (TP) regulations and "special tax adjustment" mechanisms under the Enterprise Income Tax Law (EITL) (2008) and its implementing regulations (SAT Announcement [2017] No. 6). These measures include mandatory contemporaneous documentation, disclosure of

related-party transactions, and the use of advanced data analytics to detect anomalies (Grant Thornton, 2021). Empirical studies suggest that enhanced enforcement has raised effective tax rates (ETRs) for Chinese multinationals domestically and curtailed specific profit-shifting strategies (Chen et al., 2020). However, enforcement effectiveness diminishes when Chinese enterprises operate through third-country affiliates or engage in contract structuring that obscures the location of value creation. For African tax administrations, the principal challenge is the extraterritorial nature of these structures. Absent robust exchange of information (EOI) mechanisms and joint audits—such as those envisaged under the OECD's Mutual Administrative Assistance in Tax Matters Convention—African authorities face substantial constraints in challenging transfer pricing practices involving Chinese entities and their offshore affiliates.

China maintains an extensive network of bilateral Double Tax Avoidance Agreements (DTAAs), many modeled on the OECD or UN conventions, aimed at eliminating juridical double taxation and reducing tax barriers to cross-border investment. However, these treaties can also create vulnerabilities when exploited through treaty shopping, wherein enterprises interpose conduit entities to obtain reduced withholding tax rates on dividends, interest, and royalties (Avi-Yonah, 2007). African states that have concluded DTAAs with China—or with jurisdictions commonly used as conduits (e.g., Mauritius, Seychelles)—face heightened risks of base erosion. Legacy treaties negotiated with European states or offshore jurisdictions are sometimes utilized in triangular structures, further complicating enforcement. The UN Committee of Experts on International Cooperation in Tax Matters and organizations like the Tax Justice Network have underscored that poorly designed treaties may inadvertently operate as investment incentives, facilitating aggressive tax planning rather than preventing double taxation (TJNA, 2019). This dynamic can significantly erode source-based taxing rights for resource-rich African economies, particularly in extractive industries. Trade misinvoicing—deliberate over- or under-invoicing of goods and services to shift value across borders—remains a pervasive channel for illicit financial flows (IFFs) between Africa and China (Global Financial Integrity, 2020). Given the scale of Sino-African trade, discrepancies in declared values and quantities provide opportunities for tax evasion, foreign exchange manipulation, and capital flight (Karkinsky and Riedel, 2012).

The Brookings Institution and IMF estimate that trade-based IFFs constitute a substantial share of revenue leakage in African economies. While international frameworks such as the World Customs Organization's Revised Kyoto Convention and the WTO Customs Valuation Agreement establish norms for transparency, enforcement capacity remains limited. Many African customs and revenue authorities lack access to real-time trade data, forensic audit tools, and inter-jurisdictional cooperation mechanisms necessary to address complex transfer pricing arrangements and intra-group trade opacity. The OECD/G20 Inclusive Framework's Pillar Two initiative introduces a global minimum tax of 15% on the profits of large multinational enterprises (MNEs), aiming to reduce incentives for profit shifting to low-tax jurisdictions. If implemented comprehensively, Pillar Two could curtail some aggressive tax

planning practices by imposing "top-up" taxes in the parent entity's jurisdiction when the effective tax rate in a source jurisdiction falls below the minimum threshold (Oguttu, 2017). However, as of mid-2025, global implementation remains fragmented. China has adopted a cautious approach, with domestic legislation still under deliberation, whereas some associated jurisdictions, such as Hong Kong, have advanced toward compliance (Etter-Phoya et al., 2020). For African countries, the implications are mixed:

- **Curtailment of BEPS:** Large-scale profit shifting by MNEs could decline, marginally protecting African tax bases.
- **Revenue Allocation Dynamics:** Pillar Two may reallocate taxing rights toward residence jurisdictions, potentially reducing source-country revenues in Africa.
- **Administrative Capacity:** Compliance with Global Anti-Base Erosion (GloBE) Rules, Competent Authority procedures, and reporting requirements may impose significant administrative burdens on African tax administrations (ATAF, 2022).

The overall distributional outcome will depend on whether African jurisdictions adopt complementary measures—such as qualified domestic minimum top-up taxes (QDMTTs)—to preserve taxing rights.

5. CASE EXAMPLES

The following stylized case studies aim to demonstrate the practical application of the mechanisms described in previous sections. While the examples are anonymized and synthesized based on patterns documented in policy literature, academic research, and media reporting, they highlight recurrent legal and regulatory challenges in cross-border infrastructure and resource transactions. The first scenario is one where there is Infrastructure Contracting via Offshore Holding Structures. Consider a scenario in which a state-owned enterprise (SOE) from China secures a road construction contract valued at approximately USD 500 million in a Sub-Saharan African state. The project is structured as a public-private partnership (PPP), ostensibly facilitating risk-sharing and mobilizing private capital (Katterbauer, 2022). However, a substantial portion of project-related invoices for equipment procurement and managerial services is issued by an offshore affiliate of the SOE. This affiliate is incorporated in a jurisdiction with an extensive network of bilateral tax treaties and comparatively low withholding tax rates. This arrangement has significant implications for allocating taxing rights and eroding the host state's tax base. Specifically:

- **Erosion of Taxable Profit:** Domestic tax liability has already diminished due to investment incentives commonly provided to attract large-scale infrastructure projects, such as tax holidays or reduced corporate income tax rates.

- **Base Erosion via Deductible Payments:** The offshore affiliate's imposition of royalties and management fees further reduces the host jurisdiction's taxable base.
- **Treaty Shopping and Transfer Pricing Risks:** Using an intermediary entity in a low-tax treaty jurisdiction exemplifies "treaty shopping," enabling the investor to circumvent higher withholding taxes and potentially manipulate transfer pricing arrangements.

From a legal perspective, this raises concerns under Articles 7 and 9 of the OECD Model Tax Convention regarding the attribution of business profits and arm's length pricing for related-party transactions. Moreover, absent robust transfer pricing regulations, effective withholding tax mechanisms, and exchange of information frameworks, the host state is vulnerable to Base Erosion and Profit Shifting (BEPS) risks. Relevant academic and policy sources underscore the need for domestic anti-avoidance rules, such as Controlled Foreign Corporation (CFC) legislation, thin capitalization rules, and substance requirements, to address the artificial shifting of profits (Koske et al., 2015). The second scenario is Commodity Exports and Resource Rent Leakage. In a second scenario, an African mining joint venture—majority-owned by a Chinese investor—enters into off-take agreements that establish pricing formulas linked to downstream transactions involving Chinese refining facilities. Suppose these pricing methodologies or the contractual determination of ownership transfer are structured to allocate substantial profit margins to the refining entity abroad. In that case, the African source state may capture only a limited share of the economic rent derived from its natural resources.

This practice implicates several legal and policy concerns:

- **Transfer Pricing Manipulation:** Pricing mechanisms tied to related-party downstream sales may not reflect arm's length principles, contrary to Article 9 of the OECD Model and domestic transfer pricing regulations.
- **Risk of Double Non-Taxation:** If the host country's tax regime is permissive (e.g., generous deductibility of expenses, lack of anti-abuse provisions), substantial profits may escape taxation entirely.
- **Stability Clauses and Fiscal Regimes:** Many resource contracts include stabilization clauses, which limit the host state's ability to amend fiscal terms. This can exacerbate the challenge of responding to aggressive tax planning practices.

International best practices, such as those promoted by the Extractive Industries Transparency Initiative (EITI) and the African Mining Vision, advocate for ring-fencing provisions, production sharing agreements with profit oil/gas or mineral rent mechanisms, and mandatory disclosure of pricing formulas to mitigate such risks. The third scenario is Trade Mis-invoicing and Illicit Financial Flows (Karkinsky and Riedel, 2012). The third scenario concerns systematic misreporting of import and export invoice values in transactions between African states and Chinese counterparties. Under-invoicing of

exports reduces export tax bases, while over-invoicing of imports enables illicit capital flight, undermining both customs revenue and foreign exchange reserves. Empirical studies, including those by Global Financial Integrity and research institutions such as Brookings, identify trade misinvoicing as a primary conduit for illicit financial flows from the African continent. The legal and institutional dimensions include:

- **Customs Valuation Rules:** Many African jurisdictions adopt the WTO Customs Valuation Agreement, but enforcement remains weak due to limited administrative capacity and corruption risks.
- **Anti-Money Laundering (AML) Frameworks:** Trade mis-invoicing constitutes a predicate offense under Financial Action Task Force (FATF) Recommendations, necessitating coordination between tax, customs, and financial intelligence authorities.
- **Data Exchange and Digitalization:** Initiatives such as the African Continental Free Trade Area (AfCFTA) e-certification system and Automatic Exchange of Information (AEOI) frameworks can reduce misreporting risks.

Ultimately, trade misinvoicing reflects broader challenges in customs governance, cross-border regulatory cooperation, and the alignment of domestic tax law with international transparency standards. These scenarios underscore the critical interplay between tax treaty provisions, domestic fiscal legislation, and international tax cooperation frameworks. Effective policy responses include strengthening General Anti-Avoidance Rules (GAARs) and Specific Anti-Avoidance Rules (SAARs) and implementing OECD BEPS minimum standards. Additionally, enhancing capacity for transfer pricing audits and beneficial ownership transparency and promoting regional tax cooperation initiatives, such as those advanced by the African Tax Administration Forum (ATAF), is crucial. Finally, addressing these issues requires domestic law reform and international coordination to close loopholes exploited through treaty shopping, base erosion strategies, and illicit trade practices (Adera, 2024).

6. QUANTIFYING REVENUE LOSSES: SCOPE AND LIMITATIONS

Estimating precise revenue losses attributable to tax base erosion linked to China-related economic activities presents significant analytical challenges. These challenges stem primarily from the limited availability of bilateral transaction-level data, the complexity introduced by multiple conduits and jurisdictions involved in cross-border financial flows, and the confidentiality provisions surrounding many project contracts and financing terms. These factors collectively impede transparent assessment of the scale and mechanisms of tax base erosion and profit shifting (BEPS) related to Chinese investments in African countries. Despite these data limitations, the broader literature on BEPS, illicit financial flows (IFFs), and trade misinvoicing indicates that revenue leakage from multinational profit shifting and trade mispricing represents an economically significant phenomenon for many African

economies. Empirical studies suggest that the resulting fiscal losses can amount to several percentage points of gross domestic product (GDP), constituting a substantial source of forgone public revenue. This erosion of the tax base undermines the capacity of African states to mobilize domestic resources essential for sustainable development and public service provision. From a legal and policy perspective, international frameworks provide crucial guidance for addressing these challenges. The OECD's Base Erosion and Profit Shifting (BEPS) Action Plan, endorsed by the G20, establishes comprehensive measures to enhance tax transparency, close gaps in international tax rules, and curb aggressive tax planning strategies by multinational enterprises. Key components include the implementation of Country-by-Country Reporting (CbCR), mandatory disclosure rules, and the revision of transfer pricing guidelines to reflect economic substance and value creation (Karkinsky and Riedel, 2012).

Furthermore, the International Monetary Fund (IMF) has underscored the importance of strengthening domestic tax administration capacity and fostering international cooperation through information exchange agreements. The IMF's technical assistance programs emphasize enhancing audit capabilities, utilizing data analytics for risk assessment, and improving legal frameworks to combat treaty abuse and treaty shopping practices that facilitate base erosion. On the bilateral and multilateral level, mechanisms such as the Multilateral Convention to Implement Tax Treaty Related Measures to Prevent BEPS (MLI) facilitate the modification of existing tax treaties to incorporate anti-abuse provisions and dispute resolution mechanisms. Additionally, adherence to the Common Reporting Standard (CRS) developed by the OECD promotes automatic exchange of financial account information, thereby increasing transparency and reducing opportunities for tax evasion. In the African context, regional initiatives such as the African Tax Administration Forum (ATAF) and implementing the African Union's Model Tax Treaty aim to harmonize tax policies and strengthen collective responses to BEPS and IFFs (Gnassou, 2020). Enhanced collaboration between African tax authorities and their Chinese counterparts, supported by technical assistance from international organizations, is critical to improving data sharing and enforcement. In conclusion, while precise quantification of China-related tax base erosion remains constrained by data and legal complexities, integrating enhanced tax administration, international legal instruments, and multilateral cooperation offers a promising pathway to curbing revenue losses. The empirical evidence and global best practices jointly underscore the need for African states to adopt a comprehensive legal and policy approach to safeguard their tax bases in increasing economic engagement with China(Griffith et al., 2014).

7. POLICY IMPLICATIONS AND RECOMMENDATIONS

The complexity and multifaceted nature of the tax governance challenges arising from international investment and resource exploitation in Africa necessitate a comprehensive, multi-actor approach. The following recommendations are delineated according to principal stakeholders: African governments and tax administrations, the People’s Republic of China and Chinese firms, and

multilateral and technical partners involved in global tax governance and capacity building. Given the limited administrative capacity and resource constraints prevalent in many African jurisdictions, it is imperative to prioritize capacity-building initiatives focused on sectors exhibiting heightened risks of tax base erosion and profit shifting (BEPS). Targeted allocation of audit resources should concentrate on extractive industries, large-scale infrastructure contracts, and significant foreign direct investment inflows. Advanced data analytics and risk-based taxpayer selection mechanisms enhance audit efficiency and effectiveness (Cheung et al., 2012). Regional programs, such as those administered by the International Monetary Fund (IMF) and African Regional Technical Assistance Centers (AFRITACs), are critical in strengthening institutional competencies. These initiatives should integrate state-of-the-art methodologies for transfer pricing scrutiny and customs valuation, aligning with international best practices. The proliferation of discretionary tax incentives and exemptions has often engendered vulnerabilities exploited through treaty shopping and artificial profit shifting. African states should enact reforms to rationalize such incentives, ensuring transparency through mandatory public disclosure of incentive regimes linked to investment projects (Dharmapala, 2014).

Furthermore, continuous monitoring and rigorous cost-benefit analyses of fiscal incentives are essential to safeguard public revenues. Legislative reforms should aim to curtail treaty abuse by narrowing loopholes and enhancing anti-avoidance measures. Current DTA frameworks frequently incorporate provisions that excessively limit source-state taxing rights, undermining African states' fiscal sovereignty. There is a pressing need to renegotiate and modernize existing DTAs by incorporating robust anti-abuse clauses, limitation-of-benefits (LOB) provisions, and beneficial ownership tests to deter treaty shopping and conduit financing arrangements. Conditional granting of treaty benefits predicated on demonstrable economic substance should be considered. Engagement with technical advisory bodies such as the African Tax Administration Forum (ATAF), the OECD's Africa Initiative, and the Tax Justice Network provides legal and technical guidance during treaty renegotiation. The practical implementation of international standards, such as the Common Reporting Standard (CRS) and automatic exchange of information (AEOI) protocols, is paramount in enhancing transparency concerning related-party transactions and using conduit entities. African tax authorities should prioritize bilateral and multilateral mutual agreement procedures (MAPs) to resolve cross-border tax disputes (Katterbauer, 2022). Joint audits with revenue authorities from investors' home jurisdictions constitute a pragmatic approach for addressing complex transfer pricing and profit-shifting cases. To combat trade misinvoicing and related customs valuation challenges, African states must invest in modernizing customs information systems. Integrating forensic audit techniques and cross-referencing customs declarations with data reported by trade partners—particularly from China—can significantly mitigate under-invoicing and over-invoicing practices. Harmonizing customs risk assessment models with tax administration frameworks is recommended to create synergies and enhance enforcement capabilities.

As economic activities increasingly transcend physical borders, African jurisdictions should adopt

legislative frameworks to tax digital and intangible value creation effectively. This includes enacting withholding tax regimes, anti-avoidance rules targeting withholding taxes, and domestic tax provisions that capture income generated through remote services utilized within African markets, which align with emerging international consensus on taxing the digital economy. Chinese lenders and contractors operating overseas should enhance transparency by disclosing beneficial ownership structures of projects and avoiding opaque conduit arrangements that erode the tax base of host countries. This practice aligns with international standards on beneficial ownership transparency and supports host governments' revenue mobilization efforts (Janský and Kokeš, 2015).

The Chinese tax administration should bolster its responsiveness to requests for competent authority assistance from African tax authorities. Strengthening joint capacity-building initiatives and facilitating cooperative audits will foster trust and improve enforcement effectiveness in transnational tax matters. Chinese multinational enterprises should implement rigorous transfer pricing documentation aligned with OECD guidelines and demonstrate substantial economic presence in their holding entities. This mitigates reputational risks and reduces fiscal risks associated with aggressive tax planning and potential disputes with host country tax authorities (Bradbury et al., 2018).

International organizations and technical assistance providers should prioritize supporting African states in implementing BEPS Action Plan measures, including the OECD/G20 Pillar Two global minimum tax rules. Emphasis must be placed on contextualizing these frameworks to African economies, ensuring coherence with domestic incentive regimes, and preventing adverse distributional impacts that could disproportionately harm developing countries. Donor agencies and multilateral development banks (MDBs) should scale up concessional financing to modernize customs and tax administration infrastructure. Investments in information technology systems and skilled human capital capacity development are vital to enhancing revenue collection efficiency and combating illicit financial flows. Global tax standard-setting bodies, including the OECD, G20, and emerging multilateral platforms, must embed a development perspective in rule-making processes. Ensuring meaningful representation and input from resource-rich, low-capacity developing countries is essential to create equitable international tax rules that protect their tax bases and foster sustainable development.

8. LIMITATIONS

This study primarily synthesizes extant policy documents and secondary literature, culminating in constructing a conceptual framework to understand the dynamics of Chinese foreign direct investment (FDI) in Africa. It does not, however, provide original transaction-level empirical analyses. Consequently, several critical avenues for future scholarly inquiry are identified to deepen the empirical and legal understanding of this subject matter. First, future research should prioritize utilizing microdata sources—including corporate registries, customs databases, and loan contract disclosures—to conduct granular empirical analyses of Chinese FDI structures across African jurisdictions. Such analysis would

enable the quantification of revenue impacts stemming from investment activities, thus offering a more precise assessment of economic benefits and potential fiscal leakage. From a legal perspective, these efforts should also examine the compliance of such FDI structures with international investment agreements and domestic tax regulations, thereby elucidating the interplay between investment promotion and regulatory oversight. Second, comparative case studies should be undertaken involving African states that have effectively audited, challenged, or renegotiated contractual arrangements with Chinese firms. These studies would elucidate successful enforcement mechanisms and dispute resolution strategies, potentially offering replicable models for other host countries. Moreover, such case studies could explore the role of bilateral investment treaties (BITs), state sovereignty in contract renegotiation, and the efficacy of domestic legal institutions in upholding fair investment practices (Etter-Phoya et al., 2020). Third, policy simulations that analyze the implications of adopting the OECD/G20 Inclusive Framework on Base Erosion and Profit Shifting (BEPS) Pillar Two rules are essential. These simulations should consider varying degrees of global uptake to model how tax revenues might be redistributed between African host states and the home jurisdictions of foreign investors. Legal research in this area should further investigate the compatibility of Pillar Two with existing international tax treaties, the sovereignty concerns of African states, and the administrative capacities required to implement such tax reforms effectively. Integrating empirical microdata analysis, comparative legal case studies, and advanced policy simulations will comprehensively understand the fiscal and legal impacts of Chinese FDI in Africa. This multidimensional approach will contribute significantly to evidence-based policymaking and strengthening regulatory frameworks that safeguard African countries' economic interests while maintaining an attractive investment climate.

9. CONCLUSION

The intensification of economic relations between China and Africa presents significant sustainable development and economic growth opportunities. However, the increased integration of Chinese investment and trade within African economies simultaneously introduces complex international taxation challenges that intersect with the inherent structural vulnerabilities of many African tax administrations. This dynamic underscores the multifaceted nature of China as an economic actor in Africa: while the Chinese government has enacted robust domestic anti-avoidance frameworks—including transfer pricing regulations—and actively participates in multilateral tax governance initiatives such as the OECD/G20 Inclusive Framework on Base Erosion and Profit Shifting (BEPS), the corporate practices of Chinese multinational enterprises (MNEs) often involve intricate project financing and the strategic use of intermediate jurisdictions. Such strategies may exacerbate risks of base erosion and profit shifting, particularly in African host states characterized by limited administrative capacity and weaker enforcement mechanisms. Addressing these challenges necessitates a comprehensive and coordinated approach at multiple levels. From the perspective of African states, there is an urgent need for capacity building focused on enhancing institutional capabilities in tax

administration, audit, and enforcement. This should be complemented by adopting more nuanced and development-oriented treaty policies, including renegotiating bilateral investment treaties (BITs) and double taxation agreements (DTAs) to prevent treaty shopping and better safeguard tax bases. On the Chinese side, increased transparency and cooperation from governmental authorities and Chinese enterprises are critical to ensuring compliance with international tax norms and mitigating aggressive tax planning strategies. Moreover, a reformed and inclusive international tax architecture must support this bilateral and regional cooperation. Such reform should seek to recognize emerging and developing economies' specific challenges and development priorities, moving beyond a predominantly OECD-centric framework toward mechanisms that equitably allocate taxing rights and foster global tax justice. The role of concerted multilateral support is paramount in this context. International organizations, including the United Nations Committee of Experts on International Cooperation in Tax Matters, the OECD, and the African Tax Administration Forum (ATAF), alongside development partners, must facilitate a blend of technical assistance, legal modernization, and the pragmatic adoption of international tax instruments tailored to the developmental aspirations of African states. This approach will enable African countries to more effectively mobilize domestic resources, capture a fairer share of the economic gains from China–Africa engagements, and ultimately finance the Sustainable Development Goals (SDGs). In conclusion, while promising in its potential for mutual prosperity, the evolving China-Africa economic relationship simultaneously demands vigilant legal and institutional reforms to address the international taxation issues it generates. Only through coordinated domestic reforms, enhanced international cooperation, and a more equitable global tax framework can African states harness the full benefits of this engagement and promote sustainable, inclusive development.

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THE CIRCULAR TRANSITIONS AND GREEN EMPLOYMENT IN ASEAN ECONOMIES: INSIGHTS FROM A DECADE OF CHANGE (2000–2023)

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ABSTRACT

This study examines the relationship between circular economy strategies and employment in four ASEAN countries (Indonesia, Malaysia, Thailand, and the Philippines) from 2000 to 2023. The analysis focuses on the effects of adopting low-carbon technologies, promoting eco-innovation, and managing waste-related greenhouse gas emissions on labor markets within the Sustainable Development Goals framework. The circular economy has become a central policy focus in ASEAN, with the dual objectives of economic growth and environmental sustainability. However, limited research has examined the link between circular economy performance and employment. To address this gap, this study employs a Fixed Effects Regression model to estimate employment as a function of circular economy indicators, controlling for country-specific and temporal variations. The model incorporates variables such as the share of low-carbon technology imports, the Eco-Innovation Index, waste-related greenhouse gas emissions, and broader economic factors, including GDP growth and population trends. The analysis emphasizes intra-country changes over time to demonstrate how environmental innovation and circular economy strategies influence labor markets. By integrating descriptive statistics with econometric analysis, the study reveals the social and economic impacts of transitioning to a circular economy in emerging markets. In this context, this study has two goals. First, it will show how circular economy practices help create jobs and grow green sectors in ASEAN. Second, it will provide evidence to help governments design fair and innovative sustainability policies. The results will inform regional discussions about how ASEAN can balance environmental goals with job growth and long-term economic strength.

Keywords: *Circular Economy, Employment, ASEAN Countries.*

JEL Codes: *O44, Q56, J21, C33, F63.*

1. INTRODUCTION

The phrase circular economy seems to have been formally introduced into an economic

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framework for the first time by Pearce and Turner in 1990 (Pearce and Turner, 1991). As stated by Preston (2012), a circular economy transforms the way resources are used in the economy. In this system, waste generated by factories becomes a valuable input for other processes, allowing products to be reused, upgraded, or repaired rather than simply discarded. From an environmental perspective, the objective of a circular economy is to reduce the production and consumption system of new material and energy, as well as waste and emissions. By reducing atmospheric emissions and increasing the use of recyclable materials and renewable energy, along with minimizing land usage, raw materials, energy, and water use, a circular economy is expected to have a positive impact on the environment (OECD, 2020). The circular economy involves competitiveness, economics, and innovation. It goes beyond recycling and waste management by addressing fundamental changes to consumption and production models. Furthermore, it can generate new job opportunities and deal with inequalities, such as access to shared services.

In 2015, ASEAN leaders approved the ASEAN Socio-Cultural Community (ASCC) Blueprint 2025, which promotes greater regional cooperation and advances the region's transition toward a circular economy (ASEAN, 2021). To achieve sustainable and inclusive growth, ASEAN needs to adopt a new economic model that goes beyond the traditional “take, make, use, dispose” approach and prioritizes resource efficiency (Platform, 2025). The circular economy has become a central policy focus in ASEAN, with the dual objectives of economic growth and environmental sustainability. However, limited research has examined the link between circular economy performance and employment. To address this gap, this study employs a Fixed Effects Regression model to estimate employment as a function of circular economy indicators, controlling for country-specific and temporal variations. By integrating descriptive statistics with econometric analysis, the study reveals the social and economic impacts of transitioning to a circular economy in emerging markets. The study is structured into five sections. It begins with an introduction. The second section shows the literature review. The third and fourth sections are dedicated to detailing the data set and research methodology. Finally, the fifth section gives an explanation of the study’s findings.

2. LITERATURE REVIEW

Many studies have observed the growing influence of the circular economy. Utilizing the panel regression model to estimate the data from the ASEAN region, Jermsittiparsert et al. (2020) and Saengchai et al. (2019) investigate the factors influencing the Circular Economy (CE) in the Association of Southeast Asian Nations (ASEAN). Jermsittiparsert et al. found that the higher levels of human capital and development, had a negative and significant effect on waste generation. Conversely, Saengchai et al. discovered that total natural resource rent (TNRR) positively influenced waste generation. Through regression analysis, Lakshmi et al. (2025) and Sulich and Sołoducho-Pelc (2022), examined the effect of CE on economic growth and green jobs, respectively. While both studies share the same fundamental

objective, yet they still significantly diverge in their scope, geographical area, and the mechanisms they investigate. Applying regression analysis and ANOVA, Lakshmi et al. found that there is a significant connection between circular economic indicators and economic output via employment. In comparison, Sulich and Sołoducho-Pelc employed a linear regression model to examine the creation of green jobs and found that Sustainable Development Goals (SDGs) can promote CE and generate the creation of Green Jobs.

Applying panel data analysis, Aydınbaş and Erdinç (2023) and Nademi and Kalmarzi (2025) provide insights to the dynamics of the circular economy (CE) in the European Union covering the period from 2010 to 2019. Aydınbaş and Erdinç examine the factors that influence the adoption of the CE, while Nademi and Kalmarzi focus on how the CE affects unemployment rates. Aydınbaş and Erdinç found that GDP per capita and human capital are statistically significant for a circular economy index. On the other hand, Nademi and Kalmarzi highlighted that all eight indicators of the CE significantly reduced the unemployment rate in European countries. The studies by Emami et al. (2025) and Škrinjarí (2020) use quantitative methods to analyse CE progress within two distinct economic areas: the ASEAN community and selected European countries. Using Economic-Wide Material Flow Analysis (EW-MFA), Emami et al. explored the environmental and material shortage of the CE in ASEAN, while Škrinjarí investigated the institutional and wealth necessity for CE in Europe by utilizing Grey Relational Analysis (GRA).

The studies conducted by Cobbold et al. (2025) and Zhu et al. (2024) analysed the impact of technology on sustainable development. Cobbold et al. particularly found that Low Carbon Technology (LCT) imports significantly raise Green Innovation and boost foreign investment. By comparison, industrial robot adaptation specifically has been chosen by Zhu et al. to investigate the effect on the labor market. The evidence revealed that even though automation has a strong positive impact on wages, it eventually causes a negative effect for both male and female workers. Two firm-level quantitative studies have been conducted by Elia et al. (2020) and Moreno-Mondéjar et al. (2021). The first study revealed that companies with stronger integration into external supply chains are more likely to pursue circular economy goals. Meanwhile, the second study pointed out that European firms performing circular economy strategies tend to generate green jobs, specifically from energy efficiency and waste reduction initiatives.

3. DATA SET

This study examines the relationship between circular economy strategies and employment in four ASEAN countries (Indonesia, Malaysia, Thailand, and the Philippines) from 2000 to 2023. For this purpose, annual data were collected for each country. To represent the circular economy, the share of Low-Carbon Technology Imports was collected. In addition, Total Greenhouse Gas Emissions, GDP Growth, Foreign Direct Investment (FDI), Human Development Index (HDI), and Domestic Material

Consumption were obtained as control variables. The aim of the study is to investigate the impact of circular economy strategies on employment in selected ASEAN countries. Therefore, the Employment to Population Ratio is chosen as the dependent variable.

Table 1 shows the dependent and independent variables used in the study, along with their abbreviations and additional details.

Table 1. The Dependent and Independent Variables

Notation	Details	Data Source
Dependent Variables		
Employment to Population Ratio (EMP)	The percentage of a country's population that is employed	WDI
Independent Variables		
Imports of Low-Carbon Technology (LCT)	The share of low-carbon technology imports	IMF climate change database
Total Greenhouse Gas Emissions (GHG)	Total greenhouse gas emissions excluding LULUCF (Mt CO2e)	WDI
GDP Growth (GDP)	The total income generated from producing goods and services in a specific area over a set period	WDI
Foreign Direct Investment (FDI)	The net amount of money coming from foreign investors, after subtracting any withdrawals, expressed as a percentage of GDP	WDI
Human Development Index (HDI)	A summary measure that reflects average progress in key areas of human development	UNDP
Domestic Material Consumption (DMC)	GDP, PPP (constant 2021 international $) / Resource Productivity	OEC

4. METHODOLOGY

The primary goal of this research is to explore how circular economy strategies affect employment in selected ASEAN countries. The LCT imports as a circular economy indicator and the main independent variable. The hypothesis of our research is expected to have a mixed effect. In the short run, the circular economy may cause disruptions in some sectors and job losses. While in the long-term, the transition could generate new green jobs, strengthen skills, and encourage the development of more sustainable industries.

The autoregressive distributed lag (ARDL) approach, introduced by Pesaran and Shin (1999) and improved by Pesaran et al. (2001), is the ideal statistical method for testing our research hypotheses. This analysis was conducted with Eviews 12 software. In this context, when variables may not be stationary at level but are stationary at 1 or known as I (1), Pesaran and Smith (1995) suggest using the

panel ARDL. In our panel data, the time period (in years) exceeds the number of countries, as stated by Pesaran et al. (1999).

First, we test the cross-section dependency to check if one country's data was being affected by other countrşes in the group. The results of the Cross-Section Dependence Test for the variables used in the analysis are given in Table 2.

Table 2. Cross-Section Dependence Test Result

Test	Statistics	d.f	Prob.
Breusch-Pagan LM	8.965755	6	0.1755
Pesaran scaled LM	0.856140		0.3919
Pesaran CD	1.086717		0.2772

According to the results of the Cross-Section Dependence test, the p-value of all variables was above 0.05, meaning there was no significant dependence among the indicators. Therefore, the first generation unit root tests were chosen to check data stability.

Table 3 depicts the evidence of unit root tests, covering the stationary properties of every variable at level and first difference under Levin-Lin-Chu, Im-Pesaran-Shin, and Fisher-ADF.

Table 3. First Generation Unit Root Test Result

Variable	LLC		IPS		ADF	
	Level	1st Difference	Level	1st Difference	Level	1st Difference
EMP	0.5536	0.0002	0.8674	0.0004	0.9369	0.0010
LCT	0.2351	0.0008	0.3996	0.0000	0.5283	0.0000
GHG	0.0476	0.0000	0.7570	0.0000	0.2350	0.0000
GDP	0.0000	0.0000	0.0001	0.0000	0.0004	0.0000
FDI	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
HDI	0.0000	0.0029	0.0896	0.0015	0.0626	0.0032
DMC	0.1235	0.0000	0.6169	0.0000	0.4851	0.0000

Based on the first generation unit root tests above, only GDP and FDI are stationary at level. Most variables are non-stationary at level, because the p-value is above 0.05. However, after taking the first difference, all variables became stationary under the LLC, IPS, and ADF. It can be concluded that every variable is I (1) and this mix results is the accurate reason to apply the ARDL model. The quality of the model was also tested. According to Normality, autocorrelation, and heteroskedasticity tests, the results indicated that there are no big problems. It means that the model is appropriate for finding connections.

The table below shows the empirical results from the PMG-ARDL model estimation. It covers the long-run and short-run coefficients that catch the relationship among the variables.

Table 4. The Results of the Models

Variable	Coefficient	t-statistic	Prob.
Long-run (Pooled) Coefficients			
LCT	0.033770	0.668785	0.5056
GHG	-0.000726	-3.026719	0.0033
GDP	0.004272	0.443385	0.6587
FDI	0.007947	1.459337	0.1484
HDI	0.815171	18.22376	0.0000
DMC	0.000226	2.948514	0.0042
Short-run (Mean-Group) Coefficients			
COINTEQ	-0.129059	-1.720642	0.0896
D(Y(-1))	0.228264	2.523867	0.0138
D(X1)	0.010956	0.590183	0.5569
D(X1(-1))	-0.072801	-1.005927	0.3178
D(X2)	0.000190	1.895655	0.0620
D(X2(-1))	0.000255	1.099848	0.2750
D(X3)	0.001322	1.248400	0.2159
D(X4)	-0.002069	-2.290959	0.0249
D(X4(-1))	-0.000622	-0.343736	0.7320
D(X5)	-0.151190	-0.434032	0.6655
D(X5(-1))	0.855095	1.630119	0.1074
D(X6)	-4.85E-05	-2.955558	0.0042
D(X6(-1))	-4.16E-05	-4.230109	0.0001

The evidence presented in Table 2. According to the panel PMG ARDL analysis, there is a strong positive relationship between the HDI and the employment to population ratio in the long-run. A 1% increase in HDI will significantly affect employment by 0.815%. In addition, there is a significant positive relationship between DMC and employment, meaning a 1% increase in DMC will slightly increase employment by 0.0002%. Furthermore, there is a significant but negative relationship between GHG and employment. A 1% increase in GHG will eventually decrease employment by 0.0007%. In the short run, the speed of adjustment is around 13% per year, meaning that the labour market will gradually return to balance.

5. CONCLUSION

This study aims to explore and investigate the effect of circular economy strategies on

employment in Indonesia, Malaysia, Thailand, and Vietnam. The selected ASEAN countries are still in developing stages and have the potential for transitioning into a more circular economy or greener models. From the analysis, we found that HDI strongly affects the employment figures. The investment in human capital is critical for allowing labor to adapt to a circular production system. The higher HDI figures are related to better education, health, and income, which eventually strengthen workers' skills. Furthermore, the evidence showed that the DMC was significant and positive to employment, because material-intensive circular activities, such as reuse and waste collection will have high demand on labor and can dıirectly influence job creation. In contrast, the GHG negatively affects employment, due to high emissions. Therefore, it reinforces the need for greener and cleaner practices promoted through CE strategies. Although the low-carbon technology imports do not yet significantly affect employment, this likely indicates their early adoption phase and the fact that they need a lot of capital in these economies. These Technologies may increasingly encourage employment by local value-chain development, as CE frameworks become more developed and green industries grow locally. Overall, the circular economy strategies can support job creation in selected ASEAN countries, especially when incorporated with human capital development and progressive structural transformation.

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ECONOMIC POLICY UNCERTAINTY AND THE NON-PERFORMING LOANS: A DCC-GARCH AND MARKOV SWITCHING ANALYSIS IN THE CASE OF TURKISH BANKING SECTOR

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ABSTRACT

For developing economies such as Türkiye, where policy shocks can have profound repercussions on the banking system, it is particularly important to assess the impact of macroeconomic uncertainty on financial stability. This study rests on the premise that financial fragility may arise not only from macroeconomic fluctuations but also from the unpredictability of economic policy direction. From a theoretical standpoint, uncertainty shocks influence the real economy through both the investment and credit channels. For this reason, heightened economic policy uncertainty (EPU) is expected to increase banks' non-performing loans (NPLs) by constraining credit supply and weakening borrower quality.

This study's primary purpose is to investigate the dynamic relationship between economic policy uncertainty and banking sector credit risk in Türkiye over the period 2006:M1-2024:M12. Methodologically, a two-stage econometric strategy is employed. In the first stage, time-varying correlations between EPU and NPLs are estimated using the Dynamic Conditional Correlation GARCH (DCC-GARCH) model. In the second stage, the Markov Switching Regression (MSR) model is utilized to capture the regime-dependent dynamics of the relationship across low- and high-volatility periods.

Empirical findings indicate that the correlation between EPU and NPLs strengthens markedly during episodes of heightened uncertainty, including the 2008 Global Financial Crisis, 2010-2011 European Debt Crisis, the 2018 Currency Crisis, the 2020 COVID-19 outbreak, and the 2022 Russia-Ukraine War. While the DCC-GARCH results suggest that uncertainty shocks move synchronously with fluctuations in the financial system, the MSR results reveal that the impact of EPU on NPLs is considerably stronger during high-volatility regimes.

Overall, the results underscore that macroeconomic stability is a fundamental prerequisite for financial stability. Reducing policy uncertainty and enhancing the predictability of monetary and fiscal policies would contribute to a more resilient financial system by mitigating credit risk and systemic vulnerabilities within the banking sector.

Keywords: *Economic Policy Uncertainty,Non-Performing Loans, DCC-GARCH, MSR.*

JEL Codes: *C56, E44, G21.*

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1. INTRODUCTION

In emerging market economies (EMEs), changes in policy trust and financial stability can quickly lead to major stress. Macroeconomic uncertainty has become a key concern for both policymakers and researchers. A strong body of evidence shows that uncertainty shocks don't just unsettle markets; they also hinder real economic activity, trade, and investment while increasing financial volatility (Bloom, 2009; Jurado et al., 2015). In this context, Economic Policy Uncertainty (EPU) is a significant risk factor that shapes expectations about future fiscal, monetary, and regulatory decisions. Since the banking sector is crucial for financial intermediation, understanding how EPU affects bank balance sheets and credit risk is not just an academic task; it is essential for effective policy. Recent findings from the Turkish economy highlight this issue, showing how EPU weakens growth, consumption, and investment (Şahinoz and Coşar, 2018).

From a theoretical side, uncertainty shocks affect the real economy mainly through investment and credit channels. Recent evidence from firms supports this trend, showing that during times of high uncertainty, firms not only cut back on their credit demand, but banks also become more cautious. They tighten credit supply, which worsens financial frictions (Kim et al., 2023). At the same time, economic policy uncertainty can lower borrower quality and increase funding costs in banking. Lenders consider higher default risks and adjust credit spreads accordingly (Ashraf and Shen, 2019). In the real options framework, firms facing increased uncertainty usually delay or scale back irreversible investment projects, which lowers overall credit demand (Dixit and Pindyck, 1994; Bloom, 2009). Together, these factors suggest that in economies where banks are the main source of external finance, ongoing policy uncertainty is likely to damage credit quality and lead to a rise in NPLs.

Recent research on NPLs has mainly looked at typical macroeconomic and bank-specific factors, like GDP growth, interest rates, exchange rates, and credit growth (Nkusu, 2011; Beck et al., 2015; Klein, 2013; Baş and Kara, 2021). While many studies connect uncertainty to financial market fluctuations and economic performance, credit risk in emerging market banks has received little attention. Newer studies have started to explore how EPU affects bank risk-taking, loan pricing, and NPLs. This suggests that policy uncertainty can change banks' risk profiles and how they set aside funds (Ozili, 2022; Shabir et al., 2021; Ashraf and Shen, 2019). However, there is still limited study on the changing relationship between these factors, especially for Türkiye, which faces ongoing financial and political instability. This gap in research drives our investigation into how EPU impacts banking sector vulnerability during different volatility states, using a dynamic regime-switching analysis.

The primary objective of this study is to examine the nexus between EPU and banking sector credit risk in Türkiye between the 2006:M1 and 2024:M12 period. To achieve this, a dual-pronged empirical strategy employs in this study. First, the Dynamic Conditional Correlation GARCH (DCC-GARCH) model is used to assess the time-varying correlations between EPU and NPLs, enabling

identification of periods when uncertainty and credit risk exhibit strong co-movement. Second, the Markov Switching Regression (MSR) model is applied to determine whether the impact of EPU on NPLs differs across low and high volatility regimes. This regime-switching approach provides new insights into the non-linear dynamics of credit risk under varying levels of uncertainty.

The remainder of this paper is structured as follows: Section 2 and section 3 presents literature review and the data and methodology respectively. Section 4 shows empirical findings, section 5 concludes.

2. LITERATURE REVIEW

Recent research on financial stability has increasingly highlighted EPU as a potential macroeconomic risk factor. The theoretical background based largely on the real options framework (Karadima and Louri, 2021). Specifically, inquiries into bank balance sheets have focused on the nexus between uncertainty and NPL (Botshekan et al., 2021; Ozili, 2022).

The empirical literature mostly supports these theoretical hypotheses. Adverse relationship between EPU and NPL appears to intensify during systemic crises; Zeqiraj et al. (2024) document a marked rise in Eurozone NPLs driven by EPU during the COVID-19 pandemic. A similar pattern is found by Botshekan et al. (2021) in the Iranian context, where DCC-GARCH models highlight a strong co-movement between uncertainty and credit risk during major global shocks. Karadima and Louri (2021) investigate major European banking sectors, indicate that while EPU shocks inflate NPLs. Papadamou and Pitsilkas (2025) provide long-run evidence from Greece, noting that consumer NPLs are particularly slow to adjust to equilibrium.

3. DATA AND METHODOLOGY

Our data consists of Türkiye's EPU index and Turkish banks' NPLs for the period 2006:M1-2024:M12. Türkiye EPU index, which is obtained from Economic Policy Uncertainty database and calculated by Kılıç and Ballı (2024), is created by employing text mining methods from the electronic archives of six most important newspapers of Türkiye. While banks' NPLs were obtained from the Central Bank of the Republic of Türkiye (CBRT) database.

Summary of the variables is presented in Table 1.

Table 1. Summary of the Variables

Variable	Symbol	Source
Türkiye EPU	LEPU	Economic Policy Uncertainty
NPLs	LNPL	CBRT

The empirical analysis employs the DCC-GARCH and the MSR frameworks to explore the

evolving interaction between the Türkiye EPU index and the NPLs. The DCC-GARCH specification, originally introduced by Engle (2002), provides a flexible multivariate structure that enables the modelling of time-varying correlations. Conceptually, model augments the Constant Conditional Correlation approach of Bollerslev (1990) by allowing correlations to adjust dynamically to new information, thereby capturing fluctuations in co-movements that static models would overlook.

A key advantage of the DCC-GARCH model is based on the ability to detect structural shifts in the co-movement between variables throughout the sample period. This feature is particularly valuable when the relationship under examination is likely to respond to geopolitical tensions, market disruptions, or global shocks. By jointly modelling the conditional variances and correlations, the approach produces correlation estimates that account for volatility clustering which allows researchers to investigate how interdependencies evolve under periods of higher stress or uncertainty (Chiang et al., 2007).

Overall, the DCC-GARCH methodology provides a comprehensive and empirically robust tool for capturing the temporal behavior of interconnected risk factors and for evaluating how these relationships adjust in response to shifting geopolitical and market conditions.

The DCC-GARCH model employed in the study can be expressed as follows:

$$x_t = \mu_t + \varepsilon_t \varepsilon_t \sim N(0, H_t) \tag{1}$$

$$\varepsilon = H_t^{\frac{1}{2}} \varepsilon_t \mu_t \sim N(0, I) \tag{2}$$

$$H_t = D_t R_t D_t \tag{3}$$

Here, time-varying conditional variances and dynamic conditional correlations are represented by D_t and R_t, both of dimension $m\,x\,m$. Additionally, conditional means denote standardized error residuals, each of dimension $m\ x\ 1$ (Mishra and Ghate, 2022).

MSR model is an augmented version of simple probability models that utilize a first-order Markov process for regime probabilities. Two regimes are defined: low volatility and high volatility regimes, differentiated by regime-specific variances. The MSR model has an advantage over single-regime models because of lower volatility persistence and greater forecasting performance (Lamoureux and Lastrapes, 1990; Cai, 1994). The transition from Regime 1 to Regime 2 (or vice versa) is determined by the unobserved state variable s_t, that can be expressed as $\Pr(s_t = j | s_{t-1} = i) = p_{ij}$ (Ertuğrul and Öztürk, 2013). The term p_{ij} indicates the probability of state i followed by state j (Bautista, 2003). The transition probability matrix with two state is presented in Equation 4.

$$p = \begin{bmatrix} p_{11} & p_{12} \\ p_{21} & p_{22} \end{bmatrix}, \quad \sum_{j=1}^{2} p_{ij} = 1 \tag{4}$$

The MSR model presentation for Türkiye's EPU and NPL is presented in Equation 5 and Equation 6.

Low Volatility Regime:

$$LNPL_t = \alpha_{1,0} + \alpha_{1,1} LEPU_{t-i} + \varepsilon_{1,t} \quad (5)$$

High Volatility Regime:

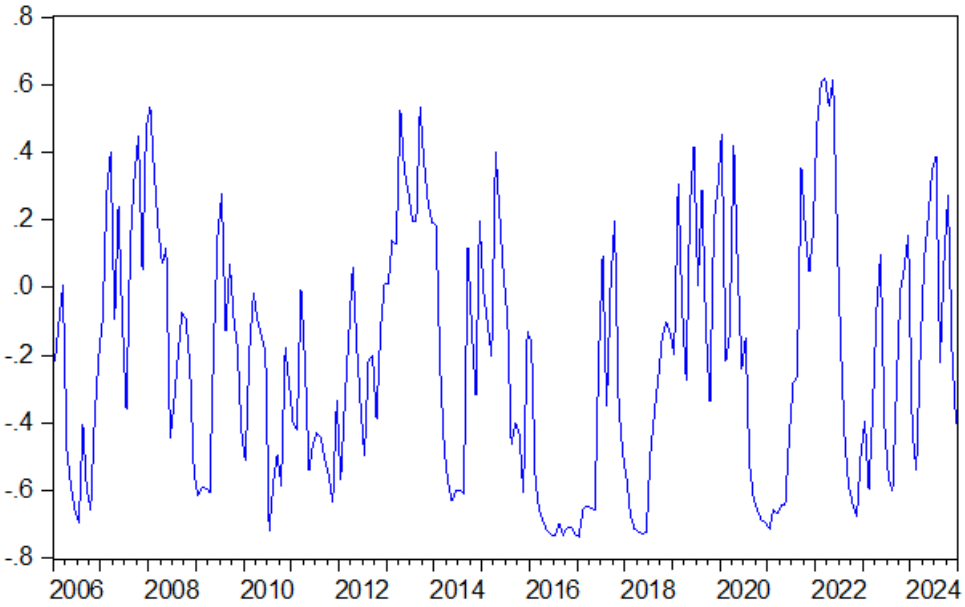
$$LNPL_t = \alpha_{2,0} + \alpha_{2,1} LEPU_{t-i} + \varepsilon_{2,t} \quad (6)$$

In the equation, $\alpha_{1,0}$ and $\alpha_{2,0}$ denote regime-dependent constants, $\alpha_{1,1}$ and $\alpha_{2,1}$ denote autoregressive coefficients, and $\varepsilon_{1,t}$ and $\varepsilon_{2,t}$ denote white noise error terms.

4. FINDINGS

The findings on the dynamic correlation between Türkiye EPU and NPLs are presented in Figure 1 below.

Figure 1. DCC-GARCH Findings



The dynamic conditional correlations obtained from the DCC-GARCH model in Figure 1 indicate a co-movement between Türkiye's EPU and NPL that varies significantly over time and intensifies periodically. Correlations rose particularly during the 2008-2009 period, when the effects of the global financial crisis persisted; the 2011-2012 period, which was the European debt crisis; the 2018 period, when exchange rate and liquidity pressures increased; the 2020-2021 period, which saw the COVID-19 shock; and the 2022 period, when the Russia-Ukraine war began. This time-varying correlation indicates that during periods of crisis, EPU tends to increase banking NPL ratios, while the correlation weakens during calmer periods in the markets. The general trend indicates that the impact of EPU shocks on NPL ratios exhibits an asymmetric and seasonally strengthening structure, and that this relationship becomes more pronounced during periods of high financial fragility.

The findings of the MSR model are presented in Table 2.

Table 2. MSR Findings

Dependent Variable: LNPL	
Variables	**Markov Model**
Regime 1: High Volatility Regime	
LEPU	0.86***
C	17.15***
Regime 2: Low Volatility Regime	
LEPU	0.39***
C	16.67***

Note: "***" represents 1% significance.

According to the findings of the MSR model obtained from Table 2, the relationship between EPU and NPL ratios indicates significant changes depending on the regime. Accordingly, it indicates that NPL ratios are strongly affected by uncertainties in high volatility regimes. On the other hand, in low volatility regimes, while NPL ratios are affected by uncertainty, the impact is considerably weaker compared to high volatility regimes.

5. CONCLUSION

This study examines the dynamic correlation between Türkiye EPU and NPLs, as well as the different regime volatilities. The DCC-GARCH model was used for dynamic correlation analysis, while the MSR model was used for regime volatility analysis. To this end, the study covers the period from 2006:M1 to 2024:M12, during which significant political/geopolitical events occurred.

According to the findings obtained from the DCC-GARCH and MSR models, the relationship between EPU and NPL ratios has both a dynamic and regime-dependent structure. Findings from the DCC-GARCH model indicate that correlations between EPU and NPL change over time and that these correlations strengthen particularly during periods when financial events occur. Findings from the MSR model also indicate that EPU affects NPL ratios in both low and high regimes, but that the effect is stronger in the high volatility regime compared to the low volatility regime.

Based on these findings, it can be concluded that EPU affects the NPL ratios of the banking sector with varying intensity over time, and that this effect increases significantly, particularly during periods of crisis. Therefore, it is critically important for policymakers to closely monitor the banking sector during periods of crisis and to design appropriate financial stability policies.

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DETERMINATION OF CAPACITY UTILIZATION RATE AND PRODUCTION-CONSTRAINING FACTORS IN THE MANUFACTURING INDUSTRY[4]

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ABSTRACT

The capacity utilization rate is a critical indicator showing how much of an economy's production potential is being utilized. Identifying the factors that limit production is crucial for planning production processes and utilizing resources effectively. This study examines the determination of capacity utilization rates in manufacturing industry enterprises, identifies the factors that restrict production, and investigates the main factors that cause the capacity utilization rate to fall below the 70% threshold. In this context, data was collected and analyzed using a survey method from companies operating in the Kocaeli İMES Organized Industrial Zone. Based on this data, a detailed analysis of the factors whichrestrict production was conducted to develop strategic recommendations to improve company's performance, contribute to the more effective use of the region's industrial potential, also identify the factors contributing to the decline in the capacity utilization rate. For this purpose, the analysis was conducted using binary logistic regression. The variables used in the analysis are defined basedon whether the Capacity Utilization Rate was below or above 70, and consist of variables representing production constraints such as insufficient demand, labor shortages, difficulties in accessing raw materials, and financial problems. The findings of the logistic regression analysis revealed that insufficient demand significantly increases the likelihood of the capacity utilization rate falling below 70%. This is followed by labor shortages, insufficiencies in raw materials/equipment, and financial difficulties. The results highlight that, consistent with the literature, demand conditions play a decisive role in capacity utilization, and emphasize the need to develop capacity management strategies specific to each sector and region.

Keywords: *Manufacturing Industry, Capacity Utilization Rate, Logistic Regression.*

JEL Codes: *L6, E22, C38.*

1. INTRODUCTION

The manufacturing industry plays a significant role in the Turkish economy. Manufacturing value added accounts for approximately 17% percent of GDP, and manufacturing industry employment

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accunts for 20% percent of total employment (TCMB, 2023). The capacity utilization rates of manufacturing businesses, based on their current physical capacity, announced by the Republıc of Turkey Central Bank (TCMB), are an indicator of how much of their total production capacity is being used. The capacity utilization rate is an important indicator for economic decision-makers, investors, and policymakers. During periods of economic crisis, investments typcally decline and as a result, the growth rate in production capacity slows down. One of the most significant effects of crises on production capacity is the idling of existing production facilities by reducing capital growth (Demiroğlu, 2013). In such situations, where future production capacity is affected, determining the capacity utilization rate plays a critical role in many aspects, including economic growth, industrial performance, and labor force utilization. Moreover, these estimations are also essential for planning production processes and ensuring the efficient use of resources. The primary objective of this study is to determine the capacity utilization rate and the factors constraining production in Kocaeli Manufacturing Industry. Data were obtained using a face-to-face survey of 77 companies operating in the Kocaeli İMES Organized Industrial Zone. Based on the obtained data, logistic regression analysis was applied to analyze the relationships between the capacity utilization rate and the factors constraining production. The dependent variable used in the model is given a value of one for CUR values of seventy percent and below, and a value of zero for values above seventy percent. This regression model shows the probability that a one-unit change in the independent variables will result in the dependent variable. The variables are the capacity utilization rate and demand deficiency, labor shortage, financial difficulties, difficulty in accessing raw materials/equipment. According to the logistic regression analysis, changes in all independent variables have a statiscally significant effect on the estimation of CUR ($p<0.05$). As the labor shortage increases by one unit, the risk of the CUR falling below 70 increases by 2.48. This is followed by financial difficulties, demand deficiency and raw material/equipment shortages. These findings, consistent with the literature, show that while demand plays a decisive role in capacity utilization, clearly demonstrate the need to define sector and region-specific capacity management strategies in addition to general economic policies.

2. LITERATURE

The Capacity Utilization Rate (CUR) is a key economic indicator that shows how much of their existing physical capacity manufacturing enterprises are being used (TCMB). While there are studies in the literature that address macroeconomic factors such as the relationship between Capacity Utilization Rate and real sector confidence index, industrial production index and stock market indices, studies on capacity utilization rate itself are limited. Capacity Utilization Rate is closely related to macroeconomic variables such as economic growth, inflation and investment decisions. High Capacity Utilization Rates are considered an indicator of economic expansion and increasing industrial production, while low Capacity Utilization Rates may indicate economic stagnation and contraction (Demir and Özcan, 2023). In a study examining the relationship between Capacity Utilization Rate and exports in Türkiye, it is

evaluated that the direction of the manufacturing industry capacity utilization rate can be predicted according to the trend of exports (Aktepe and Yumuş, 2023). In the study examining the manufacturing industry capacity utilization rate between 2007-2017, it is evaluated that high production costs; High transportation costs, a shortage of skilled labor, high tax and social security contribution burdens on employment, and high input prices, along with high VAT and excise tax rates on these inputs, have been identified as reasons preventing the capacity utilization rate from reaching the desired level (90%) (Koç et al., 2017). In their study, Karahan and Çalık (2021) analyzed the capacity and competitiveness of businesses registered in the Van Organized Industrial Zone. The average capacity utilization rate of businesses was determined to be 54.4%, and the most established businesses were found to be in the food, construction, chemical, petroleum, rubber, and plastics sectors. Factors determining competitive advantage were identified as costs, quality, technical knowledge, marketing innovation, organizational innovation, process innovation, and product innovation. A study analyzing micro-data on capacity utilization in Swedish manufacturing firms suggests that differences in capacity utilization and changes over time should be evaluated based on individual factors rather than aggregate effects, and that demand uncertainty reduces capacity utilization, especially for high-profit margin firms (Amberg et al., 2025). In their study, Koşaroğlu and Özek (2013) concluded that an increase in the capacity utilization rate positively affects the expectations of the real sector, and that strategies should be followed to ensure the development of both the financial and real sectors, accepting the existence of a relationship between the manufacturing industry capacity utilization rate, the real sector confidence index, and the BIST-100 index. Another study examining the long-term and short-term relationships between BIST sector indices and capacity utilization rates concluded, based on cointegration analysis results, that there is a long-term relationship between the Financial, Industrial, and Technology indices and capacity utilization rates, excluding the BIST Services index (Şahin and Kırıcı, 2019). Albayrak (2018) concluded that there is a long-term cointegrated structure between the real sector confidence index and the manufacturing industry capacity utilization rate in Turkey, and that, according to Granger causality results, there is a unidirectional causality between the real sector confidence index and the capacity utilization rate. In Ay's (2019) study, a Granger Causality test analysis between manufacturing industry capacity utilization rate and the real sector confidence index revealed a bidirectional causal relationship between the two variables.

Factors limiting production include insufficient demand, labor shortages, difficulties in raw material procurement, and financing problems. Identifying and analyzing these factors is crucial for the effectiveness of industrial policies. In conclusion, while various studies on Capacity Utilization Rates exist in the literature, detailed analyses at the regional level are limited.

3. MATERIALS AND METHODS

Data were obtained using a face-to-face surveys of 77 firms in the Kocaeli IMES Organized

Industrial Zone for the year 2025. The survey was prepared considering the Economic Trends Survey (İYA) conducted by the Central Bank of the Republic of Turkey (TCMB) to monitor capacity utilization rates of manufacturing businesses. In this study, the firms' current capacity utilization rates and the values they assigned to factors limiting production were determined as percentages. A binary logistic regression analysis was performed using the obtained data. In the analysis, the dependent variable, Capacity Utilization Rate, was defined according to whether it was below or above 70, while the independent variables consisted of factors representing production constraints such as the demand deficiency, labor shortage, difficulty in accessing raw materials, and financing difficulties.

3.1. Model

The observed capacity loss in businesses and the factors causing it have been identified as: demand deficiency, labor shortage, raw material/equipment shortage, and financial difficulties. The impact of factors restricting production on capacity utilization has been analyzed using binary logistic regression. This method, which allows the dependent variable to be categorical, determined which factors increase the likelihood of the capacity utilization rate falling below the critical value of 70 percent. The model takes the values of one and zero depending on whether the dependent variable (CUR) is below or above 70 percent. The independent variables in the model represent the factors restricting the production of businesses: demand deficiency, labor shortage, raw material/equipment shortage, and financial difficulties. The general function of binary logistic regression is as follows:

$$\ln\left(\frac{p_l}{1-p_l}\right) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_l x_l \qquad (1)$$

The dependent variable used in the model is given a value of 1 for CUR values 70 percent and below, and a value of 0 for values above 70 percent. This regression model shows the probability that a one-unit change in the independent variables will result in the dependent variable. The model results are shown in Table 1.

Tablo 1. Variables in the Equation

Variables	**B**	**S.E.**	**Wald**	**df**	**Sig.**	**Exp(B)**	**95% C.I.for EXP(B)**	
							Lower	**Upper**
1. Demand Deficiency	,733	,258	8,078	1	,004	2,082	1,256	3,452
2. Labor Shortage	,910	,348	6,841	1	,009	2,485	1,256	4,917
3. Raw Materials/Equipment	,696	,263	7,007	1	,008	2,005	1,198	3,356
4. Financial Difficulties	,818	,318	6,611	1	,010	2,265	1,215	4,224
Constant	-20,733	6,736	9,474	1	,002	,000		

a. Variable(s) entered on step 1: 1 Demand Deficiency, 2 Labor Shortage, 3 Raw Materials/Equipment, 4 Financial Difficulties.

According to logistic regression analysis, changes in all independent variables have a statiscally

significant effect on the estimation capacity utilization rate ($p<0.05$). The r-squared (R^2) of the model is 98.7. Here, B>0 means that the probability increases as the coefficient of the variable representing the case increases. Considering that all variables are significant in predicting the dependent variable ($p<0.05$), when this calculation is performed using the demand variable as an example, B=0,733; $e^{(0.733)} = 2.08$, indicating the risk of the capacity utilization rate falling below 70 percent. as the demand deficiency increases by 1 unit, the risk of the capacity utilization rate falling below 70% increases by 2.08. As the labor shortage increases by 1 unit, this risk increases by 2.48. As the raw material/equipment shortage increases by 1 unit, this risk increases by 2, and when financial difficulties increase by 1 unit, the risk increases by 2.26. Moreover, the average capacity utilization rate of companies was is 76.3. Identifying which factors are most effective in causing capacity loss is crucial for preventing potential losses and taking strategic measures.

4. FINDINGS

This study analyzes the Capacity Utilization Rate, an indicator of how effectively the production capacity of the manufacturing industry is used, and the factors that restrict production. Specifically, the impact of factors causing capacity utilization loss in the manufacturing industry, such as the demand deficiency, labor shortage, financing difficulties, and raw material/equipment shortages, on the capacity utilization rate was determined. The independent variables in the model represent the problems experienced by companies. All independent variables increase the probability of capacity loss. The coefficient for the demand deficiency variable was found to be statistically significant, and it was observed that a 1-unit increase increased the probability of the capacity utilization rate falling below 70 percent by 2.08 units. This finding is consistent with studies in the literature. However, for the Kocaeli IMES Organized Industrial Zone, labor shortage was found to be the most prominent variable. It was determined that a 1 unit increase in labor shortage increased the risk of the capacity utilization rate falling below 70 percent by 2.48 units. This finding demonstrates the need to identify factors restricting production through regional-level analyses and develop strategies accordingly. When examining the sub-components representing the labor shortage factor, the inability to provide sufficient labor despite demand is the dominant factor, although employee-related losses and shortages are also present. From this perspective, it has been observed that the sector experiences a shortage of trained employees. Training programs can be encouraged by both supporting existing employees with training and organizing training programs for new employees, followed by their employment in the sector. When the financial difficulties experienced by companies increase by 1 unit, the risk of the capacity utilization rate falling below 70 percent increases by 2.26 units. When the factors representing this increase are examined, uncertainty and lack of access to credit are observed. It is clear that reviewing the terms of credit facilities provided within industrial zones or making arrangements to include more businesses would benefit businesses in the region by enabling them to use their capacities more effectively. The

fact that the risk of a 2 unit increases with a 1 unit increase in the raw material/equipment shortage factor shows that even the lowest observed factor significantly increases the risk of capacity utilization falling below 70 percent, and demonstrates the need to develop strategies to address the problems of companies. Taking measures to minimize factors that restrict production will be an important step towards sustainable growth and economic stability. These findings clearly demonstrate the need to define sector and region-specific capacity management strategies in addition to general economic policies.

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DOES INFLATION MATTER MORE THAN GROWTH? A PANEL NARDL ANALYSIS FOR OECD

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ABSTRACT

In this study, 25 countries in OECD were selected and examined with panel dataset created for years 1993-2023. Military expenditures were determined as the dependent variable, and economic growth and inflation rate were determined as independent variables. The short- and long-term relationships between the variables were analyzed within the framework of the nonlinear model. It is aimed to reveal whether there are asymmetric causality structures among these variables. Panel NARDL and PMG Estimator were used together in the study. According to the results obtained, the inflation rate had a more significant effect on military expenditures than economic growth. While the budget allocated to military expenditures shows a significant increase in positive inflation shocks, it has a more limited reducing effect in negative inflation shocks. The effect of economic growth on defense expenditures is weak and a statistically significant coefficient has not been obtained.

Keywords: Military Expenditures, Inflation, Economic Growth, Panel NARDL Model, Asymmetric Causality.

JEL Codes: *H56, E31, O40, C33, C22.*

1. INTRODUCTION

Military expenditure characterized by dual nature as both economic and strategic policies. Military expenditure is different than other expenditures because of it is shaped by political pressure and economic volality. In this contex military expenditure is specific and variable for developed and developing countries. According to the Stockholm International Peace Research Institute (SIPRI, 2024) global military spending have exceeded 2.7 trillion dollars, the highest level in history. Therefore, there is a need for a theoretical and empirical reassesment of the effects of military expenditures.

Neo-classical theories defens that military expenditures crowd out private investments, reduce national savings. In the other hand military expenditures effect growing in long run term negatively by opportunity cost (Ram, 1986). In contrast to Neo-classical theories, Keynesian perspective explains that

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high military spending stimulates demand, increase economic growth (Benoit, 1973; Dunne et al., 2005). These two views trying to explaining between opportunity cost hypothesis and demand stimulation hypothesis difference in varying contexts.

Endogenous growth theories examine economic growth in long run term by goverment expenditures. Accorging to endogenous growth theory, the long run term effects of public expenditures and defend spending depend on human capital, innovation and institutional quality (Barro, 1990; Aizenman and Glick, 2006). In this framework military expenditure may enhance growth if supporting tecnique development or infrastructure but may also affect negatively. For example, goverment spending based on non-productive spending absorbs from more productive sectors (Knight et al., 1996). Another point is that military spending be financed by tax revenues in developing countries. This may have structual consequences that directly effect inflation Gupta et al., 2002; Clements et al., 2007). Especially defense budgets in real terms reduces defense effectiveness and leads goverments to allocate additional resoruces in term of high inflation. This situation effects to growth directly (Yıldırım and Sezgin, 2005).

Recently research has shown that the relationship between military expenditures, growth and inflation rates are not linear. For example high inflation rates affect military expenditures strongly or weakly in different periods. Therefore, the relationship between defense, growth and inflation should be considered asymetric (Ewing and Malik, 2004; Shin et al., 2014; Syed et al., 2021).

The main aim of this study is to analyze the effects of military expenditures on economic growth and inflation rates within the framework of nonlinear asymmetric structures and to reveal how this relationship advanced economies. In this context, a comprehensive panel data set of 25 selected OECD countries are examined the period 1993-2023 is used. These countries offer comparative advantages in this kind of macroeconomic analysis as they have similar fiscal discipline norms, data quality and institutional governance. Thus, the impact of military expenditures on growth, inflation rates, price stability can be assessed in a more generalizable way with being unlimited to individual country cases.

In the methodological framework of the study, the nonlinear autoregressive distributed lags (NARDL) method is preferred. This method is suitable of observationing effects of negatively and positively.

2. LITERATURE REVİEW

Benoit (1978) analyzed the relationship between military expenditures and economic growth between countries. According to his findings, there is a positive relationship between defense expenditures and economic growth. In other words, the growth rate is also high in a country with high defense expenditures.

The historical comparative study by Rasler and Thompson (1985) demonstrates that during periods of major warfare, public expenditures, military spending, and tax revenues tend to move

together. Based on long-run historical evidence, the authors show that increases in defence spending are accompanied by higher tax revenues and that this relationship reinforces itself over time. These results clearly indicate a positive and bidirectional defence–tax nexus.

Chowdhury (1991) tested 55 developing countries with multiple regression analysis and comparative country analysis between 1960 and 1985. Defense expenditures, inflation and growth are considered variables, and defense expenditures have an indirect but positive effect on inflation. It is understood that this effect is even more evident in countries with weak fiscal discipline.

Dunne, Perlo-Freeman and Soydan (2004) analyse a panel dataset for 11 small industrialised economies spanning the period 1960–2000, jointly considering defence expenditures, public debt, and tax revenues. The results indicate that rising defence expenditures place significant pressure on public budgets, triggering upward adjustments in tax revenues. The evidence points to a positive and predominantly one-way relationship running from defence spending to tax revenues.

Kollias, Manolas and Paleologou (2004) conducted a time series analysis for Greece for the period 1960-2000. Defense expenditures, inflation and budget deficit were the variables, and Dickey-Fuller Test (ADF) and Phillipps-Perron PP Unit Root Tests, Johansen Cointegration Test and VECM Granger Causality Test were performed. A single-tone causality relationship was found from defense expenditures to inflation. In other words, as defense expenditures increase, inflation also increases.

Dunne, Smith, Willenbockel (2005) tested a total of 28 developed and developing countries with panel regression between 1960 and 1996. Defense expenditures, economic growth, population growth and capital accumulation are variables, and the effect of defense expenditures on economic growth in developing countries has been found to be negative.

Besley and Persson (2009), drawing on a broad cross-country sample and long-term historical data, examine the link between tax revenues and military conflict. By using the tax-to-GDP ratio as a key indicator of state capacity, they show that defence and conflict pressures contribute to the strengthening of fiscal capacity, while enhanced fiscal capacity, in turn, facilitates higher levels of defence spending. There is a positive and two-sides relationship in the long run.

Dincecco (2009) and Dincecco, Federico and Vindigni (2011) examine the interaction between military spending, taxation, and fiscal centralisation, focusing primarily on European and Italian historical cases. Their analyses demonstrate that increases in military expenditures are systematically associated with higher levels of taxation and that this relationship is closely linked to institutional development and state capacity. Overall, their findings indicate the existence of a positive and two-sides long-term run relationship between defence expenditures and tax revenues.

Rota (2011) analyses a historical panel dataset covering 32 countries over the period 1880–1938, focusing on the relationship between military burden, fiscal capacity, and political regimes. The findings

indicate that defence expenditures contribute to the expansion of fiscal capacity, which in turn supports higher levels of military spending. This evidence further confirms that the relationship between defence expenditures and tax revenues is two-sides effect in the long run.

D'Agostino, Dunne and Pieroni (2013) took the growth rate as the dependent variable and tested public expenditures as the control variable, with military expenditures being the independent variable. He made a comparative estimate with the OLS method by taking the years 1998-2010 for African countries. The increase in military expenditures has a negative impact on African countries.

Shahbaz, Afza, and Shabbir (2013) examined the period 1971-2009 for Pakistan with the ARDL Test, the Granger Causality Test, and the CUSUM, CUSUMSQ Test. Defense expenditures, inflation and growth are variable, and according to the findings, there is a positive long-term relationship between defense expenditures and inflation. In this causality relationship from inflation to military expenditures, military expenditures increase as inflation increases.

Čevik and Ricco (2015) investigate the fiscal consequences of security and defence expenditures using a panel dataset covering approximately 150 countries over the period 1970–2013. Their analysis shows that increases in security-related spending are associated with upward adjustments in tax revenues, with causality predominantly running from defence expenditures to fiscal revenues. This finding indicates that defence-related pressures play an income-enhancing role in public finances in the short term.

Espuelas (2015) adopts a long-run historical perspective by analysing a panel of 10 European countries and focusing on military expenditures, total tax revenues, and direct taxation. The study finds that war and defence pressures generate not only temporary increases in public revenues but also permanent improvements in the state's tax-collecting capacity. In this context, the relationship between defence expenditures and tax revenues is identified as positive and two-sides.

Arshad, Syed and Shabbir (2018) tested the period 1988-2015 with the LSDV method by taking the share of military expenditures in gross national product, trade deficit, population, and defense imports as independent variables, with per capita income as the dependent variable. According to the findings, it was concluded that the increase in military expenditures increased the cost to the state and negatively affected the per capita income.

Pieroni (2019) tested the 1961-2005 period for 18 NATO member countries. Military expenditures, economic growth and public debt were selected as variables and the panel ARDL test was performed. It has been revealed that defense expenditures have a negative impact on growth in the long run and tight fiscal policies have a decisive role.

Tian, Lopes da Silva and Liang (2023), using a broad cross-country sample covering the period 1990–2020, demonstrate that increases in defence expenditures exert a statistically significant and

positive effect on tax revenues. Their findings provide empirical support for fiscal policy arguments suggesting that defence spending is predominantly financed through the taxation channel in the short and medium term run.

Bolouri (2025) examines the relationship between defence expenditures, tax revenues, public debt, and budget balances by employing an extensive dataset encompassing 167 countries over the period 1817–2024. Using long-run panel methods, the study shows that while defence spending increases are frequently financed through borrowing, tax revenues become an increasingly important source of financing in cases of persistent and structural rises in military expenditure. Accordingly, the relationship appears largely unidirectional in the short term, whereas a two-sides interaction between defence spending and fiscal capacity emerges over the long-term run.

3. DATASET AND ANALYSIS

The panel dataset used in the analysis consists of 25 countries observed over the period 1993–2023, yielding a balanced panel with 775 observations (25 × 31) and no missing values. The model includes three core variables: military expenditures (ME), inflation rates (INF), and economic growth measured by GDP growth (GDPGR). All variables are expressed in logarithmic form where appropriate to ensure scale consistency and to facilitate elasticity-based interpretation. The cross-sectional dimension (N = 25) and the time dimension (T = 31) provide sufficient variation to capture both country-specific dynamics and long-run temporal relationships among the variables within a panel econometric framework

Table 1. Summary Statistics

Variables	Observation	Average	Std. Err.	Minimum Value	Maximum Value
ME	775	1.5193	0.671733	0.216858	4.139697
INF	775	5.345155	18.16459	-4.44755	410.4519
GDPGR	775	2.428171	3.530393	-16.2269	24.61557

Note: *The panel data set consists of 25 countries and 31 years (25x31=775) and there are no missing observations. **Military expenditure (ME) is a dependent variable. ***Inflation (INF) and Economic Growth (GDPGR) are independent variables.

The panel NARDL model accommodates mixed integration orders and captures short-and long run- asymmetries. The decomposition of inflation into positive and negative shocks allows a more realistic modelling of Policy effects. According to Table 1. inflation correlates more strongly with military expenditure than growth. The dataset covers a long horizon and includes advanced economies

with similar institutional structures. This improves cross-country comparability and supports robust estimation.

Table 2. Correlation Coefficients

Panel A. Standard Correlation Matrix				**Panel B. Partial Correlation**	
Variables	lnME	lnINF	lnGDPGR	Variables	lnME
lnME	1			lnINF	0.2702***
lnINF	0.2653***	1			(0.0000)
	(0.0000)			lnGDPGR	-0.0652*
lnGDPGR	-0.0378	0.0933***	1		(0.0698)
	(0.2929)	(0.0093)			

Note: *, **, and *** represent significance levels of 10%, 5%, and 1%, respectively. Parentheses indicate probability (p-value) values.

The results presented in Panel A show a positive and statistically significant relationship between inflation rates and defense expenditures. On the other hand, although a negative correlation coefficient was calculated for economic growth and defense expenditures, this relationship is not statistically significant.

The results in Panel B indicate a negative and statistically significant relationship between inflation and defense expenditures, as well as a negative and significant relationship between economic growth rates and defense expenditures. Furthermore, considering the magnitude of the correlation coefficients, it is understood that the relationship between inflation rates and defense expenditures is relatively stronger.

Table 3. Cross- Sectional Dependence Test Results

Variables	**LM_{BP} Statistics**	**$LM_{adj.}$ Statistics**
lnME	3697.382***	
lnINF	3885.895***	
lnGDPGR	4046.979***	

According to the results of the LMBP and LMadj tests, the null hypothesis indicating the absence of cross-sectional dependence for the variables lnME, lnINF, and lnGDPGR is rejected based on both test statistics. Therefore, it is necessary to proceed with second-generation panel unit root tests that take

cross-sectional dependence into account in the unit root analyses of the variables. Within this scope, the Pesaran (2007) CIPS test, which is among the second-generation tests and is frequently used, was employed in the study.

Table 4. CIPS Panel RootTest Results

Variables	**Constant CIPS Statistics**	**Constant and Trend CIPS Statistics**
lnME	-2.210**	-2.334
dlnME	-4.808***	-4.859***
lnINF	-3.186***	-3.425***
lnGDPGR	-3.584***	-3.595***

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

According to the results of the unit root test in Table 4, the null hypothesis indicating the presence of a unit root can only not be rejected for the level values of the lnME variable (trend equation), whereas the unit root hypothesis is rejected for the lnINF and lnGDPGR variables. In order to determine the degree of stationarity of the lnME variable, the first difference was taken (dlnME) and the CIPS test was applied again. For the dlnME variable, the null hypothesis indicating the presence of a unit root was rejected, and it was found that this variable is first-order stationary. In this case, the lnINF and lnGDPGR variables are stationary at the level, while lnME is integrated of the first order. Therefore, it was found that the variables are integrated at different orders. In this study, due to the identification of at least one non-stationary variable, an analysis process based on cointegration relationships was adopted. Therefore, Westerlund's (2008) panel cointegration test, which investigates long-term relationships in the presence of variables of different degrees, was used to test cointegration relationships.

Table 5. Westerlund (2008) Cointegration and Symmetry Test Results

Panel A. Cointegration Test Results		**Panel B. Symmetry Test Results**		
Test type	Test statistic	Coefficients	F-statistic	Probability (Prob. Value)
Durbinh-grup	7.907***	lnINF	11.8410***	0.0006
Durbinh-panel	2.479***	lnGDPGR	15.1528***	0.0001

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

According to the results of the cointegration test in Table 5 Panel A, the null hypothesis stating that there is no cointegration was rejected. This finding indicates that defense expenditures, economic

growth, and inflation rates move together in the long term. Based on the cointegration finding, it was theoretically appropriate to use the ARDL technique, which allows for modeling stationary and non-stationary structures in the estimation phase of the long-term regression model. However, ARDL structures are based on the symmetry assumption, and in line with the findings in Table 5 Panel B indicating that the explanatory variables have asymmetric effects on lnME in the long term, the NARDL technique, an asymmetric alternative to the ARDL technique developed by Shin et al. (2014), to separately assess the effects of positive and negative shocks in inflation rates and economic growth rates on the defense expenditures of 25 countries.

Table 6. Estimation of Long-Term and Short-Term Models

Dependent Variable: lnME				
Long-Term				
Independent Variables	**Coefficients**	**Standard Error**	**t Statistics**	**Probability (Prob. Value)**
$lnINF^{+}$	0.5077***	0.0937	5.4215	0.0000
$lnINF^{-}$	0.1576***	0.0435	3.6236	0.0003
$lnGDPGR^{+}$	-0.0252	0.0378	-0.6651	0.5062
$lnGDPGR^{-}$	0.0753**	0.0347	2.1676	0.0305
Short-Term				
Independent Variables	**Coefficients**	**Standard Error**	**t Statistics**	**Probability (Prob. Value)**
ECT	-0.0898***	0.0197	-4.5606	0.0000
dlnINF	-0.0331***	0.0106	-3.1254	0.0018
dlnGR	-0.0150***	0.0025	-6.0685	0.0000
Constant term	0.0169	0.0131	1.2869	0.1985

Note: *, **, and *** represent significance levels of 10%, 5%, and 1%, respectively. The appropriate model was determined based on the smallest AIC value.Constant term model PMG(1,1,1) was estimated.

Table 6 shares the findings related to the long-term and short-term models estimated using the pooled mean group estimator (PMG) by Pesaran et al. (1999).

4. CONCLUSION AND EVALUATION

In the long term, positive and negative shocks to inflation rates have been found to have a positive and statistically significant effect on defense spending. In this context, a 1% positive shock to inflation rates increases defense spending by approximately 0.51%, while a 1% negative shock to inflation rates increases defense spending by approximately 0.16%. In terms of economic growth rates, a 1% negative shock increases defense spending by approximately 0.08%, while no statistically significant coefficient estimate was obtained for positive shocks. The short-term model is symmetric, showing that a 1% increase in inflation reduces defense spending by approximately 0.03%, while a 1% increase in economic growth reduces defense spending by approximately 0.02%. When findings from long-term and short-term models are evaluated together, changes in inflation rates in the long-term increase defense spending, while inflation increases in the short term decrease defense spending. On the other hand, the inverse findings regarding economic growth show similarities in both the long and short terms. In the long term, economic growth declines, rather than increases, have an effect on defense spending increases. In the short term, it is possible to see the net effect of increases in economic growth. Controlling inflation is crucial for stable defense planning.

Governments must take asymmetric fiscal adjustments into account. Growth alone is not a sufficient driver for military spending. Inflation has a lasting long-term impact on military spending. This explains why inflation is more important than growth and has a strong long-term impact. Short-term inflation temporarily reduces the military expenditure variable (ME), but its long-term impact is dominant. This indicates structural rigidity in defense budgeting. These results show that defense spending reacts more sensitively to inflationary environments. The existence of asymmetric effects highlights fiscal inertia and rigid defense commitments. Policymakers should consider inflation dynamics when evaluating defense spending. The asymmetric models found in the analysis show that traditional linear models underestimate the role of inflation.

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UNCOVERING THE DRIVERS OF BMI: A DECISION TREE EXPLORATION OF LIFESTYLE AND HEALTH INDICATORS

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Halil TUNCA[**]

ABSTRACT

This study explores the key factors affecting Body Mass Index (BMI) using a decision tree to understand better how demographic, socioeconomic, and lifestyle factors collectively influence weight status. Data from the Turkish Statistical Institute (TÜİK), including demographic, health, and lifestyle variables, were analyzed, with BMI categorized into four groups: Underweight, Normal, Overweight, and Obese. Feature engineering methods, such as one-hot encoding and variable selection, were used, and a Decision Tree model based on entropy criteria was optimized via hyperparameter tuning and evaluated using accuracy, precision, recall, and F1-score metrics. Results show that age is the most influential predictor of BMI classification, followed by socioeconomic factors like income and education. Lifestyle behaviors—including fruit and vegetable intake, lemonade or cola consumption, and physical activity—also significantly impact outcomes. The model performed well at identifying extreme BMI groups (Underweight and Obese) but had moderate accuracy with the intermediate groups (Normal and Overweight) due to overlapping features. Overall, the study emphasizes the importance of integrating demographic, socioeconomic, and behavioral factors in BMI prediction and provides valuable insights for developing targeted public health interventions. Although the model's predictive power is moderate, its interpretability makes it a useful tool for guiding data-driven obesity prevention efforts and future research, potentially incorporating behavioral and genetic variables to improve accuracy.

Keywords: *Decision Tree Classifier, Health Determinants, Lifestyle Factors, BMI Prediction, Machine Learning for Health.*

JEL Codes: *I12, I14, C45, I18.*

1. INTRODUCTION

Obesity and elevated body mass index (BMI) are among the most pressing global health challenges, contributing to increased morbidity, mortality, and economic burden worldwide. Excessive body fat accumulation beyond normal levels poses significant health risks for individuals. Body Mass Index (BMI)—calculated as weight in kilograms divided by height in meters squared—serves as a

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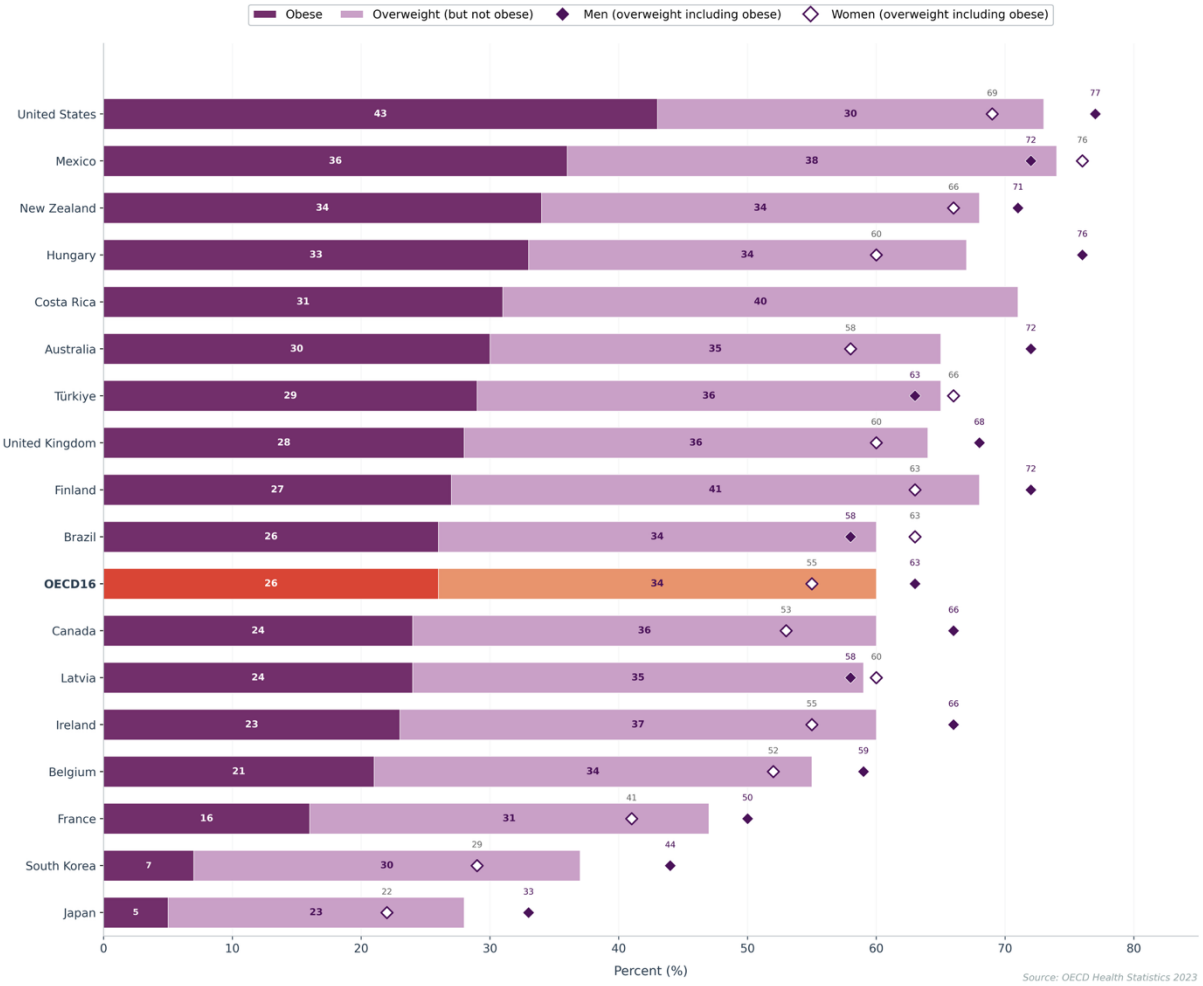
standardized measure to evaluate weight status. According to the World Health Organization (WHO), adults aged 18 years and older with a BMI of 25 or above are classified as overweight, while those with a BMI of 30 or above are considered obese. This classification system applies to all adult age groups and both sexes, and BMI can be determined through either direct physical measurements or self-reported height and weight, making it valuable for both clinical and population-level analyses (OECD, 2023a).

The condition of being overweight or obese substantially increases the risk of developing multiple non-communicable diseases, including type 2 diabetes, cardiovascular diseases, and certain cancers. The COVID-19 pandemic further illuminated these risks, as individuals with obesity exhibited higher rates of hospitalization and mortality (OECD, 2023b). Obesity also disproportionately affects individuals with lower socioeconomic status, reinforcing persistent health disparities across gender and income groups. The prevalence of calorie-dense diets high in trans and saturated fats, coupled with rising sedentary lifestyles, has accelerated this global trend. Moreover, pandemic-related restrictions exacerbated unhealthy behaviors, undermining the progress of public health initiatives promoting wellness (WHO, 2022).

According to OECD Health Statistics (2023), more than 60% of adults across 16 OECD member countries were overweight or obese, and over one-fourth of the population was obese. Among these countries, Türkiye stands out as one of the most affected nations, with over half of its adult population classified as overweight or obese. Notably, Türkiye is one of only three OECD countries where women exhibit higher rates of overweight and obesity than men, a pattern suggesting that socio-cultural and economic dynamics play a critical role in shaping gender-specific health outcomes. In contrast, countries like Japan and Korea maintain significantly lower obesity prevalence, emphasizing regional and lifestyle-driven differences in population health (see Figure 1). These findings underscore Türkiye's urgent need for data-driven strategies to mitigate obesity risks and promote healthier lifestyles aligned with national and global public health goals.

Figure 1. Measured Overweight and Obesity Rates Among Adults by Sex



Building on this context, the present study employs nationally representative data from the Turkish Statistical Institute (TÜİK) and an interpretable decision tree model to uncover how demographic, socioeconomic, and lifestyle factors jointly shape BMI categories in Türkiye. By examining BMI groups, the study aims to identify key predictors of weight status and to highlight actionable insights for targeted public health interventions.

The remainder of this paper is organized as follows. Section 2 presents the data sources, variable definitions, and methodological approach, including preprocessing procedures, feature importance analysis, and the specification of the decision tree. Section 3 reports and interprets the empirical findings, emphasizing model performance, misclassification patterns, and the decision rules that characterize different BMI groups. Section 4 concludes the study by summarizing the main results, discussing their policy implications, and outlining potential directions for future research.

2. DATA AND METHODOLOGY

2.1. Data Description

This study uses data from the Turkish Statistical Institute (TÜİK), including demographic, socioeconomic, lifestyle, and health-related variables. The dataset comprises information on gender, age, educational attainment, employment status, income, dietary habits, physical activity levels, and self-reported health conditions, including chronic diseases and mental health indicators. BMI was calculated using standard height and weight measurements and categorized into four classes: Underweight, Normal, Overweight, and Obese, in line with World Health Organization (WHO) thresholds.

Each variable was organized and coded to facilitate statistical and machine learning analyses. Table 1 summarizes the dataset structure and variable types, covering key determinants of health behaviors and BMI variation across the Turkish population. This dataset provides a comprehensive foundation for exploring how demographic, socioeconomic, and behavioral factors interact to influence BMI outcomes.

Table 1. Dataset variable overview

Variable Name	Description	Type	Unit/Range	Notes
Gender	Gender of the respondent	Categorical	1=Male, 2=Female	Demographic information
EducationalLevel	Highest level of education completed	Categorical	Ordinal	Education background of the respondent
MaritalStatus	Marital status	Categorical	Single, Married, etc.	Respondent's current marital status
EmploymentStatus	Employment status	Categorical	Employed, Unemployed, Retired, etc.	Current employment status
CalculatedAge	Age of the respondent	Continuous	Years	Derived from birth year
Income	Monthly income	Continuous	Local currency	Self-reported income level
SocialSecurity	Social security status	Categorical	Yes/No	Access to social security benefits
SocialActivity	Frequency of social activity participation	Categorical	Frequency categories (e.g., weekly)	Level of social engagement
FruitConsumptionFrequency	Frequency of fruit consumption	Categorical	1=Daily, 2=4-6 times/week, etc.	Intake of fruits per week
VegetableSaladConsumptionFrequency	Frequency of vegetable/salad consumption	Categorical	1=Daily, 2=4-6 times/week, etc.	Excludes potatoes and certain soups
LemonadeColaConsumption	Frequency of lemonade or cola consumption	Categorical	Frequency categories	Self-reported sugary beverage intake

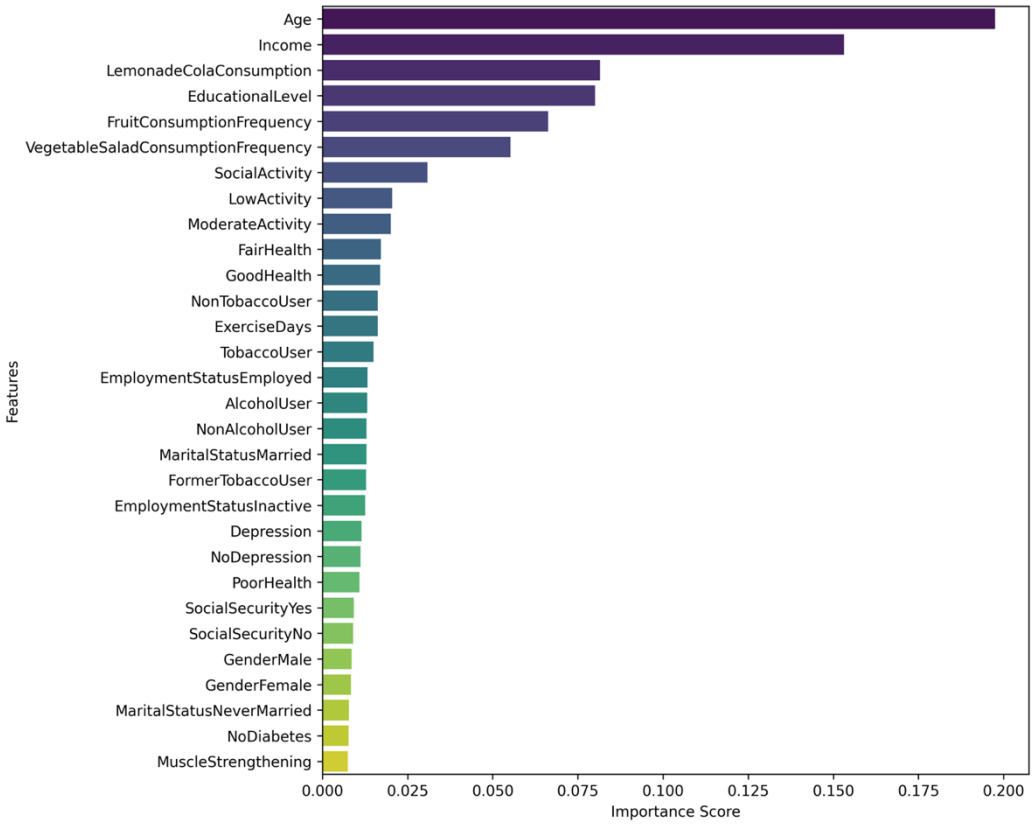
TobaccoUseStatus	Tobacco use status	Categorical	Current, Former, Never	Smoking behavior
AlcoholUseStatus	Alcohol use status	Categorical	Yes/No	Self-reported alcohol consumption
DailyActivityLevel	Daily activity level	Categorical	Sedentary, Moderate, Active	Physical activity level
ExerciseDays	Number of days exercised per week	Continuous	Days	Days per week dedicated to exercise
MuscleStrengthening	Muscle-strengthening activity frequency	Categorical	Frequency categories	Includes gym or home-based strength training
ChronicDiseaseDiabetes	Presence of diabetes as a chronic condition	Categorical	Yes/No	Self-reported health condition
ChronicDiseaseDepression	Presence of depression as a chronic condition	Categorical	Yes/No	Self-reported health condition
GeneralHealthStatus	Self-assessment of general health status	Categorical	1=Excellent, 2=Good, 3=Fair, 4=Poor	Perceived overall health
BMI	Body Mass Index	Continuous	kg/m²	Calculated from height and weight

2.2. Data Preprocessing and Feature Engineering

Before model training, categorical variables such as gender, marital status, education, employment, and health behaviors were numerically encoded to enable algorithmic processing. Continuous variables (e.g., age and income) were standardized to improve comparability. The target variable, BMI, was converted from continuous to categorical, framing the task as a multi-class classification problem.

Feature importance was initially assessed using a Random Forest Classifier to identify the most influential predictors. Age, income, and educational level emerged as dominant demographic and socioeconomic indicators. In contrast, lifestyle-related factors such as fruit and vegetable consumption, sugary drink intake, and physical activity levels also played significant roles. Figure 2 illustrates the feature importance distribution, highlighting the relative contribution of each variable to BMI classification.

Figure 2. Feature Importance Scores for Health and Lifestyle Classification



2.3. Decision Tree Model

A Decision Tree Classifier was developed to classify individuals into Body Mass Index (BMI) categories using demographic, socioeconomic, and lifestyle predictors. Decision Trees recursively partition data into homogeneous subgroups by minimizing impurity measures such as entropy or the Gini index (Tangirala, 2020; Suthaharan, 2016). These impurity measures quantify the degree of disorder within a node, with smaller values indicating greater homogeneity among samples.

In this study, the entropy criterion was adopted to guide the splits, defined as:

$$Entropy = -\sum_{i=1}^{C} p_i \log_2(p_i) \quad (1)$$

where p_i represents the probability of class i within the node. A node achieves maximum purity when all observations belong to a single class. The algorithm recursively selects features that maximize information gain (IG), calculated as (Zhang and Gionis, 2022):

$$IG(S, A) = Entropy(S) - \sum_{v \in Values(A)} \frac{|S_v|}{|S|} Entropy(S_v) \quad (2)$$

where S_v denotes the subset of samples for which attribute A takes value v. This ensures that each split produces the greatest separation between BMI classes.

The Decision Tree was designed with a maximum depth of three, balancing interpretability and generalization capability. A shallow depth facilitates model transparency, which is essential for health-related classification tasks where decision logic must remain explainable to policymakers and clinicians (Balcan and Sharma, 2024; Lee, Lee, Mun, and Kim, 2022). The recursive partitioning process continues until all nodes are either pure or reach the maximum depth constraint, avoiding overfitting while maintaining predictive strength (Breiman, 2001).

2.4. Hyperparameter Tuning and Evaluation

To enhance predictive accuracy and model interpretability, a grid search was used to tune hyperparameters for the Decision Tree's primary parameters, including the splitting criterion, maximum depth, minimum samples per split, and pruning complexity (Stamate, Alghamdi, and Zamyatin, 2018). The optimal configuration achieved was:

- Splitting criterion: *Entropy*
- Maximum depth: *3*
- Minimum samples per split: *2*
- Minimum samples per leaf: *1*
- Complexity pruning parameter: *0*

The dataset was split into training (70%) and test (30%) sets to evaluate generalization performance. Model performance was assessed using accuracy, precision, recall, and F1-score, standard metrics in supervised learning (Rosa and Cesa-Bianchi, 2016). The F1-score, defined as the harmonic mean of precision and recall, is calculated as:

$$F_1 = 2 \times \frac{Precision \times Recall}{Precision + Recall} \tag{3}$$

This measure provides a balanced assessment of the model's reliability by accounting for both false positives and false negatives.

The final model demonstrated moderate overall accuracy but effectively distinguished the *Underweight* and *Obese* categories, aligning with previous findings in health-based classification studies (Breiman, 2001; Zhang and Gionis, 2022)

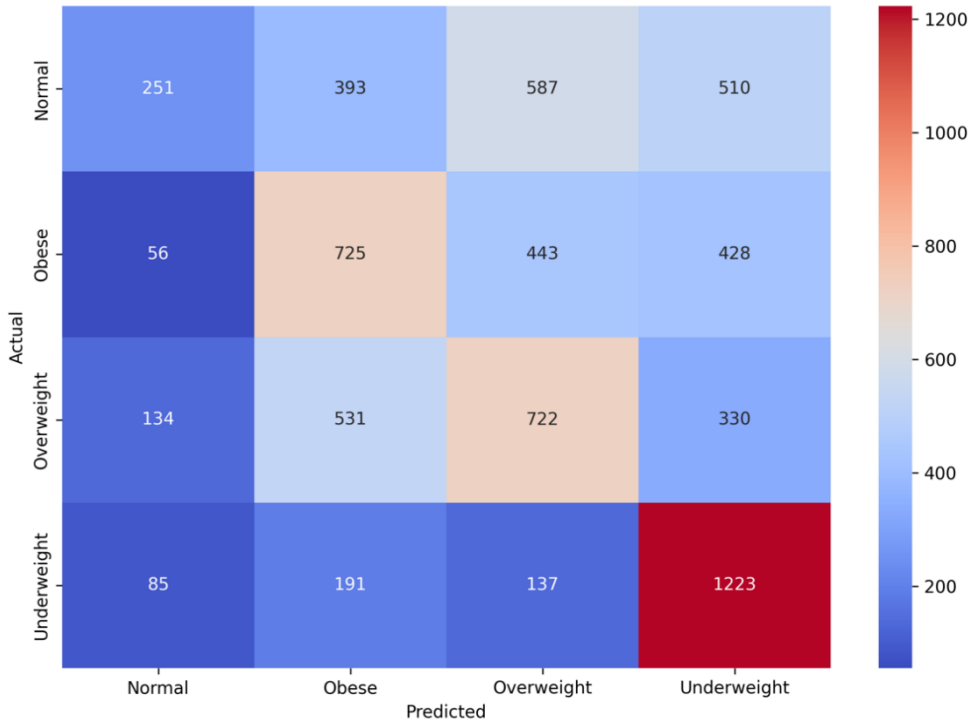
3. RESULTS AND DISCUSSION

The Decision Tree model's classification results are presented in Figure 3, which displays the confusion matrix comparing predicted and actual BMI categories (Normal, Obese, Overweight, and Underweight). The confusion matrix provides a visual summary of the model's performance and highlights the distribution of correct and incorrect classifications across BMI groups.

The model demonstrates strong performance in distinguishing extreme BMI categories, particularly Underweight and Obese, while intermediate categories such as Normal and Overweight remain more challenging. For instance, the model correctly classified 1,223 Underweight instances, while misclassifying 85 as Normal, 191 as Obese, and 137 as Overweight. Similarly, in the Obese category, 725 cases were correctly predicted, while some overlap occurred with adjacent categories—56 instances were misclassified as Normal, 443 as Overweight, and 428 as Underweight. These findings suggest that the model effectively recognizes clear BMI distinctions but faces limitations where behavioral and socioeconomic characteristics overlap between categories (Cleophas and Zwinderman, 2014).

The Normal and Overweight classes exhibit the highest misclassification rates. In the Normal group, 251 cases were correctly identified, while substantial confusion occurred: 393 were labeled Obese, 587 Overweight, and 510 Underweight. Similarly, the Overweight group had 722 correct predictions but was misclassified as Normal (134), Obese (531), or Underweight (330) in several cases. These errors indicate that shared lifestyle and socioeconomic traits blur categorical boundaries, consistent with prior findings that adjacent BMI categories often exhibit overlapping distributions.

Figure 3. Confusion Matrix of Predicted vs. Actual BMI Categories



The overall model performance is summarized in Table 2. The accuracy of 0.433 indicates moderate classification success. A precision score of 0.436 suggests that approximately 44% of predicted instances were correctly classified, while the recall score of 0.433 reflects the model's ability to identify actual BMI categories. The F1-score of 0.404 represents a balance between precision and

recall, capturing the trade-off between correctly identifying true positives and minimizing false positives. The slightly higher F2-score (0.417) emphasizes a bias toward recall, favoring the identification of true cases over precision. These results collectively highlight that while the model captures meaningful patterns in the data, the overlapping nature of BMI determinants limits overall precision.

Table 2. Performance Metrics of the Decision Tree Classifier for BMI Classification

Metric	Value
Overall Accuracy	0.433
Precision	0.436
Recall	0.433
F1 Score	0.404
F2 Score	0.417

The Decision Tree visualization (*Figure 4*) provides an interpretable hierarchical model of BMI classification, clearly illustrating how demographic, socioeconomic, and lifestyle variables interact to predict BMI categories. The root node (Age ≤ 36.5) demonstrates that age is the most dominant predictor, confirming its role as a fundamental determinant of body composition and metabolic variation. Individuals under 36.5 years old show a higher probability of being classified as *Underweight* or *Normal*, whereas older individuals are more frequently categorized as *Overweight* or *Obese*, reflecting the age-related increase in adiposity and reduced metabolic rate (Breiman, 2004; Zhang and Gionis, 2022).

Beneath the age threshold, physical activity level becomes the following critical determinant. For younger individuals with low activity (LowActivity ≤ 0.5) or moderate activity ≤ 0.5, the model frequently classifies cases as *Underweight*, showing that insufficient physical activity contributes to deviations from healthy BMI, potentially due to muscle mass loss or imbalanced energy intake. Conversely, for individuals with higher activity levels, the probability of being classified as *Overweight* or *Obese* decreases, emphasizing the protective effect of regular activity on maintaining normal BMI ranges (Cleophas and Zwinderman, 2014).

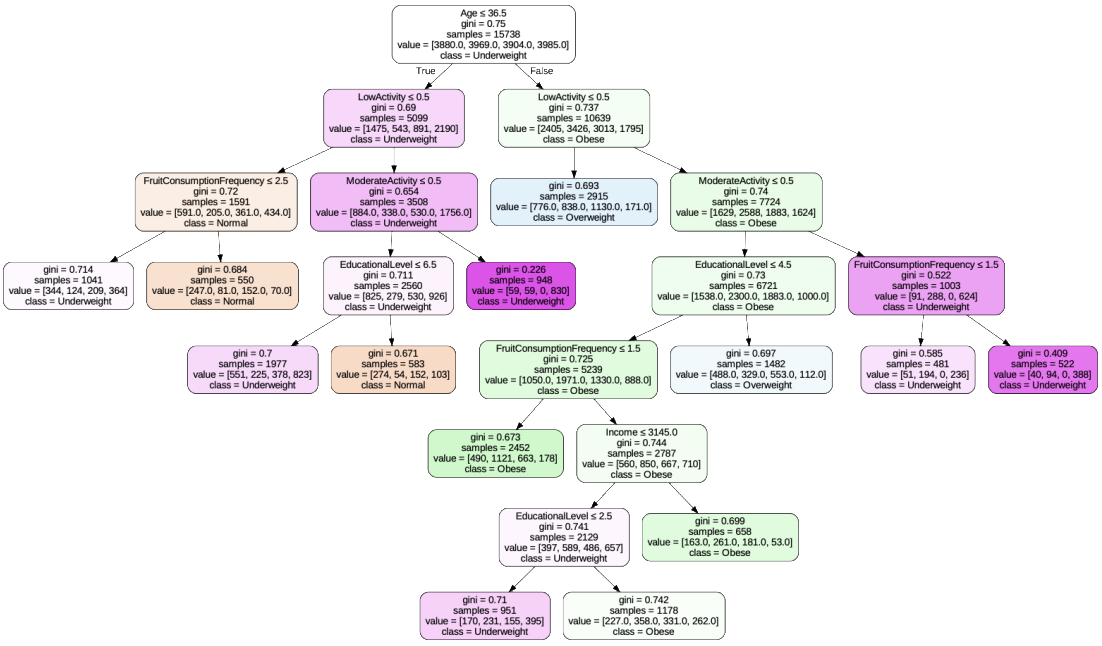
The Fruit Consumption Frequency (≤ 2.5 times per week) node further refines predictions among younger adults, where lower consumption rates are linked with *Underweight* outcomes. This relationship reflects the importance of balanced dietary patterns, where low intake of nutrient-dense foods may correspond to inadequate caloric or micronutrient intake. For individuals with moderate to high fruit consumption and moderate activity, BMI classifications shift toward *Normal* and *Overweight*, suggesting that dietary balance interacts with physical activity to stabilize BMI outcomes.

Among older individuals (Age > 36.5), educational level and income appear as strong secondary determinants. The branch *Educational Level ≤ 4.5* corresponds largely to *Obese* classifications, implying that lower educational attainment—often associated with limited health literacy and restricted access to nutritious foods—is a significant obesity risk factor. Higher education levels (> 4.5), however, are more likely associated with *Normal* or *Overweight* categories, indicating better health awareness and lifestyle management.

Similarly, the Income ≤ 3145 split shows that lower-income individuals have a higher likelihood of *Obese* classifications, while higher-income groups (>3145) correspond to *Normal* and *Overweight* outcomes. This aligns with socioeconomic health gradient theory, where income and education jointly shape dietary quality, healthcare access, and physical activity opportunities (OECD, 2023b).

At deeper levels, the interactions between fruit consumption, education, and activity level produce sub-branches associated with *Underweight* and *Obese* outcomes. For example, low fruit consumption frequency combined with limited education tends to push classifications toward *Underweight*, while moderate fruit consumption coupled with low activity and income shifts outcomes toward *Obese*. These splits highlight the model's ability to capture nonlinear relationships between lifestyle and socioeconomic variables—consistent with prior work on decision-tree interpretability in health data.

Figure 4. Decision Tree Structure for BMI Classification



4. CONCLUSION

This study provides a data-driven yet human-centered understanding of the factors influencing Body Mass Index (BMI) among adults in Türkiye. By applying a Decision Tree model to national health and lifestyle data, the analysis revealed that age, socioeconomic status, physical activity, and dietary

behaviors are the most significant predictors of BMI. Age emerged as the strongest determinant, shaping BMI trajectories across the life course, while education and income influenced the ability to maintain healthier lifestyles and dietary choices. The results also highlighted that insufficient physical activity and low fruit consumption are key behavioral risks contributing to both undernutrition and obesity. Despite the model's moderate predictive accuracy, its interpretability offers policymakers valuable insights, underscoring the importance of addressing socioeconomic inequalities and promoting accessible, health-conscious environments. The findings underline that tackling obesity and weight-related disparities requires more than individual behavioral change—it calls for social and structural transformation that enables equitable health opportunities. Future research integrating behavioral, environmental, and genetic factors could further refine these predictive frameworks. Ultimately, this study underscores how machine learning can support evidence-based, human-centered health interventions, bridging data analytics with public well-being and helping societies move toward more inclusive and healthier futures.

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RETHINKING FINANCIAL ANALYSIS IN THE CONTEXT OF SUSTAINABILITY REPORTING

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ABSTRACT

In this paper, the review of the changing paradigm of financial analysis is critically discussed, arguing that sustainability reporting should be incorporated as the only way of obtaining a comprehensive evaluation of corporate value. Integrating ESG (Environmental, Social, and Governance) analysis with an evaluation of a company's sustainability into financial analysis has become a contemporary challenge in the financial sector to enhance the reliability of a company's financial statements. Considering ESG criteria is crucial nowadays to help provide a full understanding of the company's performance and a comprehensive picture of its policies and practices. The paper is a synthesis of existing literature regarding the materiality of ESG factors in financial reporting through a systematic literature review. It discusses the shortcomings of traditional financial statements, the growth of sustainability reporting systems, and the established connections between ESG performance and financial performance. The results indicate that a siloed financial analysis method is becoming outdated. The paper is concluded with a proposal of an integrated analytical model that can prepare analysts, investors, and academics for the challenges of the new corporate reporting, where extra financial information cannot be ignored.

Keywords: *ESG Integration, Financial Analysis, Financial Performance, Sustainability Reporting, TCFD Implementation.*

JEL Codes: *G32, M14, M40.*

1. INTRODUCTION

Corporate reporting and performance evaluation are changing radically (Rojo-Suárez et al., 2024). Investment and credit decisions have been based on financial statement analysis, which placed emphasis on the income statement, balance sheet, and cash flow statement over decades. However, more scholars, practitioners, and regulators think that these traditional measures constitute one side of the coin (Singh and Sørensen, 2024). Such conventional practices do not mirror the long-term risks and factors that would stimulate value in terms of environmental stewardship, being a responsible member of society, and quality of governance. As can be seen in this report, the standpoint is that financial analysis is a part

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that needs to be thoroughly reconsidered in order to reflect the sustainability reporting. The research question that will drive the review is: *"How can financial analysis methodologies be adapted to systematically integrate sustainability data to provide a more accurate and comprehensive assessment of corporate performance and risk?"*

2. LITERATURE REVIEW

The literature review of the chosen publications in this report has been carried out in a systematic way, and the purpose of this is to carry out an examination of the dynamic intersection of financial analysis and sustainability reporting. The main objective of this literature review will be to cover the conceptual space, identify themes and gaps that prevail, and to also reach a coherent narrative by answering the research question: *"How can financial analysis methodologies be adapted to systematically integrate sustainability data to provide a more accurate and comprehensive assessment of corporate performance and risk?"* The review is founded on a sample of well-selected sources that vary in the case of academic research to institutional perspectives. Such a wide range of sources ensures that one gets a multi-dimensional perspective by incorporating theoretical frameworks, empirical evidence, and utilization tools that are practical. The investigation of the article by Khan et al. (2016) proves that the approach of integrating the concerns of sustainability into the process of financial analysis is a ground-breaking undertaking. This particular source assumes that the financial analysis is shifting away from the traditional model of shareholder-oriented towards the broader model of stakeholder-oriented. As Eccles et al. (2014) note, the success of any company in the long term is determined by how it handles relationships with not only its shareholders, but with the stakeholders more so.

Singh and Sørensen (2024) confirm that the financial analysis according to the traditional model depends on historical accounting information extensively. Eccles et al. (2014) posit that the conventional paradigm of financial analysis fails to consider the value created or destroyed in the overall interaction of a company with all the stakeholders in the company. In response to this lack of coverage of the interaction between stakeholders, the idea of integrated reporting was created. According to Handayani and Rokhim (2023), combined information on financial and sustainability aspects is practiced in integrated reporting. This study assumes that this is central in the translation of the stakeholder theory into corporate practice that can be measured. This is informed by the realization that ESG factors tend to be significant in the context of the financial performance of a firm. The seminal work by Khan et al. (2016) is a strong empirical study supporting this assumption, and it shows that companies that perform well in the material ESG issues are also much more successful than their competitors both in terms of stock returns and profitability. On the other hand, there is no such advantage in the performance of the immaterial ESG issues. This illuminates why the measurement of materiality in any form of integrated analysis is important.

The materiality of ESG factors, particularly those of a financial perspective, works through a number of channels. When viewed through a prism of risk management, good ESG practices would reduce firm-specific risks. Such risks include regulatory fines, reputation damage, and operational disruptions of a company, as confirmed by Amel-Zadeh and Serafeim (2018). On the other hand, when the ESG performance is poor, it raises the cost of capital since an investor would require a greater return to bear uncontrolled ESG risks. On the opportunity side, ESG integration may be used to identify businesses that would be more effective at long-term value generation by becoming innovative in their sustainable products, resource efficiency, and employee/customer loyalty (Friede et al., 2015). The regulatory environment is changing fast in order to standardize such practices. Compulsory reporting policies in jurisdictions such as the European Union via the Corporate Sustainability Reporting Directive (CSRD) are championing the concept of ESG integration from a voluntary niche activity to a compulsory part of primary financial analysis (European Commission, 2022).

3. METHODOLOGY

The research follows a systematic approach of literature review, which is informed by the principles outlined by Snyder (2019). The reason for choosing this particular approach is because of its transparency and rigor in sourcing, selecting, and synthesizing existing research. The methodology provides a comprehensive state-of-the-art overview, identifies central themes, and delineates conceptual boundaries within the field of integrated financial and sustainability analysis. The methodology process was executed through the phases of planning, conducting, and then reporting.

3.1. Research Design and Protocol

The review was designed to answer the main research question: "How can financial analysis methodologies be adapted to systematically integrate sustainability data to provide a more accurate and comprehensive assessment of corporate performance and risk?" In order to ensure a focused yet comprehensive analysis, the scope was defined to include literature published within the last decade. This period captures the period of most rapid development in sustainability reporting frameworks and ESG integration.

3.2. Data Collection and Source Selection

In an effort to strike a balance between depth and scholarly rigor, the collection of data entailed a search strategy that was multi-tiered. The analysis was based on a collection of texts that were published in the past ten years. This provided a wealth of insights into governments, practitioners, academics, and institutions. Academic databases such as Google Scholar, Scopus, and Science Direct were used as the search strategy. The search keywords were as follows: ESG integration financial analysis, materiality of reporting on sustainable reporting, financial performance of sustainable investments, and TCFD SASB implementation. Peer-reviewed journal articles, seminal books, and authoritative reports of international

organizations (IFRS, EU) were used as inclusion criteria. The two-pronged approach was useful in making the review rely on the resources provided and the overall ongoing academic discussion.

3.3. Data Analysis and Synthesis

This was an inductive and qualitative method of analysis that was founded on thematic analysis. All the major ideas and stances, together with the empirical evidence, were coded after reading all the selected sources carefully. The first codes were, but not limited to: limitations of traditional financial analysis, ESG financial materiality, integrated reporting, double materiality, cost of capital, and the valuation adjustments. Emergent thematic categories were then used to group these codes and organize the findings of this review. The synthesis involved reading and combining evidence from the various sources to construct a story that is coherent per theme. To be more persuasive, the findings of Khan et al. (2016) concerning materiality were updated with the practitioner feedback of IFC (2023) to present the argument about the industry-based analysis.

3.4. Limitations

Although all endeavors were put in place to have a complete review, this methodology has its limitations. Sustainability reporting is an active area of research, and the number of new studies and regulations is constantly growing. Therefore, this review is a reflection of the discussion at a particular time. Moreover, the fact that it relies on a pre-determined set of core texts, but is supplemented with a wider search, implies that the review is not an extensive meta-analysis of all pieces of literature on the subject. However, the systematic and transparent methodology employed makes the synthesis robust and credible and well-representative of the contemporary knowledge, as well as responding to the research question.

4. THE IMPERATIVE FOR CHANGE: LIMITATIONS OF TRADITIONAL ANALYSIS

Conventional financial analysis is based on a paradigm that works well in the industrial era and in most cases fails to cope with the issues of the 21st century. Its main weakness is that it covers issues that are related to sustainability as externalities, which are costs that a company imposes on society without showing them in its financial reports (Rojo-Suarez et al., 2024). An example is that the expense of carbon emissions, the risk of water shortage, or the reputational loss of poor labor practices in the supply chain are barely visible to traditional balance sheets until they result in any serious financial loss, fines, or write-downs. This forms a huge information vacuum for the analysts and investors.

According to the IFC (2024), when analyzing accounting data on a purely backward-looking basis, it is not possible to consider forward-looking risks and opportunities. A company can seem profitable nowadays, and at the same time, it may drain natural or social capital on which its sustainability depends in the long term. This is supported by the comparative study on sustainable

investing by Handayani and Rokhim (2023), which states that the markets are starting to price these risks, with the ESG-oriented portfolios demonstrating the variation of risk-return profile, such as reduced volatility and increased resistance to market crises.

5. BRIDGING THE GAP: EVIDENCE OF THE ESG-FINANCIAL PERFORMANCE LINK

There is a solid theoretical justification of integration on the basis of empirical evidence. Comparative analysis of sustainable and conventional investments showed no financial performance cost on sustainable investment. In fact, volatility and competitive long-term returns were lower based on evidence presented by Handayani and Rokhim (2023). This implies that ESG integration is an aid to risk reduction, besides being a tool of increasing returns. The spheres of financial impact are varied and effective:

1. Cost of Capital: Firms with low ESG scores tend to have a higher cost of debt and equity since the investors will need to pay more depending on the risk incurred (Singh and Sørensen, 2024).

2. Operational Performance: Strong ESG credentials can result in operational efficiencies (e.g., low energy bills, low water bills), higher employee productivity and employee retention (a key social measure), and regulatory shock resiliency (JEF, 2024).

3. Valuation and Assets: ESG factors will have a direct impact on valuation. One such risk is the climate risk, which may result in stranded assets, which can be the fossil fuel resources or other carbon-intensive infrastructure that will become obsolete even before the end of their economic usefulness and will require to be written down substantially.

6. A PROPOSED FRAMEWORK FOR INTEGRATED FINANCIAL ANALYSIS

A rethinking of the financial analysis will be based on the synthesis of the reviewed literature, by suggesting a five-stage framework that will be exhaustive and is aimed at integrating sustainability data into the very core of financial valuation in a systematic way.

6.1. Stage 1: Dynamic Materiality Assessment

The first thing that the analyst should do is to go beyond a generic checklist of ESG issues and identify problems that have concrete financial implications for the company and industry. The materiality varies according to the industry, as stipulated in the IFC (2024) and the SASB standards. As an example, the issue of water scarcity is very tangible to a beverage company and not a software company. This step entails the use of a set of standards, such as SASB, to develop a short list of material ESG factors. Moreover, the notion of dynamic materiality has to be reiterated; nowadays, issues that are not material may be material because of the new regulations or the changes in technology, or even the changes in preferences of buyers, so this process should be an ongoing process rather than a one-off exercise.

6.2. Stage 2: Critical Data Integration and Quality Interrogation

After identifying the material issues, the analyst should collect the data on sustainability reports, corporate websites, and third-party ESG data providers. This phase is characterized by critical questioning of the quality of data, and not only its gathering or collection. The following two questions should be posed: Does the data have a third-party guarantee, and to what extent (limited or reasonable assurance)? Does it stay consistent across time and similar to industry counterparts? The article by Finance Journeys (2023) warns about such risks as greenwashing, where superficial disclosures are made. The analyst will have to cross-refer claims, verify against international frameworks such as GRI or TCFD, and record any critical variations between the policy statements and performance data of a company.

6.3. Stage 3: Multi-dimensional Quantitative and Qualitative Analysis

This stage is founded on a bilateral analysis. Concerning the quantitative aspect, the analysts will be expected to come up with normalized ESG performance ratios so that cross-sectional comparison and time series comparison can be made available. This can include carbon intensity (tons/CO2/million revenue), water efficiency, employee turnover rate, or the proportion of executive pay based on sustainability objectives. Meanwhile, a qualitative analysis plays a role in the process of establishing the robustness of the governance and management systems of a firm. According to the research by Singh and Sorensen (2024), this encompasses an evaluation of the expertise and controls of boards, the presence of whistleblower policies, and the corporate track record of dealing with relationships with the stakeholders. A company with huge quantitative measurements and poor governance could be a higher-risk investment.

6.4. Stage 4: Explicit Financial Impact Mapping

This is the critical point when ESG analysis will shift from being an independent practice and becoming an integral part of financial forecasting. The analyst will have to clearly map out all material ESG factors to their likely impact on the three core financial statements. For example:

1. Income Statement: Poor labor practices (a social factor) can disrupt operations or create a negative reputation for a company, and thus decrease future revenues and also increase recruitment and training costs.

2. Balance Sheet: A company in a carbon-intensive sector (an environmental factor) could either have future regulatory liabilities or have its fossil-fuel assets become stranded, in which case, it would require massive write-downs as described in the article by Rojo-Suarez et al. (2024) about climate risk.

3. Cash Flow Statement: Lower perceived risk can be achieved by strong governance and transparent reporting (a governance factor), and this may decrease the cost of capital and therefore have

an impact on financing cash flows.

6.5. Stage 5: Forward-looking Valuation Adjustment and Scenario Analysis

The last step involves integration of the mapped financial impacts into the conventional valuation models. It may be done by making adjustments to estimated cash changes in a Discounted Cash Flow (DCF) model, such as by scaling down revenue growth rates of a firm with substantial ESG-related reputational risk or accelerating operating cost projections of a firm subject to potential carbon taxes. In addition, the discount rate (Weighted Average Cost of Capital) might be adjusted to reflect an ESG risk-premium. Based on the recommendations of the TCFD, one has to perform the scenario analysis. To be aware of the potential range of outcomes and strategic robustness of the company, the analyst will need to model the valuation of the company in different plausible futures, such as a rapid low-carbon transition scenario versus a business-as-usual scenario. This prospective approach changes the valuation from a static snapshot to a dynamic assessment of risk and opportunity in a changing world.

7. CONCLUSION

All in all, the review of literature has shed light on the separation between financial and sustainability analysis as an outdated model. It is evident that ESG factors are material from a financial perspective. A comprehensive understanding of corporate value is impossible without encompassing ESG factors. While setbacks remain regarding data quality and standardization, the move towards sustainable financial reporting is undeniable. In the coming years, financial sustainability will have to blend the rigors of accounting with the foresight of sustainability science. This report has outlined a pathway for essential integration by arguing that the future of accurate financial reporting depends on ESG factors.

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FEMINIST APPROACH TO MONETARY POLICY AND FINANCIAL INCLUSION: THE CASE OF ALBANIA

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ABSTRACT

The classical monetary policy, which is mostly concerned with regulating inflation, ensuring financial stability, and the economic growth of the GDP, has always been regarded as gender-neutral. Neutrality, however, according to feminist economists, conceals serious structural inequalities in access to credit, employment, and decision-making. The paper discusses the movement to feministically reorient monetary policy as one way of achieving both financial inclusion and gender justice. The paper, as its focal point, focuses on ways of feminist economic ideals to change monetary governance using gender sensitive systems such as gender-disaggregated lending data, availability of credit services to women, as well as having women in central bank systems. The study relies on the writings of such researchers as Seguino (2019), Grabel (2022), and Nikolaidi (2022), who highlight the adverse outcome of contractionary monetary policies by stating the need to support the women-dominated sector, including care, education, and services, and an inclusive growth with the implementation of expansionary policy. These are evaluated and implemented in the international financial institutions, particularly the IMF, where they are encouraged to develop a gender impact assessment on their surveillance and lending systems. The findings reveal that, besides being fair, feminist monetary policy is also macroeconomically sound because of the participation of women in the financial systems. To solve the problem in Albania, rationalization of central banking and credit issuance based on the goals of gender equity might be utilized to resolve the inequities in the economic participation of the two genders and to develop economically in the country. It is found that the paper gave a conclusion; the feminist monetary reform is both a moral and economic requirement: the transformation of the monetary systems to the tools of market discipline into the tools of inclusive and socially responsible development, which would contribute to the stabilization, empowerment, and equality.

Keywords: *Financial Analysis, Financial Performance, Sustainability Reporting, ESG Analysis, ESG Factors.*

JEL Codes: *G32, M14, M40.*

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1. INTRODUCTION

Following a cluster of global crises, the financial crisis of 2008, the COVID-19 pandemic, and the long-term climate change disruption, it is becoming clear that the dominant methods of fiscal and monetary policies have not been effective in providing just and sustainable economic prosperity. Feminist political economists have reacted by developing transformational frameworks for injecting gender equality into the macroeconomic governance. Such frameworks question the perceived neutrality of financial and monetary instruments and claim that policies made without considering and being sensitive to gendered consequences tend to worsen inequality.

Technocratic logics such as inflation targeting, financial stability, and GDP growth by monetary policy, in particular, have dominated the technocratic logics of economic policy. To feminist economists, narrow goals fail to consider distributional and gender impacts of using such monetary tools as interest rates, liquidity injections, and credit allocation. Monetary policy can be used, introducing a feminist approach, as a primary tool facilitating financial inclusion to give women and other marginalized groups access to credit, and advance the overall aspirations of social and economic justice (Elson and Seth, 2019).

Feminist critique not only focuses on theoretical economics but also applies to policies. Feminist researchers have demonstrated not only that an emphasis on gender equality in economic governance is grounded in moral necessity but also that it is logistically a virtuous course of action. Closing the gender gap improves efficiency in the labor markets, increases productivity, and leads to more robust economic frameworks. These advantages apply mainly when economies are increasingly challenged by demographic rearrangement, climatic uncertainty, and digital revolution.

2. LITERATURE REVIEW

Grabel (2022) suggests an alternative model enabling global financial governance, which would be the opposite of a rigid and top-down approach to international financial institutions. Relying on the idea of a so-called possibilism as developed by Albert Hirschman, she promotes changes allowing national states and especially countries of the Global South to respond to local needs, like being gender inclusive. Grabel (2022) shows that the value that work drives home is the need to make the process of permissive multilateralism and not harmonize structures, which tend to make neoliberal austerity and burden gendered.

Under this redesigned financial governance system, feminist economists demand that central banks and multilateral financial institutions assist in developing care infrastructure, issuing concessionary lending to women entrepreneurs, and evaluating the gendered consequences of monetary policies. As a case in point, the mandates in credit easing initiatives must be to provide female-owned businesses, and inflation targets must be accompanied by employment targets, especially in areas with

a greater percentage of female labor force, like the care sector.

This critique is further expanded on in the Feminism in Public Debt anthology (Bohoslavsky and Rulli, 2024) to sovereign debt management. The authors emphasize that austerity-led debt repayment programs impact the female population disproportionately due to the reduction in the public sector in various fields, namely, healthcare, education, and childcare. Women's services are mostly tapped and operated, and they were the first to be cut and shaped in the debt restructuring plan led by the IMF and the World Bank. Thus, Feminist economists have insisted that debt sustainability structures should incorporate gender impact tests and protect social expenditure that serves women.

However, feminist scholars demand participatory policymaking in financial institutions, which leads to gender equality in decision-making units and leadership in the IMF, World Bank, and central banks. Such a redistribution could play a vital role in increasing the diversity of the lived experiences embodied in the policy decisions and the responsiveness of the policy to the needs of women and marginalized groups.

3. METHODOLOGY

The research is a conceptual form of qualitative research, where all the data is secondary data, which is founded on feminist economics. The methodology is an amalgamation of theoretical materials, policy reports on various regions of the world, and evidence-based research on monetary policy, financial inclusion, and gender equality. These and other sources also contain the IMF Gender Strategy (2022), UN Women reports (Elson and Seth, 2019), and scholarly works of feminist researchers, including Grabel (2022), Powell (2023), and Green (2022). The method used to examine it was categorizing the effects of monetary instruments on gender outcomes in terms of themes, and this was done using interest rates, credit policies, and liquidity support. The case study material concerns Albania, and it is internationally compared to understand the preparedness of the institutions to feminist monetary systems. The interpretive tool of study used in the paper was that of feminist critique, which aimed at intersectionality, inclusivity, and structural reform. The data was interpreted with the help of narrative synthesis that revealed gaps in the policies such as absence of gender-disaggregated financial data and low representation of women on the decision-making processes of financial institutions the methodological position view.

4. GENDER EQUALITY AND THE MONETARY POLICY EQUIPMENT

Central banks have traditionally been regarded as apolitical institutions with the central role of ensuring stable prices. However, Seguino (2019) has made it clear how the monetary policy can have far-reaching implications on employment, wages, and access to credit, which are highly gendered. For example, contractionary monetary policies, which increase the cost of borrowing, will work to oppress employment in the public sector and the service sector, where women happen to be overrepresented.

Conversely, full employment strategies favoring women can be facilitated through expansionary policies provided they have gender-sensitive objectives. The case of Albania can be incredibly significant when discussing the possibility of implementing feminist monetary and fiscal policy at the national level. According to the doctoral project by Mishelds (2023), the Gender Responsive Budgeting (GRB) became institutionalized in Albania in 2012 with the adoption of Decision No. 465 written by the Council of Ministers. Since then, it has been integrated into the Organic Budget Law, which was written in 2016. These reforms put Albania at the forefront regarding gender mainstreaming in the region's fiscal policies.

Furthermore, public banking institutions and development banks have an important role. Nikolaidi (2022) recommends that the financial institutions owned by the government invest in green and care-oriented projects, which are at the same time labor-intensive and dominated by women. These institutions can also contribute to changing the discriminatory credit markets and leading to inclusive economic growth by connecting financial incentives and credit guarantees with gender equality indicators. Most of this development is limited to the fiscal world. Gender inclusion in Albania's monetary policy and financial sector has not been developed. There is no clear policy that an individual Bank, such as the Bank of Albania or a commercial bank, must adopt a gender lens on credit provision, liquidity stability, or the regulatory role. In addition, Albanian banks do not publicly report gender-disaggregated loan data, which creates a challenge when assessing the level of women's financial inclusion.

Feminist theorists question the composition and decision-making structures of the central banks, which are heavily dominated by men and are technocratic. A diverse gender leadership is more inclined to use the measure of societal results in addition to the financial ones. Responsive monetary policy is gender-neutral; thus, it also includes institutional reform so that the voice of women can be heard in the governance of the macroeconomic issues. Even the composition of credit markets should be investigated. Most women, particularly those who operate informally or live in rural settings, have no access to formal credit due to the nature of collateral requirements, poor financial literacy level, and discrimination against them in lending practices. Central banks can address such disparities by requiring commercial banks to gather and submit gender-disaggregated data on lending, and finally, through incentives to financial institutions that encourage the usage of women-friendly financial products.

Women own fewer than one-third of small and medium-sized enterprises (SMEs) in any country in the world, and the information from Albania is anecdotal that women encounter increased collateral requirements and a lower rate of acceptance of loans. This is especially true in rural settings, where property rights and informal labor restrict women's access to formal banking systems. The lack of specifically female credit lines or women's financial literacy programs implies a substantial policy gap that the monetary authorities can fill through regulatory interventions. Furthermore, civil society organizations involved in gender equality do not engage much with the monetary authorities in Albania. Transparency and inclusivity might be achieved by instituting mechanisms enabling feminist

economists, women entrepreneurs, and advocacy groups to participate in monetary policymaking. This is especially critical in countries in the process of reforms in the financial sector or looking further to be integrated into the European Union.

5. IMF AND WORLD INSTITUTIONS

Gender inequality has recently been considered a macro-critical issue by the International Monetary Fund (IMF). The IMF has spent the past three years (since 2022) making gender central to its surveillance, lending, and capacity-building functions. This is a significant change, albeit feminist scholars do not embrace it fully. The IMF's conditionalities on previous occasions have helped develop austerity and cutbacks in social services, which have a larger effect on women. However, this new gender approach by the IMF presents a common chance for countries like Albania to demand technical aid and funds associated with gender-friendly financial activities. The progressive policy space should be safeguarded and enlarged, as Grabel (2022) observed, particularly in the crisis engulfing the global debt and climate post-pandemic situation. Feminist economists say that the IMF has to go beyond making promises and implement their frameworks that must be followed. Central banks and ministries of finance need to report on gender outcomes.

In addition, the IMF needs to intensify the capacity-building activities, such as training the central bank staff on gender-aware monetary policy and setting benchmarks to assess progress. Women could be incited to provide gender accomplishments, countries' Article IV consultations, and financial stability evaluations. This would assist in introducing gender concerns into the mainstream of monetary management.

6. CONNECTING THE FISCAL AND THE MONETARY POLICIES IN A FEMINIST FRAMEWORK

Although taxation-based monetary policy has been considered the major version of gender-responsive changes (through the policy of GRB), there is evidence to show that monetary policy as a gender-responsive practice is still a puzzle. It takes some coordinated efforts to bridge this gap. An example is that gender budgeting must not only evaluate expenditure programs but also look at ways that the policies of central banks influence the availability and cost of credit to women. Monetary tools should align with care infrastructure funding, such as green bonds or specific liquidity facilities.

According to Diane Elson (2019) and James Heintz (2019), unpaid care work is essential to economic productivity, but macroeconomic models ignore it. Monetary authorities can rectify such biases by redesigning the monetary policy to favor the care economy, e.g., having low interest rates for a care-related sector or enticing banks to lend to female caregivers. In Albania, the monetary tools would have to be aligned with the national gender equality strategy, which would entail a paradigm shift. This may entail an obligatory gender impact on monetary policies, promoting the inclusion of gender signs

in inflation reports of the Bank of Albania, need to post gender-disaggregated data on credit and savings by commercial banks, the creation of gender advisory convictions in financial control organs, and providing resources in software and programs on financial literacy separately to women and underprivileged groups.

7. RESEARCH GAP

The literature on gender-responsive fiscal policy has many resources, and empirical and conceptual research on feminist monetary policy, especially regarding Southeast Europe, is very limited. The case of Albania depicts a more general tendency in the world: even the rhetoric of progressiveness can exist in fiscal arenas and is associated with gender-blind performance of money.

The important knowledge gaps are shortage of sex-disaggregated statistics in financial and banking systems, there is scanty evidence on how this variation of interest rate influences the participation of women in the labor market, lack of policy evaluation processes linking monetary policy with the results of gender equality, inadequate insight into the way the public banks can make the female-inclusive financing a priority, and lack of consideration of the way digital financial services and fintech might strengthen or narrow gender gaps.

Moreover, to fill these gaps, it is necessary to examine these issues through interdisciplinary studies involving economics, gender studies, and public policy. In the case of Albania, more localized studies that look at information on the granting of credit by banks at a particular level, gender disparity in the approval of licenses, and the interventions that the central bank may facilitate, would be very helpful in influencing policy change.

8. CONCLUSION

Feminist monetary policy defines the challenges of policy neutrality in macroeconomic governance and presents the case of inclusive sustainable development. Although certain countries have taken steps to institutionalize gender equality in their fiscal policies, such as Albania, the financial sector is one of the frontiers that should be reformed. Through feminist re-conceptualization of central banking, credit distribution, and regulatory practice, financial inclusion, lessening systemic discrimination, and the inclination of economic policy to social justice are feasible. Such betterment of feminist ideologies to monetary governmentality is both normative and economic. The narrowing gender gaps result in stronger economies, increased growth, and better financial stability. In the case of Albania and other developing and transitioning economies, it will be time now to take the gender equality agenda out of the fiscal planning rooms to the center of financial regulation and monetary policymaking. The concept of the gender responsive monetary policy must not be regarded as a departure from the central banking orthodoxy but as a continuation of the same that accommodates the intricacy of the modern-day economies. It is through integrating feminism into financial governance that we can have a

macroeconomic policy that will benefit society.

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AN ANALYSIS OF THE RISE OF BRICS AND THE DYNAMICS OF DE-DOLLARISATION

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ABSTRACT

This paper investigates the change of BRICS from an economic union to a new global power center and analyses its economic, financial and geopolitical implications. With the inclusion of important countries like Saudi Arabia, the UAE, Iran, Egypt and Ethiopia, BRICS has turned into a giant platform still representing a large part of the world's population and GDP. The article reviews the quest for an alternative global order to the institutions dominated by the West and the attempt to establish a sanctions-resistant financial architecture at the core of this expansion. Within this framework, the group's growing influence over global energy markets and attempts to de-dollarize are elaborated upon, and the financing models provided by BRICS through the New Development Bank (NDB) are also examined. In evaluating BRICS's capacity to convert its economic power into justifiable corporate action, this paper considers both the opportunities that a new multipolar world presents and the challenges it brings. It will apply bibliometric analysis for a thorough review of the existing literature regarding the transformation of BRICS. This analysis will likely uncover the steady rise in academic publications on BRICS over time, specifically the spike that followed the 2023 enlargement. Moreover, it will point out the main authors and the most impactful publications in this area, and the connection of issues such as de-dollarisation and alternative financing with other key terms in the literature will be explored. By highlighting the distribution of papers, the analysis will chart the influence of BRICS on global research. This bibliometric approach will add a quantitative dimension to the theoretical framework of the study, and the findings will provide new and robust perspectives on the future role of BRICS.

Keywords: *BRICS, Global Geopolitics, De-Dollarisation, New Development Bank.*

JEL Codes: *F02, F33, F55.*

1. INTRODUCTION

Cooperation among Brazil, Russia, India, China, and South Africa — collectively known as

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BRICS — has grown steadily since the first BRIC (Brazil, Russia, India, and China) meeting in 2006. Over the years, the group has established several key institutions, such as the New Development Bank and the Contingent Reserve Arrangement. China, with its considerable political and economic influence, plays a dominant role within BRICS, often outweighing its partners. At the same time, Beijing has advanced its own major initiatives, including the Belt and Road Initiative (BRI) and the Asian Infrastructure Investment Bank (AIIB). However, projects like the BRI have sometimes caused tension with other BRICS members, notably India (Hooijmaaijers, 2019). Today, BRICS is perceived as an alternative power block to the West. The New Development Bank (NDB) is understood as an emerging alternative to the Western global institutions. Hence, the global balances are expected to change in the very near future.

Although some voices underline that NDB has a limited power and cannot be the main force to change the rules of the global games, there are still some other promises within the formation of BRICS (Duggan et al., 2021). This study analyses the transformation of BRICS from an economic union into a new global power focus and the economic, financial and geopolitical implications of this process. With the accession of key countries such as Saudi Arabia, the UAE, Iran, Egypt and Ethiopia, BRICS has become a powerful platform representing a significant portion of the world's population and GDP. The article analyses the search for an alternative global order to Western-centred institutions and the effort to create a sanctions-resilient financial architecture at the heart of this expansion.

In this context, the group's increasing control over global energy markets and efforts to de-dollarise are detailed, and alternative financing models offered by BRICS through the New Development Bank (NDB) are also discussed. In assessing the potential of BRICS to translate its economic power into effective political action, this paper discusses the opportunities and challenges presented by this new multipolar world. It will also employ bibliometric analysis to comprehensively review the existing literature on BRICS transformation. This analysis is expected to reveal the upward trend of academic publications on BRICS over the years, especially the spike observed after the 2023 enlargement. In addition, the key authors and the most influential publications shaping this field will be identified, and the relationship of key topics such as de-dollarisation and alternative financing with other keywords in the literature will be examined. By revealing the geographical and institutional distribution of articles, the analysis will map the impact of BRICS on international academia. This bibliometric approach will add a quantitative dimension to the theoretical framework of the study, and the findings will provide new and robust perspectives on the future role of BRICS.

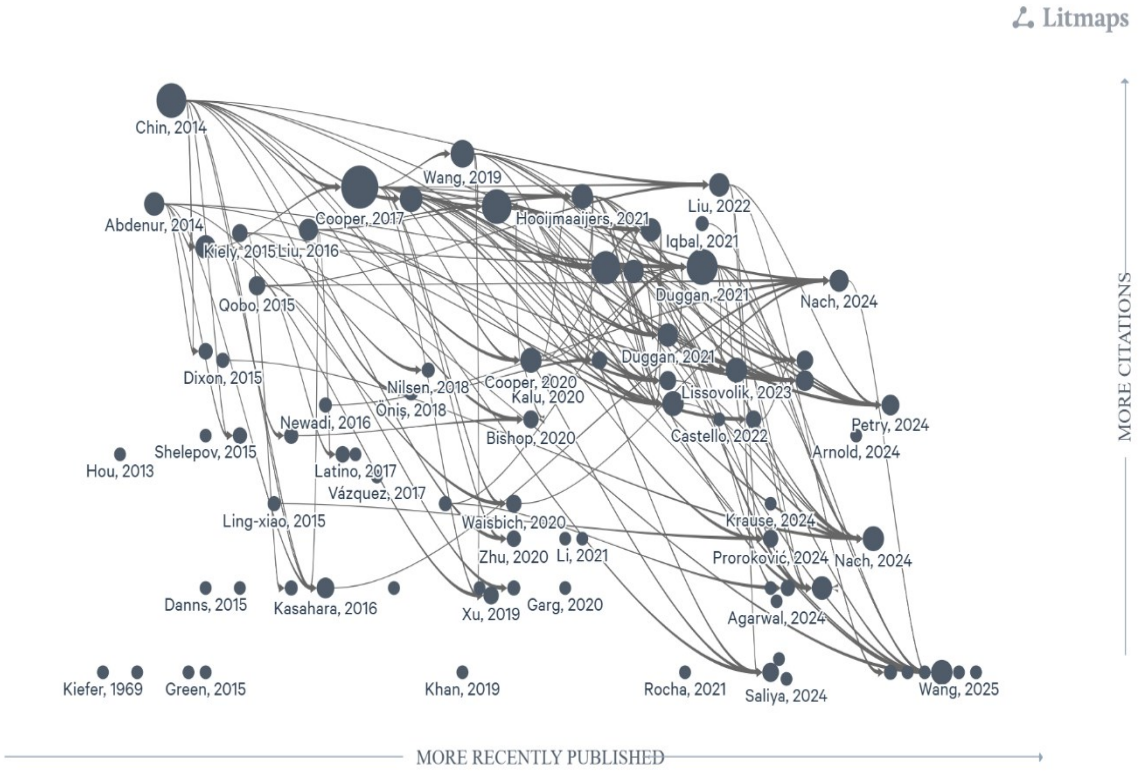
However, the impact of BRICS on the future of global currency is not limited to reserve policies and banking institutions. Current data for 2024 and 2025 also show the transformation in market psychology and expectations in international trade and investment markets (Balcı, 2023; Özen et al., 2024). Concrete steps, such as the use of local currencies in bilateral trade between Russia and China exceeding 90%, have set a serious precedent for increasing the transaction cost of the dollar and

deepening local currency swap mechanisms. This fragmentation has the potential to gradually reduce the absolute impact of US interest rates and monetary policy on global financial stability. Therefore, the financial strategy of BRICS not only offers an economic alternative but also shakes the geopolitical foundations of the global system by opening a path to economic autonomy for the Global South, independent of Western political pressure.

2. LITERATURE ANALYSIS

Literature reviews provide critical insights for researchers to understand the issue, to see the gaps in the literature and to determine the scheme of their research (Türkcan, 2024: 120). This study also adopts bibliometric analysis as a methodology to reveal the development of the issue. There is an extensive literature about the impacts of the rise of BRICS on the de-dollarisation process and global geopolitics. When the related literature is examined, it is observed that the most of the studies have been published after 2015, and the amount of research has accelerated year by year. The high attention of the researchers in the literature is an important fact about the importance of the issue from the lens of emerging global balances. Hence, analysing the related literature is critical to provide new and robust perspectives on the future role of BRICS. In this manner, a semantic approach has been adopted to search literature. Litmaps –an artificial intelligence-based literature review program- has been used to review and map the literature. Some keywords have been adopted to conduct semantic search. These keywords are BRICS, Global Geopolitics, De-dollarisation, and New Development Bank. As a result of the research, 81 studies have been selected to analyse the trends in the literature. Studies cover books, book chapters, articles and policy papers. All studies are given in the References. Figure 1 shows the map of this literature review. The vertical axis is the number of citations, and the horizontal axis is the publication year. Also, the size of the dots shows the relative importance of the study in literature. Larger dots mean higher citations by other studies.

Figure 1. Literature Review Map



Source: Authors' own elaboration.

Figure 1 exhibits the citation-based connections between the studies. The complex structure of the map proves that there is an intense citation network in the literature. Also, the momentum of the studies during the years proves that the research on BRICS has accelerated as time passes. The author who published the most about the issue is '*Cooper',* and the journal that published the highest number of studies about this issue is '*Global Policy'*. Chin (2014), Cooper (2017), Wang (2019), Hooijmaaijers (2019), Iqbal (2021), Duggan et al. (2021b), and Wang and Mishra (2025) are the most influential studies (which have the highest number of connections with other studies) in the literature. What is more is that the geographical origins of the papers exhibits the high attention of Asian researchers. Most of the literature about BRICS, NDB and de-dollarisation has been produced by the Eastern researchers.

Chin (2014) examines the fundamental reasons of the creation of BRICS Development Bank and discuss the role of it in the global economy. The study also outlines the national interests of each BRICS country about BRICS Bank. Cooper (2017) discuss the NDB's similarities and differences from Asian Infrastructure Bank (AIIB). Wang (2019) discusses the role, importance and aim of China in the creation of New Development Bank. Since China is also the founder of AIIB, its prominent role in development financing is underlined. Hooijmaaijers (2019) analyzes China's attempts to reshape global economic governance by using BRICS. Iqbal (2021) gives general information about BRICS as a driver of global economic growth and development. This general outline of the paper takes high attention in the

literature. Duggan et al. (2021b) focuses on the role and influence of BRICS on the global governance. It is underlined that NDB has not the expected power to change the global rules. Wang and Mishra (2025) discusses the role of BRICS in the global order and underlines that its expansion with the new countries increased the complexity of negotiations.

All in all, aforementioned influential studies find common ground about the prominent role and importance of China in BRICS and the foundation of NDB. Also, BRICS's intention to set an alternative structural power to Western block is underlined. Moreover, the most of the studies in the literature underlines the importance of the expansion of BRICS to strengthen the power of the Eastern block against the Western. Also, it has been pointed out that the issues of de-dollarisation and alternative financing are still regarded as a matter of geopolitics.

3. BRICS, DE-DOLLARISATION AND THE NEW DEVELOPMENT BANK

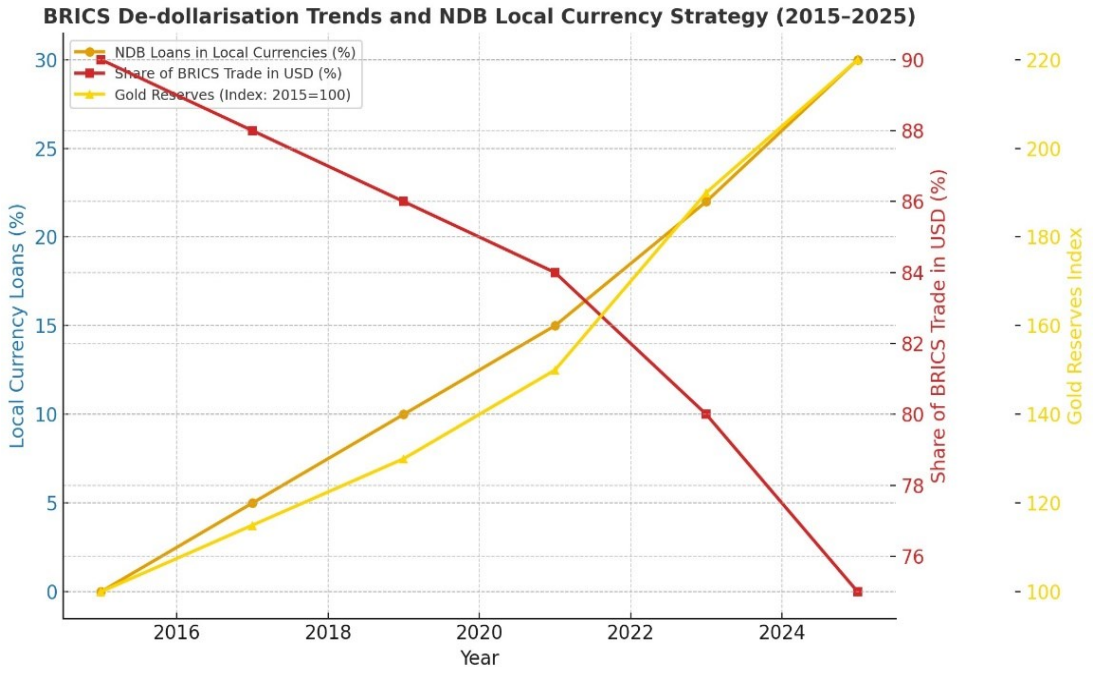
The BRICS (Brazil, Russia, India, China, and South Africa) bloc is an economic and geopolitical force that represents over 40% of the global economy and has gained prominence in recent years (2023-2025) to challenge the Western-centric financial order (Ince Yenilmez et al., 2024; de Carvalho et al., 2025). The group's main strategic goal is embodied in "De-dollarisation" efforts aimed at reducing the dominance of the US dollar in international trade and as a reserve currency. These efforts have gained momentum, particularly in the wake of the historic expansion in 2023 (BRICS Plus) and Western sanctions imposed after the Russia-Ukraine War, as countries seek to mitigate the risks of the dollar being used as a geopolitical weapon (Júnior and Branco, 2022; Wendt, 2023; Mare et al., 2024). The motivation for de-dollarisation among BRICS countries is also that a system dominated by the dollar leaves them vulnerable to fluctuations in US monetary policy and capital flight. Specifically, China and Russia have taken serious steps towards abandoning the dollar in their bilateral trade; according to 2023 data, over 90% of the bilateral trade volume of these countries was conducted in local currencies (Aksenov et al., 2023; Sjøli, 2023; Zharikov, 2023; Ajour El Zein et al., 2025; Balcı et al., 2025). However, some experts also criticise de-dollarisation as being "fiction" in the near future, stating that the dollar is still a party to approximately 90% of global forex transactions (Thiagarajan et al., 2023; Wang and Zhang, 2023).

The institutional pillar of BRICS' de-dollarisation strategy is the New Development Bank (NDB), established in 2015. Designed as an alternative to traditional Bretton Woods institutions, the NDB mobilises resources specifically for infrastructure and sustainable development projects in Global South countries. The NDB distinguishes itself by financing projects without imposing political restrictions and by having an equitable governance structure that opposes unilateral veto power (Siripurapu and Berman, 2023; Wang et al., 2023; Kan and Kantar, 2025). The bank is actively transforming its financing strategy to achieve its de-dollarisation goal, having announced a target of disbursing approximately 30% of its approved loans in local currencies by 2026. This move aims to both reduce the foreign exchange risk

for member countries and break the dominance of the dollar as an international reserve currency. Statements made by NDB President Dilma Rousseff in 2025 indicate that the Bank is reinforcing this goal through the participation of new members (Colombia, Uzbekistan, etc.) and the principles of political conditionality (TVbricks, 2025).

De-dollarisation efforts have not been limited to local currency swap agreements, but have also led to speculation about the creation of a common BRICS currency; however, NDB officials have stated that this is a medium- and long-term goal (Arnold, 2024). Additionally, central bank digital currencies (CBDCs) like China's digital yuan offer new potential for BRICS countries in establishing secure and efficient cross-border payment systems as an alternative to the traditional SWIFT platform (Johnston, 2025; Sanz Bayón, 2025). As a result of geopolitical sanctions, BRICS countries, particularly China, have dramatically increased their gold reserves to diversify international reserves and reduce dependence on the dollar; China's gold reserves rose significantly during the 2023-2024 period (Devitt and Yao, 2025). In conclusion, it is evident from the BRICS' de-dollarization initiatives and the NDB's strategic moves that the world financial system is changing from a unipolar to a multipolar design. This shift speeds up the shift to a geoeconomically crucial era where several main currencies (dollar, yuan, euro, etc.) would coexist in international trade, even though it might not overthrow the dollar in the near future (Ince Yenilmez et al., 2025; The Economist, 2025).

Figure 2. BRICS De-dollarisation Trends and NDB's Local Currency Strategy (2015–2025)



Source: Authors' own elaborations.

The graph illustrates the trend of "de-dollarisation," which means the BRICS nations moving away from dollar supremacy, using three significant indicators between 2015 and 2025. The first indicator is a blue line that indicates the percentage of local currency loans made by the New Development Bank (NDB). This percentage was almost zero in 2015 but gradually increased to thirty percent in 2025. This rise reflects the BRICS countries' determination to reduce their dependency on the dollar for development finance and also their policy of building up geopolitical resilience, especially in the aftermath of the Russia-Ukraine war.

The NDB is diversifying its investments and creating a separate financial system as a part of its strategy to counteract the negative effects of sanctions on the country's economy. Intra-BRICS trade in dollars corresponds to the red line that depicts the U.S. dollar's share dropping from 90% in 2015 to 75% in 2025. The main reason for this drop is the passage to local currency trade, especially in China and Russia. The trend implies that the dollar maintains its leading position, but the BRICS countries have, in effect, taken the initial steps towards a multipolar currency system. Moreover, with the BRICS+ (which includes Saudi Arabia, Egypt, and the United Arab Emirates) the countdown is likely to take place much earlier than expected in the future. Last but not least, the yellow line indicates that during the period 2015-2025, the total gold holdings of the BRICS group increased by 120%. This growth can be seen as an intentionally calculated attempt to mitigate the dollar's reign over global reserves. Furthermore, the increased purchases of gold by China during the 2023-2024 period signal two aims: to secure financial tranquillity and to create a reserve asset alternative to the dollar.

Overall, the graph indicates that BRICS is leading the transition from a US dollar-centred unipolar financial system to a multipolar one that depends on several reserves. This trend clearly demonstrates the concrete steps taken by the BRICS countries to strengthen their financial sovereignty and change the global power structure, even though the dollar still accounts for the majority of international currency transactions.

4. EXPLORING THE ECONOMIC AND GEOPOLITICAL IMPLICATIONS OF BRICS' FINANCIAL STRATEGY

The BRICS (Brazil, Russia, India, China, and South Africa) grouping is a huge economic power along with the G-7 and is growing faster than them, as the 2023 World Bank data describe. According to Sawal and Anjum (2023) and Cicero (2025), BRICS accounts for 46% of the global population. The US dollar has been the global reserve currency and trade currency for decades, and one of the main forces of the BRICS bloc is to create a multipolar financial architecture and fight against the dollar. Heavy reliance on the dollar makes member countries vulnerable to geopolitical pressure in the areas of financial sanctions, capital flight, and changes in US monetary policy (Krylov and Levchenko, 2023; Verdier, 2025). One of the pillars of the BRICS financial strategy is the New Development Bank (NDB), founded in 2015, which has gained a reputation for its commitment to financing projects without

attaching any political strings. The NDB has started lending to South Africa in Rand and aims to channel 30% of its approved loans in local currencies by 2026 as part of its objective to speed up de-dollarization in lending by 2024 (Toussaint, 2025). The currency risk related to the member countries will be eliminated by this step and dependency on the dollar will also be reduced structurally. While de-dollarisation has made a great impact on the economy, and the trade between China and Russia has almost completely shifted to local currencies, it has not really affected the dollar in the international arena since the local currencies still have liquidity problems in the global markets (Mosharrafa, 2024; Hossain, 2025). An important aspect of the BRICS financial strategy is that the central banks of the member countries have recently increased their gold reserves to the highest levels in history. Throughout 2024, gold stayed on top as a result of the increasing geopolitical threats and uncertainties. Central bank buying was another factor helping to show that the attempts to move reserves from the dollar and diversify them had a direct effect on the world gold markets (Forbes, 2024). The main geopolitical consequence of these moves was that there was a strong backing from institutional investors for the idea of a multipolar world order; the New Development Bank's (NDB) model of equal governance and unconditional loans is testing the US-led financial order's authority, thus declaring a political position against the old setup of IMF and World Bank rather than that of BRICS. The club of the emerging economies has also designed a "safety net" to protect against Western financial sanctions by not limiting themselves to traditional financial instruments but by coming up with alternative payment systems involving central bank digital currencies (CBDCs) like China's Digital Yuan (Eichengreen, 2022; IMF, 2025; Makoff et al., 2025). Ultimately, BRICS's financial policy is bringing forth an irreversible financial fragmentation in the global economic and geopolitical order. King (2025) asserts that the organisation's concrete measures, which represent a significant portion of the world's GDP, are moving the international monetary system away from the predominance of the dollar towards a more intricate configuration that includes several reserve currencies.

Table 1. Key Dimensions of BRICS' De-dollarisation Process (2015–2026)

Dimension	Description / Findings	Economic and Political Impact
Strategic Objective	To weaken the US dollar's position as a global reserve and trade currency, and to establish a multipolar financial order.	Achieving financial autonomy by reducing dependence on the US monetary policy.
Institutional Instrument (NDB)	Established in 2015, the New Development Bank (NDB) stands out for its loan model based on political conditionality and equal governance.	An alternative to the IMF-World Bank model: Building financial confidence in Southern Hemisphere countries.
Local Currency Usage	The goal is to have 30% of loans issued in local currencies by 2026.	As risk decreases, commercial dependence is shifting in favour of local currencies.
Bilateral Trade (Russia–China)	As of 2023, 90% of bilateral trade is conducted in local currencies.	The most concrete example of de-dollarisation; however, its global impact is limited.
Liquidity Problem	Local currencies are not liquid enough in international markets.	The main structural obstacle limiting the spread of de-dollarisation.
Gold Reserves	Central banks of member countries are rapidly increasing their gold reserves.	Dollar-denominated reserve diversification; price increase in gold markets.
Digital Currency Initiatives (CBDC)	Central bank digital currencies, like China's digital yuan, are developing alternative payment systems.	Non-SWIFT financial infrastructure; protection against sanctions risk.
Geopolitical Consequences	The legitimacy of the US-based financial system is being questioned.	The institutional foundations of the multipolar world order are strong.

Source: Authors' own elaborations.

The BRICS' de-dollarisation strategy shown in Table 1 is indicative of an intricate transition occurring simultaneously at the institutional, geopolitical, and economic levels. To begin with, as the US dollar still accounts for 90% of the world's international currency transactions, the strategic aim of the dollar's withdrawal from the reserve currency position in the near future appears to be mostly symbolic.Though, the NDB's lending model without any political conditions provides a strong alternative to the World Bank's and IMF's long-criticised "structural adjustment" methods, which in turn, strengthens the argument for financial sovereignty in the Global South nations. In addition, the practices of lending and trading in local currencies significantly lower the risk from exchange rate fluctuations, and at the same time, promote more equal financial relationships among BRICS countries.

A major factor limiting this process is the still insufficient liquidity and lack of worldwide acceptance, as local currencies are not yet at a level that would win over the confidence of international financial markets. The growth of gold reserves and the implementation of digital currency projects are two aspects of BRICS' policy for dollar diversification; one is traditional (gold) and the other is innovative (CBDC). This combined strategy not only fortifies the financial resistance but also permits the establishment of infrastructures to rival the SWIFT system, which is centred in the West, opening the door for the creation of substitute infrastructures for the SWIFT system, which is centred in the West.

Moreover, this financial revolution is not only a problem of economics but also a matter of geopolitics. The gradual construction of institutional instruments by BRICS is facilitating the transition from a unipolar to a multipolar financial system. Although this transition process might not challenge the dollar's hegemony in the medium term, it will eventually speed up the global economic power shift towards Asia and the Southern Hemisphere in the long run.

5. TOWARDS A NEW ERA OF GLOBAL MONETARY SOVEREIGNTY

After keeping its global monetary dominance throughout the world for quite some time, the US dollar is slowly losing its grip on a multipolar system supported by the data of 2024 and 2025 in particular. This development has been hastened by the dollar's use as a political weapon and the institutional risk hedging being sought by the developing countries, BRICS-like (Taylor, 2025). One of the most tangible proofs of this change is the skyrocketing growth of gold reserves by central banks; the ECB reports call for over 1000 tons of gold to be purchased in 2024, along with the fact that gold will be taking the place of the euro as the global reserve asset (Financial Times, 2025), turning the tide of de-dollarisation passively. The BRICS establishment, which is the most important element of the search for shared monetary sovereignty, is paving the way for the New Development Bank (NDB) to gradually replace the Bretton Woods era by offering financing in local currencies and without political conditions; NDB's ambition to allocate 30% of its loans in local currencies by 2026 is a vital part of this endeavor (Braga et al., 2022; Zhou, 2025).

China's yuan which is the leading rival has already acquired a significant position through bilateral trade (Responsible Statecraft, 2024), but supply and demand for global reserves and liquidity are still heavily in dollar's favor; nevertheless, China's Digital Yuan (CBDC) initiatives are seen as a technological asset in the fight for future monetary sovereignty, as they would provide a payment channel not reliant on SWIFT (Chorzempa, 2021; Saliya, 2025). The prediction that global central banks will shift from a monetary tightening phase to slow easing in the 2024-2025 period, which in turn could lead to volatility in capital flows, is a strong indicator of the US dollar still ruling over market pricing (WEF, 2025).

To sum up, the global monetary dominance is unavoidably shifting towards a more intricate and competitive multipolar monetary structure where the dollar's supremacy will be short-lived and there

will be a slow but certain co-existence as a result of the BRICS' institutional moves, the rising importance of the Yellow metal and the technological innovations, though the dollar will continue to be robust in the short run.

6. CONCLUSIONS

The findings of this investigation unambiguously indicate that the BRICS (BRICS Plus) enlargement of 2023 has converted the bloc from an economic union to a geopolitical power centre, opposing the Western-centric global order and impervious to sanctions; the joining of new members (especially big energy countries like Saudi Arabia, the UAE, and Iran) has increased the group's share of global GDP and population and has also given it more control over oil and gas markets worldwide. This is considered the clearest testimony that the notion of a multipolar world is already becoming entrenched in institutional foundations of a solid character, and the financial strategy of the BRICS states announces a transition where economic power is not just a matter of military or political influence but rather the ability to create alternative financial architectures.

De-dollarization, the core strategic goal of BRICS, exhibits two distinct realities at the implementation level: first, concrete steps such as the use of local currency in bilateral trade between Russia and China exceeding 90% create a successful model of resistance against the use of the dollar as a geopolitical weapon; second, literature and market data (with the dollar still being a party in approximately 90% of global currency transactions) support the notion that the dollar losing its global reserve currency status in the short term is a "fiction." De-dollarisation should therefore be analysed as a long-term process progressing through selective financial fragmentation, primarily among BRICS members, rather than a global collapse.

The New Development Bank (NDB) is the most prominent entity that supports the BRICS in their effort to break away from the dollar dependency, mainly through its plan to issue up to 30% of its project funds in local currencies by 2026. The model of lending without attaching conditions, as practised by the NDB, in contrast to the traditional IMF/World Bank model, is advantageous financially and politically for countries in the Global South; hence, it attracts them. The success of the NDB will be a litmus test for the BRICS' strategy of building up financial trust and cutting the cord with the global financial network. The financial approach of the BRICS nations merges two primary approaches for hedging against dollar risk: one is the classic way (like the case of central banks raising their gold reserves to unprecedently high levels) and the other one is the advanced way (like the case of China possibly creating payment channels apart from SWIFT using central bank digital currencies such as the Digital Yuan (CBDC)). The bipolarity of the reserve and payment system strategy is nevertheless a vital sign of the BRICS' commitment to financial independence in the future.

Using a bibliometric analysis as a part of the research methodology led to the revelation that the topic has not only been rising but has also caused a sharp increase in the number of studies carried out

in the academic literature; this especially happened after the 2023 expansion. Moreover, it has been shown that the issues of de-dollarisation and alternative financing are still regarded as a matter of geopolitics. Ultimately, the financial strategy of BRICS is indeed an irreversible force that is contributing to the gross fragmentation of the global financial system; the new world of developing countries without this turning point would still carry new risks related to the use of local currencies and the diversification of the payment systems that are going to be alternatives thus making the international trade less efficient and global financial flows harder to monitor; the emergence of BRICS is a sign that there will be a transition to a new epoch of monetary power, which is going to be characterized by both chances and difficulties that, apart from requiring, will need global governance and financial stability to be managed carefully.

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SUDDEN STOP IN USA AND CHINA CAPITAL MARKETS

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ABSTRACT

The aim of this study is to determine the periods of sudden stops in the USA and China capital markets, the two main actors of the global financial system, and to examine the possible causes of these periods, due to the increasing vulnerabilities in the global economy in recent years, especially the accelerated capital movements after the 2008 global financial crisis, the pandemic process and the subsequent wave of global monetary tightening, political tensions with the USA-China trade wars, trade restrictions, and the increasing vulnerabilities in the global economy in recent years. Quarterly foreign direct investment, real effective exchange rate, and portfolio investment data for the period 2010-2024 were used. Sudden stops were identified using the criterion of a capital inflow growth rate falling two standard deviations below the mean, using the approach of Calvo et al. (2004). In the econometric analysis, the Structural VAR (SVAR) model was applied to measure the causal relationships between capital movements and the effects of structural shocks. The findings show that portfolio investments are more vulnerable to sudden stops compared to foreign direct investments and therefore create an additional risk element in the financial system. It was concluded that macroprudential policies should be strengthened to reduce the vulnerabilities of short-term capital flows, investor confidence should be increased, and exchange rate policies should be maintained to encourage long-term investment.

Keywords: *Sudden Stop, Capital Markets, Structural Shock.*

JEL Codes: *F32, G15, C32.*

1.INTRODUCTION

The increasing level of integration of global capital movements has made the volatility of capital flows, particularly between developing and large-scale economies, a critical component of international macroeconomic stability. In this context, the sudden stop phenomenon is extensively discussed in the literature as a process that arises from sharp shifts in portfolio investment, foreign direct investment, and real effective exchange rate dynamics, and can trigger financial vulnerabilities (Calvo, 1998; Edwards,2004).

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For the two largest players in the world economy, the USA and China, a sudden halt in capital flows has the potential to create significant externalities in terms of both national financial conditions and global liquidity cyclesHowever, it remains a matter of debate which macroeconomic indicators trigger these abrupt stoppages, whether they occur simultaneously across countries, and especially whether shocks in the USA have a causal effect on capital flows in China. Although global risk appetite, monetary tightening cycles, trade tensions, and exchange rate pressures are presented in the literature as possible determinants of abrupt stops, it is not clear to what extent the transmission channels of these factors between countries are strong (Fratzscher, 2011; Rey, 2018).

The increasing integration of global capital movements since the 1980s, coupled with the accelerating process of financial liberalization, has made fluctuations in capital flows a central component of international macroeconomic stability, particularly for developing and large-scale economies. Calvo et al. (2004) consider sudden stops essentially a "emerging market phenomenon," while Edwards (2004) defines a sudden stop as a sudden and significant decrease in capital inflows in countries that have attracted high volumes of foreign capital up to a certain period. Although this definition focuses on gross capital inflows, in practice, the movements of net capital flows constitute a complementary reference point in identifying sudden stops.

When this historical and theoretical framework is evaluated in terms of today's global financial architecture, the synchronization and fragility effects created by capital flows between large-scale economies become more apparent. A sharp slowdown or redirection of capital movements for the two largest actors in the world economy, the USA and China, has the potential to create externalities not only on domestic financial conditions but also on global liquidity cycles, risk, and international portfolio allocation. Although financial fluctuations, monetary tightening cycles, trade tensions, and exchange rate pressures are discussed in the literature as key determinants of abrupt stops, there is no consensus on the extent to which the transmission channels of these factors between countries are strong and permanent (Calvo, 1998; Edwards, 2004; Fratzscher, 2011; Rey, 2018).

This study aims to re-evaluate the aforementioned debate in a contemporary context by using US and Chinese data from 2010Q1–2024Q4 to identify abrupt stop periods through portfolio investment, foreign direct investment, and real effective exchange rate indicators using a standard deviation-based method; it also examines the possible macroeconomic reasons underlying these periods with a critical perspective. Furthermore, through a structural VAR (SVAR) model, it investigates both the dynamic effects of domestic shocks and analyzes the potential repercussions of abrupt stops observed in the USA on Chinese capital flows.

Thus, this study aims to provide an analytical contribution to the existing literature by revealing how global capital flows spread between two major economies and under what conditions this diffusion mechanism becomes more pronounced.

2.LITERATURE

Discussing the abrupt halt mechanism in international capital movements, Calvo (1998) argues that these processes can increase financial vulnerabilities, paving the way for both financial crises and balance of payments problems. One of the key points highlighted by the author is that even if the entire current account deficit were financed through foreign direct investment, the risk of a sudden stop could not be completely eliminated. However, it is argued that equity-like inflows and long-term bond financing could make the economy relatively more resilient to such shocks. Calvo also argues that sudden stops have become widespread on an international scale to an extent that cannot be explained solely by national economic dynamics, and therefore can have more devastating consequences.

Calvo (2004) views economic growth as an inverse function of fiscal burdens, arguing that when the tax burden reaches a critical threshold, growth can abruptly decline from high to low levels. This decline is associated with a sudden halt in capital inflows, increased real depreciation, and production losses, particularly in non-tradable sectors. The author suggests that these mechanisms were observed in recent financial crises in developing countries. According to Calvo's model, strengthening fiscal institutions is central to the policy set against sudden stops, and while fiscal discipline is effective in the medium term, relying on high taxes can have adverse consequences in the short term. Calvo, Izquierdo, and Mejía (2004), in their study covering 32 developed and developing countries, examine the empirical characteristics of abrupt stops and their relationship with balance sheet effects. Their findings show that real exchange rate fluctuations are most pronounced in developing markets in conjunction with abrupt stops. The fact that countries with different characteristics exhibit similar behaviors in clusters during periods of crisis suggests that these economies have similar vulnerabilities, particularly to large-scale currency fluctuations. This vulnerability is said to stem from a combination of adjustment requirements for traded goods and high dollar liabilities in banking systems, dollarization of domestic debt. The study emphasizes that openness and dollarization are key factors determining the probability of a sudden halt, but that this relationship is non-linear; risks increase significantly, especially when high external deficit leverage and intense dollarization occur together.

Calvo's (2014) later study examines the effects of sudden stops and sudden capital inflows within a financial model framework stripped of collateral constraints. This model suggests that expectations of foreign direct investment (FDI) direct domestic investors towards long-term projects; however, when expectations deteriorate, the sudden stop dynamic can be rapidly triggered. The focus of the study on FDI offers an alternative and complementary framework to theoretical approaches in the literature that predominantly focus on credit and portfolio flows. A study examining the determinants of abrupt stops in capital movements in emerging markets identifies three types of situations (from the perspective of domestic residents) using gross international asset and liability movements. These are considered in terms of three groups: countries that did not experience any type of abrupt stop; those that experienced an abrupt stop in inflows (liabilities) but not in their net financial accounts; and countries that

experienced an abrupt stop in both inflows and net financial accounts. Based on these three events, a multinomial logit model is estimated, yielding two important results. It is found that developed countries are almost equally likely to experience abrupt pauses in gross capital inflows as emerging economies. Furthermore, the likelihood of experiencing a sudden halt in gross inflows, which translates into a sudden stop in the financial account, is influenced by the behavior of a country's international assets, and countries with assets abroad tend to repatriate them during periods of sudden halts. Economies of countries without foreign assets are far more sensitive to the behavior of foreign investors, and a sudden halt in inflows can have very negative effects on output and employment (Agosin et al., 2019). (Palandökenlier & Bal, 2024), in this study covering thirteen emerging market economies, examines the determinants of abrupt stops by disaggregating them according to capital types and draws attention to the impact of global risk indicators and short-term capital inflows on vulnerability. Although the results obtained using the SVAR approach suggest that the economic effects of debt-type inflows may be more destructive, it is debatable whether further testing is needed regarding the causality of this relationship. (Er & Tanrıöven, 2022), focusing on the case of Turkey, attempts to explain periods of abrupt pauses in equity and debt flows through a probit model and quantitatively evaluates the relationship between global and local indicators and these periods. Although this study offers a pioneering framework specific to Turkey, its empirical design, based solely on monthly data and the lack of decomposition of gross flows, limits its potential contribution to comparative international analyses. The model developed by (Rojas & Saffie, 2022) on the Armenian deposit market adds a different theoretical dimension to the literature by abandoning the homothetic consumer assumption and evaluating the sudden stop mechanism under non-homothetic preferences. In particular, by demonstrating how credit cycles deepen through the income elasticities of non-importable goods, it offers an alternative perspective to studies that explain sudden stops solely through macro-financial indicators. When the three studies are considered together, they show that abrupt stops are influenced by both vulnerabilities in the financial structure and structural differences in demand components; however, the literature still needs a more detailed examination of the sub-components of capital flows, the inclusion of micro-heterogeneities in the model, and comparative empirical designs across countries.

3.MATERIALS AND METHODS

The dataset used in this study covers the period 2010Q1–2024Q4 and consists of three key financial variables: foreign direct investment (FDI), real effective exchange rate (REER), and portfolio investments (PTFY). These variables were chosen because they represent different components of capital movements in the sudden stop literature. Having the dataset in quartile frequency allows for more consistent temporal monitoring of the effects of structural shocks and also reduces potential high-frequency noise. Before analysis, all series were tested for stationarity and the differences of variables containing unit roots were taken to make them I(0). While this process is necessary for the statistical properties required by the SVAR model, the effect of possible information loss should not be ignored.

3.1. Determining Sudden Stop Periods

The approach developed by Calvo, Izquierdo, and Mejía (2004) was used to identify abrupt pauses. According to this approach, an abrupt pause occurs when the capital inflow growth rate falls two standard deviations below its long-term average. While this threshold-value method is widely used, particularly in capital movement data containing extreme observations, the literature also notes that determining abrupt pauses based solely on quantitative thresholds can sometimes produce controversial results. Therefore, the results obtained have been interpreted in conjunction with both the behavior of the series and the economic developments specific to the period.

3.1.1. Econometric Method: Structural VAR (SVAR)

In this study, the Structural Vector Autoregressive (SVAR) model was used to analyze the structural relationships between the real effective exchange rate, foreign direct investment, and portfolio investment. The SVAR approach is suitable for examining the macroeconomic transmission mechanism of sudden stops because it can define the dynamic interaction between variables not only through lagged values but also through simultaneous structural shocks. The SVAR model can be expressed in its general form as follows:

The structural VAR model used in this study is defined through an A_0 matrix that restricts the contemporary interactions of three variables ($\Delta REER_t$, ΔFDI_t , $\Delta PTFY_t$) the structural form of the model is as follows:

$$A_0 = \begin{bmatrix} \Delta REERt \\ \Delta FDIt \\ \Delta PRTFYt \end{bmatrix} = A_1 \begin{bmatrix} \Delta REERt-1 \\ \Delta FDIt-1 \\ \Delta PRTFYt-1 \end{bmatrix} + \ldots\ldots\ldots + \begin{bmatrix} \varepsilon 1_t \\ \varepsilon 2_t \\ \varepsilon 3_t \end{bmatrix}$$

The contemporary constraints used in the study are based on the theoretical expectation that the impact of capital movements on the exchange rate appears with a delay, whereas exchange rate shocks can affect both FDI and portfolio investments within the same period. The A_0 matrix, defined according to these assumptions, is as follows:

$$A_0 = \begin{bmatrix} 1 & 0 & 0 \\ a21 & 1 & 0 \\ a31 & a32 & 1 \end{bmatrix}$$

This configuration represents a recursive causality pattern where exchange rate shocks are the primary cause, foreign direct investment is the secondary cause, and portfolio investment is the secondary cause. These constraints ensure that impulse-response functions are definable.

4. FINDINGS

Figure 1. Sudden Stop Graph of the Real Effective Exchange Rate for the USA

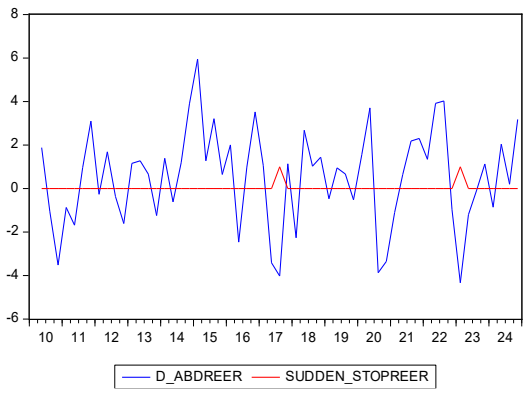


Figure 2. Sudden Stop Graph of the Portfolio Investments for the USA

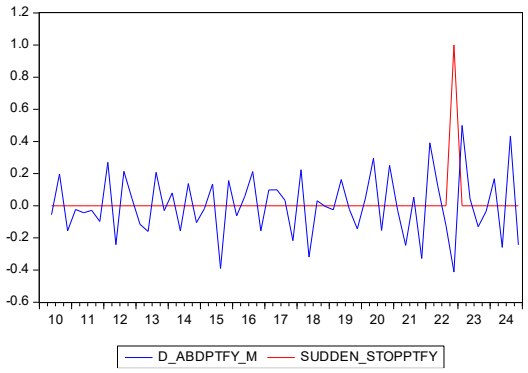
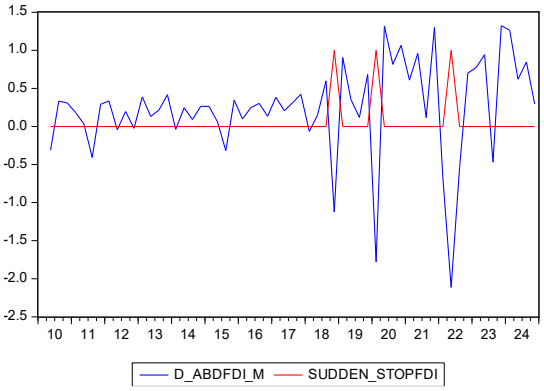


Figure 3. Sudden Stop Graph of the Foreign Direct Investment Rate for the USA



The real effective exchange rate changes in the USA during the period 2010Q1–2024Q4 generally show high-frequency but moderate-scale fluctuations. The sudden stop indicator in the chart indicates a limited number of observations where the rate falls below the threshold in specific quarters. This is consistent with the literature suggesting that abrupt stops in capital flows occur less frequently in reserve currency issuing economies like the USA, which drive global liquidity (Calvo, Izquierdo & Talvi, 2006; Forbes & Warnock, 2012).

The sharp contraction observed in portfolio investments is particularly pronounced after 2022.

Values falling below the threshold during this period can be explained by factors such as tightening global financial conditions (FED interest rate hikes), geopolitical tensions, and decreased risk appetite. The literature frequently emphasizes the sensitivity of portfolio movements to the global financial cycle (Rey, 2018). In this context, the sharp decline seen in the graph can be said to be consistent with global liquidity shocks rather than internal dynamics. While USA foreign direct investment moved within a relatively stable range during the review period, it showed quite sharp negative deviations in certain quarters. Sudden stop periods, consisting of observations below -2 standard deviations, are particularly concentrated around 2018Q4, 2020Q1, and 2022Q2. All three of these periods coincide with dates of significant breakthroughs both globally and nationally.

Figure 4. Sudden Stop Graph of The Real Effective Exchange Rate For The China

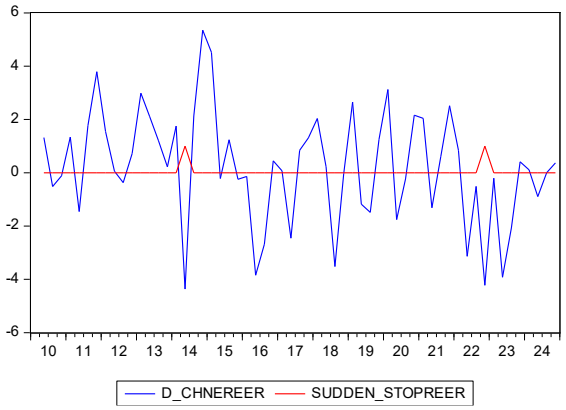


Figure 5. Sudden Stop Graph Of The Portfolio Investments for The China

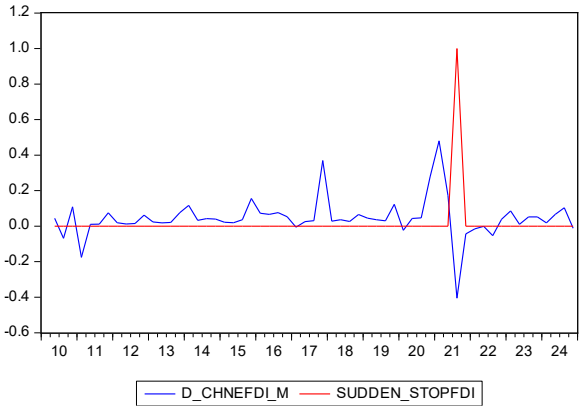
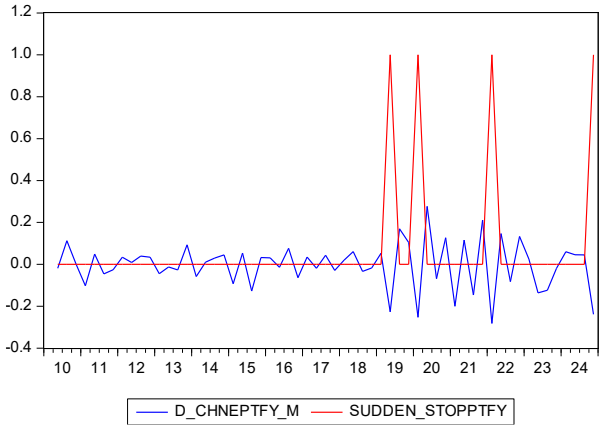
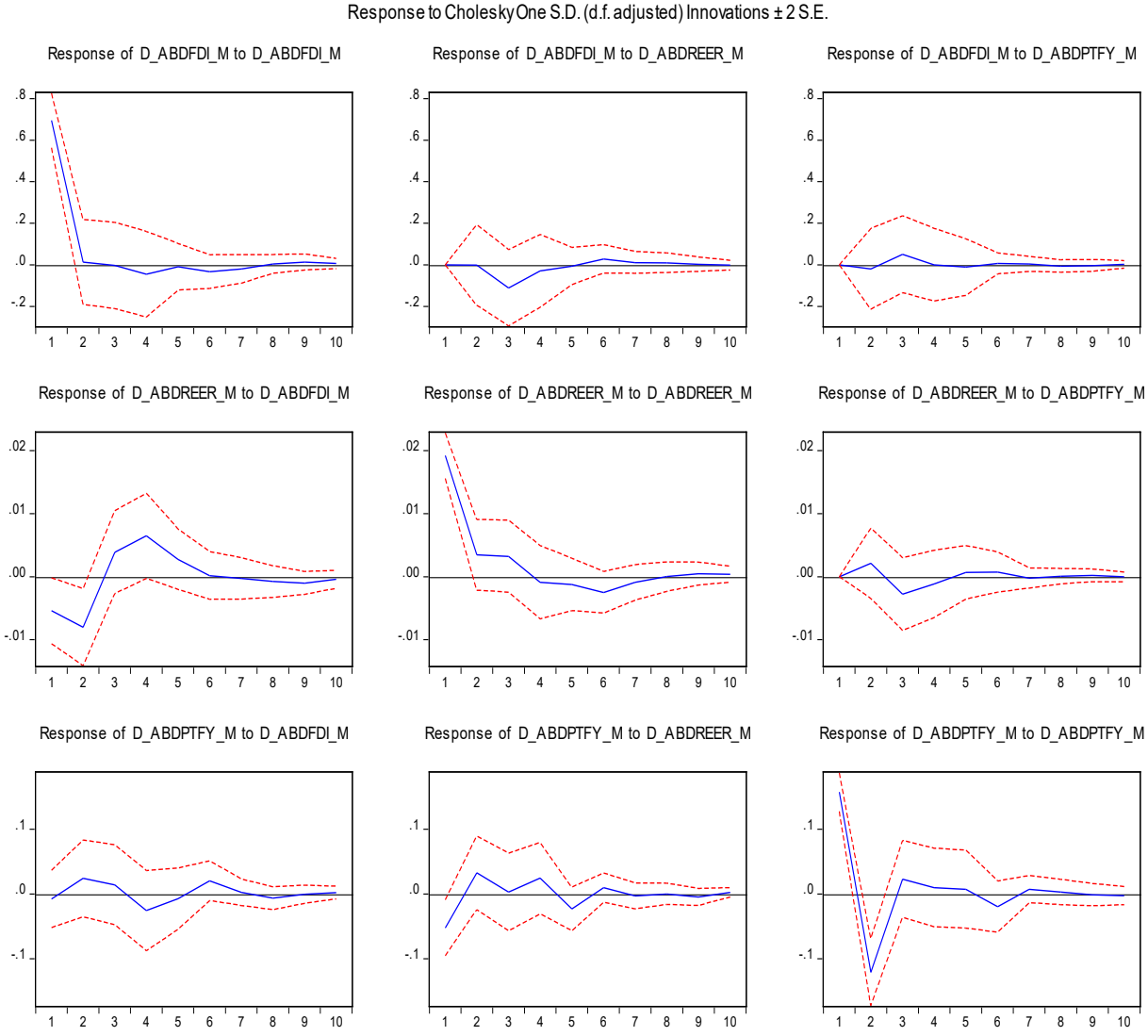


Figure 6. Sudden Stop Graph Of The Foreign Direct Investment Rate For The China



In the sudden stop analysis for China covering the period 2010Q1–2024Q4, a holistic assessment of the behavior of the three key variables revealed significant sudden stops in the real effective exchange rate only in 2014Q2 and 2022Q4; these breaks were found to be consistent with exchange rate regime adjustments after 2014 and external pressures created by global interest rate increases in 2022. The series of foreign direct investments has largely shown a stable structure, but a sharp and singular sudden stop occurred in Q3 2021, coinciding with a period when technology-focused regulatory interventions in China negatively impacted foreign investor expectations. Portfolio investments, on the other hand, have produced more intense and recurring sudden stop dynamics compared to the other two variables; sudden contractions occurred in Q2 2019 due to the uncertainty created by trade wars, in Q1 2020 due to global risk aversion stemming from COVID-19, in Q1 2022 due to the impact of the Fed's tightening cycle, and in Q4 2024 due to the vulnerabilities in the real estate market. The structure in the graphs confirms the high sensitivity of portfolio flows to short-term global conditions, their more resilient character when looking at FDI data, and the fact that the real effective exchange rate only shows vulnerability during certain periods; it also shows that sudden stops in the Chinese capital market occur with different intensities and frequencies depending on the type of variable.

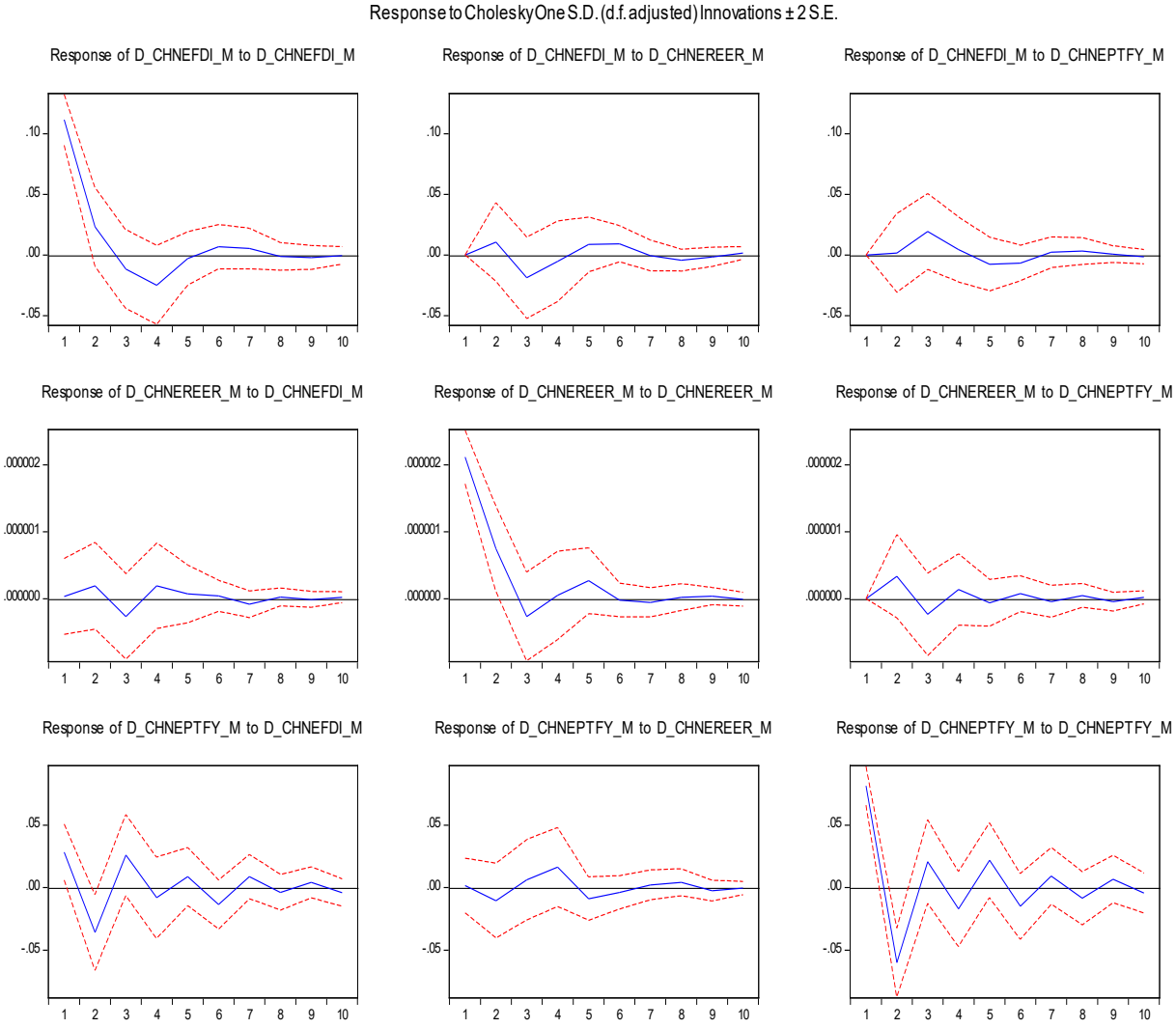
Figure 7. Impulsive Image of the USA



REER's response to its own shock is initially positive and strong; it then rapidly dampens in subsequent periods. This pattern is consistent with findings in the literature that exchange rate shocks are generally effective in the short term and show rapid reversal.The FDI's response to the REER shock is weak and transient. A small-scale negative response is observed in the initial 2–3 periods, after which the effects become statistically insignificant. This is not inconsistent with the generally accepted view that FDI is only minimally affected by short-term exchange rate shocks; because FDI decisions are strategic and long-term, and do not react as quickly as financial capital (Alfaro et al., 2020). However, it must be carefully considered whether the weak response is due to a structural feature of the series or to limitations of the model.

Portfolio investments initially react negatively to the REER shock, but the shock subsides quickly. This indicates that exchange rate uncertainty reduces risk appetite and can decrease portfolio inflows. However, the width of the confidence intervals suggests that the effect, especially in the initial period, is uncertain.

Figure 8. Impulsive Image of the China



The impulse-response functions obtained from the SVAR model constructed with stationary variables reveal the interplay structure of capital flows in the Chinese economy in detail. Firstly, the response of FDI shocks to their own dynamics is strong and positive in the short term, but weakens rapidly after 3–4 periods. This structure is consistent with the literature suggesting that direct investments are relatively slow to adjust but stable. The impact of FDI shocks on REER and portfolio investments is quite limited and short-lived, with the response on REER showing a low-scale negative fluctuation; this implies that exchange rate movements are more sensitive to portfolio flows than to FDI. When the dynamics of REER shocks are examined, it is seen that an unexpected appreciation in the real exchange rate creates a significant short-term contractionary effect on both FDI and portfolio investments. Following a REER shock, the reaction in FDI initially falls into negative territory, then rapidly dampens. Portfolio investments, on the other hand, react to the REER shock in a more volatile manner, producing both positive and negative oscillations in the short term. This pattern is consistent with empirical findings indicating that exchange rate volatility affects short-term capital flows with higher sensitivity (Calvo & Reinhart, 2000).

Portfolio investment shocks have the shortest-lived impact profile in the model. While portfolio investment shocks generate high-frequency fluctuations in their internal dynamics, they do not create a significant and sustained impact on FDI; the response quickly approaches zero. Similarly, REER's response to portfolio shocks is also short-lived; this indicates that portfolio movements in China are constrained by capital account regulations and their transmission to macro-financial variables remains weak. The lower impact of portfolio investments on FDI compared to REER is consistent with the "controlled openness" structure of China's capital movement composition described in the literature (Kose et al., 2010).

5. CONCLUSION

This study uses FDI, portfolio investment, and real effective exchange rate data from 2010Q1–2024Q4 to determine sudden stop periods for the USA and Chinese economies and to examine the dynamic relationships of capital flows through a structural VAR (SVAR) model. Sudden stop dates were determined using the standard deviation approach, and then impulse-response functions obtained from stationarized series were evaluated. The findings indicate significant differences between the two economies in terms of the nature of capital movements and their sensitivity to shocks. The results for the USA show that portfolio investment shocks generate high volatility in the short term, while FDI, although adjusted more slowly, is sensitive to real exchange rate volatility. REER shocks were observed to have a contractionary effect through both the FDI and portfolio channels, consistent with the sudden stop events identified, particularly in the 2020Q1 and 2022Q1–Q3 periods. This impact profile reveals that fluctuations in global financial conditions are reflected quickly and significantly in capital flows in the USA. The results for China exhibit a different pattern. The SVAR model shows that real effective exchange rate shocks have the broadest spillover effect in the system, while FDI shocks produce a more stable, short-lived, and limited transmission period. The finding that portfolio investment shocks, despite involving high-frequency fluctuations, do not create a lasting effect on either FDI or REER appears consistent with China's partial control mechanisms in its capital account. The portfolio-related sudden stop periods of 2019Q2, 2020Q1, 2022Q1, and 2024Q4 were also found to have created a limited spillover effect, particularly through the exchange rate channel, consistent with this finding.

Overall, the USA economy exhibits a more responsive and sensitive structure to changes in financial conditions regarding capital flows, while the Chinese economy shows a more stable and long-term character in capital movements, particularly in the FDI channel. Although exchange rate shocks play a critical role in both economies, it is noteworthy that the central effect of REER is significant in China, while portfolio investments are the dominant source of volatility in the USA. These findings indicate that the structure of the sudden stop mechanism varies from country to country; factors such as exchange rate volatility, capital account openness, and investment composition play a decisive role in the formation of sudden stop risk.

The results offer two important implications for policy. First, the high sensitivity of the USA to global financial fluctuations indicates that liquidity conditions and monetary policy expectations create a strong transmission channel for capital flows. Second, it appears that in China, capital controls and an FDI-weighted capital structure relatively limit the risk of sudden stops, but external shocks originating from REER still create significant vulnerability for the economy. Therefore, it can be said that exchange rate stability and regulations regarding the composition of capital flows play a critical role in reducing the risk of sudden stops for both economies.

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DETERMINANTS OF CONTAINER PORT THROUGHPUT: AN EVALUATION OF THE MEDITERRANEAN CORRIDOR (2005–2024)

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Talha YALNIZ[***]

ABSTRACT

This study investigates the determinants of container handling volumes at thirteen major ports situated along the Mediterranean maritime corridor—Mersin, İskenderun, Piraeus, Valencia, Barcelona, Algeciras, Tanger Med, Livorno, Gioia Tauro, Genoa, Marseille, and Port Said—using annual data for the period 2005–2024. The empirical analysis is grounded in a balanced panel data framework. The fixed effects model was first estimated, after which the Feasible Generalized Least Squares method was adopted as the primary estimation technique in line with diagnostic test results. Subsequently, port efficiency was assessed through an efficiency analysis employing both the fixed effects model and the Stochastic Frontier Analysis method. The findings indicate that increases in gross domestic product per capita and improvements in trade balance significantly enhance container handling volumes, whereas population growth imposes spatial and operational constraints. Maritime connectivity emerges as a central determinant. Moreover, substantial disparities in technical efficiency across Mediterranean ports underscore the concentration of competitive advantage within a limited number of high-performing hubs.

Keywords: *Container Port, Mediterranean Ports, Panel Data Analysis, Port Connectivity Index, Maritime Transportation.*

JEL Codes: *R41, F14, C23, L91.*

1. INTRODUCTION

The rapid increase in the volume of international trade has positioned transport systems and infrastructure planning at the core of national development strategies. Rising global levels of production, consumption, and trade relations have rendered the integration of transportation networks, resource efficiency, and regional connectivity more critical than ever. Among the modes of transportation, maritime shipping stands out as one of the most fundamental components of international trade due to

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its low unit cost, high transport capacity, and comparatively lower carbon emissions relative to other transport modes. Container shipping, as a key element of maritime transport, constitutes a system that ensures the continuity of global supply chains by regulating the flow of goods between production centers and consumption regions. Particularly over the past three decades, during which industrialization has accelerated, foreign trade volumes have expanded, and supply chains have been restructured, container transport has emerged not merely as a logistical activity, but as a critical factor situated at the intersection of economic growth, competitiveness, and regional development.

According to Lloyd's List (2025), global container traffic increased from approximately 88 million TEUs in 1990 to 880 million TEUs by 2023 (UNCTAD, 2024, 20.11.2025). This extraordinary growth is closely linked to the geographic dispersion of economic production, the global repositioning of multinational corporations, the restructuring of supply chains, and the establishment of new market linkages. The increasing volume of maritime transport has transformed the traditional functions of ports, turning them from mere cargo handling facilities into multifaceted logistics hubs that support data-driven planning and operational processes.

One of the regions where this transformation is most evident is the Mediterranean basin. Strategically located at the intersection of Europe, Asia, and Africa, the Mediterranean is considered one of the main east-west corridors of global trade. A significant portion of maritime shipping passing through the Suez Canal is directed through Mediterranean ports, making the region not only geographically but also economically a strategic center. In recent years, the increasing competitiveness of ports such as Tanger Med (Morocco), Algeciras, Valencia, Piraeus, and Mersin demonstrates that Mediterranean ports have evolved into multidimensional structures fulfilling both transshipment and gateway functions simultaneously. These ports, with their hinterland connections and regular liner shipping connectivity (LSCI), play a decisive role in the growth of regional economies. On the other hand, the intensification of inter-port competition necessitates an accurate analysis of the factors determining container handling volumes.

The factors influencing container volumes are not limited to physical infrastructure capacity alone. Macroeconomic growth, trade balance, maritime connectivity, hinterland accessibility, logistics costs, political stability, and the level of digitalization directly impact port performance. According to UNCTAD (2024) reports, there is a strong positive correlation between port connectivity and port demand; as the frequency of regular liner services and the density of connections increase, container volumes tend to rise accordingly. In this context, panel data analysis emerges as an effective method for examining the dynamic relationships among multidimensional economic and logistical variables that influence port performance.

This study analyzes the factors determining container handling volumes at major container ports located along the Mediterranean corridor (Mersin, İskenderun, Piraeus, Valencia, Barcelona, Algeciras,

Tanger Med, Livorno, Gioia Tauro, Genoa, Marseille, and Port Said) using a balanced panel data set constructed from data covering the period 2005–2024. Initially, the panel fixed effects model was employed to test the relationships among the variables, followed by the application of the Feasible Generalized Least Squares (FGLS) estimation method, which accounts for cross-sectional dependence and heteroskedasticity within the model.

The key variables used in the analysis include population, gross domestic product (GDP) per capita, trade balance, the Liner Shipping Connectivity Index (LSCI), and periodic shocks. The findings indicate that economic growth in the countries hosting Mediterranean ports increases container volumes, thus suggesting that port demand exhibits high elasticity with respect to macroeconomic growth. The population variable, on the other hand, appears to reduce container volumes. The LSCI variable, which represents the level of integration of ports into the global maritime transport network, stands out as a significant determinant. Improvements in the trade balance have, as expected, been observed to increase container volumes; this reflects the growing capacities of ports in the Mediterranean region that possess high export potential.

In addition to the panel model, the study also evaluates the relative technical efficiencies of the ports through Stochastic Frontier Analysis (SFA) and the fixed effects approach, thereby revealing the differences in operational efficiency among the ports independently of economic determinants.

Although numerous studies have examined container throughput, port performance, or maritime connectivity in different regional and global contexts, empirical research focusing specifically on the Mediterranean corridor remains limited. Existing studies often center on single-port dynamics, global port rankings, or regional competition patterns without systematically evaluating the combined effects of macroeconomic, logistical, and connectivity-related variables within a unified panel framework. This study contributes to the literature by providing a comprehensive and data-driven assessment of container handling volumes across thirteen major Mediterranean ports using a balanced panel data set for the period 2005–2024. By integrating both econometric estimation and efficiency analysis, the study offers a novel perspective on the interplay between economic growth, trade balance, maritime connectivity, and technical efficiency within the Mediterranean region.

The study consists of five sections. Following the introduction, the second section presents the related literature. The third section explains the data set and variables. The fourth section discusses the methodology and empirical findings obtained from the fixed effects model, the Feasible Generalized Least Squares estimation, and the Stochastic Frontier Analysis. The final section provides the conclusion and policy implications.

In conclusion, ensuring the sustainable performance of container ports along the Mediterranean corridor depends on policies that focus on flexible capacity management responsive to macroeconomic growth, the enhancement of connectivity, the strengthening of digital infrastructure, and the

improvement of hinterland integration. This study provides a data-driven analysis of the role of Mediterranean ports in regional development and offers a scientific framework to guide future transport investments.

2. LITERATURE REVIEW

Academic studies on container shipping and port performance have emerged as a significant area of research within maritime transport economics over the past two decades. The increase in global trade volumes, the restructuring of supply chains, and digitalization processes have transformed ports from mere cargo handling centers into strategic infrastructure components in terms of economic growth, connectivity, and competitiveness. This transformation has necessitated a multidimensional analysis of the factors determining port performance. While early studies in the literature predominantly explain container volumes through macroeconomic indicators such as economic growth, foreign trade volume, and industrial production, more recent research has revealed that variables such as port connectivity (LSCI), infrastructure investment, hinterland accessibility, energy efficiency, and digitalization directly affect port performance. Nevertheless, studies that focus on the comparative analysis of ports in the Mediterranean basin and jointly assess economic and logistical factors using multi-year panel data approaches remain limited. This highlights the need for new empirical research that comprehensively evaluates the determinants of port performance at a regional scale.

Tongzon (1995), in an empirical study covering 23 international ports, examines the factors determining port performance and efficiency. Using various operational and institutional indicators, a multiple regression model is employed. The findings show that berth throughput, operational expenses, and the number of employees significantly enhance efficiency, whereas equipment waiting times and certain cargo equipment indicators undermine port performance. The study reveals that internal operational factors (e.g., yard and equipment utilization, labor productivity) are more decisive than external factors in explaining port efficiency.

Liu (2011) investigates the main variables affecting container handling volumes in Chinese ports. Using data from 1998–2008 and applying multiple linear regression analysis, the study assesses the effects of variables such as GDP, import-export volume, and the capacities of rail and road transport on container traffic. The results indicate that GDP and industrial production in the hinterland have a strong positive effect on container volume. Additionally, improvements in transport infrastructure and increases in foreign trade directly affect port demand and enhance performance. The study emphasizes that macroeconomic growth and logistics integration are long-term determinants of port capacity.

Bottasso, Conti, Ferrari, Merk, and Tei (2013), using a panel data set covering 560 NUTS-3 regions and 116 ports in 10 Western European countries, examine the relationship between port throughput and regional employment. Covering the period 2000–2006, the study applies the System Generalized Method of Moments (System-GMM). The findings demonstrate that increases in container

and total throughput have a significant and positive impact on regional employment. Moreover, port activities generate indirect (spillover) employment effects not only in port cities but also in neighboring regions. These results suggest that port policies should be designed in an integrated manner with regional development strategies, not solely within the scope of transport planning.

Vitsounis (2014), using data from 1995–2010, analyzes convergence trends in container throughput across 36 container ports through a dynamic panel data approach and GMM estimation. The findings indicate that macroeconomic variables such as GDP, industrial production, and financial openness play a determining role in throughput convergence. The study also finds that increased trade volumes and decreased transport costs have led to rapid capacity growth, especially in developing ports. Thus, it underscores the possibility of narrowing performance gaps among ports over time and emphasizes the influence of economic growth on port competitiveness.

Rashed et al. (2017) apply an ARIMA intervention model using data from January 1995 to March 2015 to forecast container volume at the Port of Antwerp. The study provides significant insights for reducing demand uncertainty and strengthening capacity planning, serving both port management and policymakers.

Farhan and Ong (2018) apply SARIMA models to forecast container volumes at international ports, achieving high accuracy in their predictions. The study successfully reflects the impact of fluctuations on container shipping, offering valuable support for improving operational planning and strategic decision-making processes.

Mo et al. (2018) develop a GMDH-based hybrid model to forecast container volumes for Xiamen and Shanghai ports using data from January 2000 to December 2014. The linear component is modeled using SARIMA, while the nonlinear component is derived from AI methods, with results integrated via GMDH selective ensemble methodology. The model provides forecasts for container volumes for the year 2016.

Notteboom and Pallis (2019) examine the relationship between transshipment dependency and throughput volatility at Northern European and Mediterranean container ports using panel data from 1990–2016. The findings reveal that increased transshipment share is associated with higher container volume volatility, while ports with strong gateway functions experience more stable volumes. The results suggest that transshipment-focused ports in the Mediterranean are more vulnerable to demand shocks, highlighting the importance of flexible operational strategies and service diversification in capacity planning.

Pehlivan (2020) conducts a comparative study of 15 ports from Turkey and Europe using Data Envelopment Analysis (DEA) and the Hotelling T^2 test. Inputs include berth length, port depth, and terminal area; output is measured by TEU volume. The findings reveal that European ports operate with higher technical efficiency, while Turkish ports exhibit inefficiencies in terminal area utilization and

berth length. The study concludes that Turkish ports lag behind their European counterparts in terms of technical efficiency.

Tovar (2022), using panel data from 2006–2016, further explores the relationship between maritime connectivity and port efficiency at 16 Spanish container ports. The panel regression results show that increased connectivity significantly improves both operational efficiency and container handling capacity. Additionally, higher connectivity enhances service diversity and regional accessibility, contributing to long-term port performance. The study emphasizes the necessity of considering LSCI as a core determinant in port performance models.

Munim et al. (2023) conduct a comprehensive time series analysis to forecast container volumes at three major Asian ports: Shanghai, Busan, and Nagoya. Using monthly data from January 2010 to December 2019, the study applies ARIMA, SARIMA, Holt-Winters Exponential Smoothing (HWES), and Prophet models, demonstrating their usefulness for more reliable port management and capacity planning.

Ayesu (2024) analyzes the relationship between container port volume, employment, and economic growth across selected port countries in Africa and Asia from 2000 to 2021 using panel data regression. The findings reveal that increases in container handling volumes significantly and positively contribute to employment generation and economic growth. Furthermore, improvements in trade infrastructure and logistics efficiency are found to strengthen this impact. The study emphasizes that ports function not only as transport hubs but also as economic actors driving regional development.

Caldas (2024) examines factors affecting the efficiency of global container ports from a sustainability perspective using panel data from 2010–2022. Variables include GDP per capita, water depth, infrastructure capacity, port governance models, private sector participation, and technological adaptation. The findings identify economic growth, public-private partnerships, and digital infrastructure as key drivers of port performance. The study also notes that high-performing ports are more likely to adopt sustainable transport policies and environmental management practices. Caldas (2024) recommends that port competitiveness be enhanced not only through capacity expansion but also via improvements in efficiency, governance quality, and sustainability integration.

Martínez-Moya et al. (2024) evaluate the connectivity and competitiveness performance of major Mediterranean container ports using an integrated index approach. Covering the period 2010–2022, the study develops a composite “Foreland Connectivity Index” and analyzes port positions within network structures, service diversity, and access intensity. Methodologically, variable-weighting multi-criteria analysis and panel regression are applied. The findings identify ports such as Valencia, Algeciras, Piraeus, Tanger-Med, and Gioia Tauro as having high connectivity, with their competitiveness directly linked to service frequency, route diversity, and hinterland access. The study emphasizes that weighting

components of connectivity significantly influence competitiveness scores and calls for transparent, standardized indicators in policy planning.

Guo et al. (2025) apply a Multi-Scale Geographically Weighted Regression (MGWR) method using data from 43 Chinese ports between 2010 and 2022 to examine the spatial impacts of macroeconomic, infrastructural, and logistical variables on container port volumes. The results reveal that port performance is strongly affected by regional differences, and in areas with high economic concentration, infrastructure investments have a more pronounced effect on container volumes. The study emphasizes that spatial models accounting for regional heterogeneity yield more explanatory results than traditional time-series analyses in port planning.

Ji (2025) evaluates the impact of Liner Shipping Connectivity Index (LSCI) on performance using global port data from 2010–2023. Employing panel regression and sensitivity analyses, the findings confirm that LSCI has positive and statistically significant effects on container volume, port efficiency, and regional trade volume. Notably, ports in the Mediterranean and Southeast Asia with higher connectivity gain regional competitive advantages through increased transshipment shares. The study underscores LSCI as not only a performance indicator but also a strategic policy metric representing network density and modal diversity in maritime trade.

Liu et al. (2025) analyze the relationships between maritime connectivity, infrastructure quality, and maritime trade in ASEAN countries using a panel threshold ARDL model with data from 2000–2022. The findings indicate that the impact of connectivity on economic growth varies depending on infrastructure quality. In countries with high infrastructure quality, maritime connectivity significantly boosts economic growth, whereas the effect is weaker in low-quality infrastructure settings. Moreover, increases in trade volume indirectly enhance port efficiency, particularly in export-oriented ports.

Tehci et al. (2025) apply panel data regression using data from 2004–2022 for 18 container and cargo ports in Turkey. The study examines the effects of port outputs (TEU + tonnage) on exports, industrial production, and GDP. The results show that cargo volumes handled at ports significantly boost exports and industrial output, thereby contributing to provincial GDP growth.

Yalnız et al. (2025) develop the Ship Inspection Competition Index (SICI) to examine the effects of inspection processes on competition in maritime transport. Analyzing 7,557 inspections conducted under the Paris MoU between 2019–2024, the study uses ARIMA models to generate quarterly forecasts for 2025. The findings indicate that younger tankers (0–5 and 5–10 years) operate under more favorable and competitive conditions due to lower SICI scores, whereas older tankers face competitive disadvantages. Forecasts suggest this trend will persist in 2025. The study contributes methodologically to the literature by combining inspection-based competition analysis with time series forecasting, offering practical insights for fleet management and strategic decision-making.

The literature reviewed above reveals that container port performance is closely associated with macroeconomic indicators, connectivity levels, infrastructure capacity, and regional development factors. However, most existing studies either focus on specific countries or ports (e.g., China, Korea, or European ports) or rely on time series models for short-term forecasts. At the scale of the Mediterranean basin, particularly in terms of evaluating major ports across different countries within a unified panel structure and jointly analyzing economic and logistical determinants, studies remain scarce. Furthermore, regional comparative analyses including Turkish ports are often limited to technical efficiency or productivity dimensions and fail to comprehensively test the interaction between container volume and economic or connectivity dynamics. This study fills this gap by analyzing the factors that determine container handling volumes at major ports in the Mediterranean corridor over the 2005–2024 period through panel data analysis. In doing so, it proposes a novel empirical framework for understanding macroeconomic growth–connectivity interactions and regional port competition. Thus, the study offers an original contribution to the literature on Mediterranean ports, both in terms of regional comparative analysis and data-driven policy recommendations.

3. DATA SET

In the present study, various economic and structural variables are employed to analyze the factors affecting the container handling volumes of ports. The dependent variable is the annual container handling volume (TEU), while the explanatory variables include GDP per capita, the Liner Shipping Connectivity Index (LSCI), and trade balance. Additionally, the effects of major crisis periods such as the 2008 global financial crisis, the European debt crisis, and the COVID-19 pandemic are incorporated into the model through the use of dummy variables.

Table 1 provides detailed definitions of the variables used in the analysis, their expected effects, and data sources.

Table 1. Information on the Data Set

Variable	Definition	Source
TEU	Annual container throughput (ln_teu) - Dependent variable	UNCTAD / Port statistics
GDP	GDP per capita (ln_gdp) - Logarithmic form	World Bank
Population	Population (ln_pop) - Logarithmic form	World Bank
LSCI	Liner Shipping Connectivity Index (ln_lsci) - Maritime transport connectivity index	UNCTAD
Trade Balance	Trade balance (exports - imports)	IMF / World Bank
Crisis 2008	Dummy variable: 2008 global financial crisis period	Created by author(s)
Euro Crisis	Dummy variable: 2010-2012 European debt crisis	Created by author(s)

COVID-19	Dummy variable: 2020 COVID-19 pandemic	Created by author(s)
Post Covid	Dummy variable: Post COVID-19 period	Created by author(s)

In this study, a panel data regression model is employed to identify the factors affecting the container handling volumes of Mediterranean ports. The model accounts for port-specific fixed effects and analyzes the impacts of macroeconomic indicators, maritime connectivity, and global crisis periods on port performance. The estimated model is presented in Equation (1):

$$\ln TEU_{it} = \alpha_i + \beta_1 \ln GDP_{it} + \beta_2 \ln POP_{it} + \beta_3 LSCI_{it} + \beta_4 TD_{it} + \beta_5 Crisis\_2008_{it} + \beta_6 Euro\_Crisis_{it} + \beta_7 Covid\_19_{it} + \varepsilon_{it} \quad (1)$$

In the model, the natural logarithm of container handling volume (lnTEU) is used as the dependent variable. The explanatory variables include the logarithm of GDP per capita of the country in which the port is located (lnGDP), the logarithm of population (lnPOP), the Liner Shipping Connectivity Index (LSCI), and the trade balance (TD). The trade balance (TD = exports − imports) reflects whether a port is oriented more toward exports or imports. The logarithmic transformation allows for elasticity-based interpretation and helps mitigate the influence of outliers. LSCI is an index developed by UNCTAD that measures the degree of integration of ports into global maritime transport networks. The trade balance represents the difference between exports and imports (in billion $). The model also includes dummy variables representing the 2008–2009 global financial crisis ($Crisis_2008_{it}$), the 2010–2012 European debt crisis ($Euro_crisis_{it}$), the 2020 COVID-19 pandemic ($Covid_19_{it}$), and the post-pandemic period (post_covid). The α term denotes port-specific fixed effects, controlling for time-invariant characteristics such as the geographic location, infrastructure capacity, and operational efficiency of each port. ε_{it} represents the error term.

4. METHODOLOGY

Panel data analysis is an econometric method used to analyze time series data that provides repeated measurements of certain variables across cross-sectional units such as households, firms, cities, or countries (Yaffee, 2003: 1). It introduces both spatial and temporal dimensions to regression analysis. The spatial dimension comprises cross-sectional units such as countries, states, districts, firms, products, social groups, or individuals, while the temporal dimension consists of periodic observations of variables representing these units over a specified time period (Yaffee, 2003: 1–2).

Panel data analysis refers to the econometric examination of data structures obtained by observing the same units repeatedly over time. The first comprehensive study that established the theoretical and methodological foundations of panel data analysis was conducted by Baltagi (1995). In his work, Baltagi systematically addressed the theoretical framework, estimation techniques, and econometric applications of panel data models, particularly focusing on fixed effects and random effects models,

dynamic panel data models, and the error components approach.

Compared to conventional cross-sectional or time-series data, panel data structures offer several important advantages. First, panel data allows for the analysis of a larger number of observations, increasing degrees of freedom and enhancing estimation efficiency. Second, multicollinearity among explanatory variables is reduced, thereby improving the reliability of parameter estimates. Third, due to the longitudinal structure of panel data, which contains more information and variability than traditional time series, it enables the testing of a wider range of economic hypotheses (Hsiao, 2003). Fourth, it allows for the control of unobservable unit-specific heterogeneity—such as ports' geographic location or infrastructure capacity—which does not vary over time. Like a classical regression model, a panel data model consists of a dependent variable and various independent variables. Since it is a statistical model, it includes an error term. However, unlike classical regression, panel data models allow variables to vary across both units and time (Güriş, 2018: 6). If the units are denoted by *i*, time by *t*, Y as the dependent variable, and X as the independent variable, then the panel regression model can be expressed as in Equation (2) (Güriş, 2018: 7):

$$Y_{it} = \alpha_{it} + \beta_{2it} X_{2it} + \beta_{kit} X_{kit} + \varepsilon_{it} \quad (2)$$

In panel data analysis, two primary methods are generally employed (Nerlove, 2000: 5). The first is the fixed effects model, which accounts for and estimates the fixed effects across units. The second is the random effects model, which assumes that the differences between units are random and attempts to estimate the impact of such effects. The fixed effects model is more suitable for analyzing experimental data, while the random effects model is typically used for observational data. In the random effects model, it is assumed that all effects have a zero mean and that some fixed effects, such as a general mean, are present.

4.1. Cross-Sectional Dependence and Unit Root Analysis

Before conducting estimations in panel data analyses, it is necessary to test for cross-sectional dependence (correlation among units) and the stationarity of the series, as these are critical determinants for the model. The tests applied to detect cross-sectional dependence and unit-specific correlation are referred to as Cross-Sectional Dependence (CD) tests (Pesaran, 2004). The CD test evaluates whether there is correlation across cross-sectional units. The main CD tests used in panel data analysis include the Frees (1995), Pesaran (2004), and Friedman (1937) tests. Pesaran's CD test formula is presented in Equation (3) (Pesaran, 2004, 2021: 5, 19):

$$CD = \sqrt{2T/(N(N-1)}\left[\sum_{i=1}^{N-1}\sum_{j=i+1}^{N} \hat{\rho}ij\right] \quad (3)$$

In the CD equation, the limit is taken as N→∞.

In conducting panel data analysis, unit root tests must be performed as the second step. The importance of unit root tests arises from the need to determine whether the series are stationary over time, given that the time dimension is also taken into account in panel data analysis. Following the implementation of the CD tests, if no cross-sectional dependence is detected among the variables, first-generation unit root tests are applied; however, if cross-sectional dependence is present, second-generation unit root tests are employed.

In this study, in order to test whether the series contain unit roots and whether they are stationary, the Cross-sectionally Augmented IPS Test (CIPS), which is one of the second-generation unit root tests and which is used in the presence of cross-sectional dependence in panel models as proposed by Pesaran (2007), is employed. The CIPS test is expressed by the formula given in Equation 4 (Pesaran, 2007: 271–272).

$$CIPS = 1/N \sum_{i=1}^{N} t_i^{CADF}(N, T) \quad (4)$$

In Equation 4, NNN represents the total number of cross-sectional units in the panel, such as countries or firms, whereas t_i^{CADF} denotes the Cross-sectionally Augmented Dickey–Fuller (CADF) test statistic corresponding to each cross-sectional unit t_i.

4.2. Model Selection and Diagnostic Tests for Deviations from Assumptions

In order to determine the appropriate estimation method between the Fixed Effects (FE) and Random Effects (RE) models, the Hausman (1978) test is employed. The test statistic is defined as follows:

$$H = (\hat{\beta}_{RE} - \hat{\beta}_{FE})' [Var(\hat{\beta}_{RE}) - Var(\hat{\beta}_{FE})]^{(-1)} (\hat{\beta}_{RE} - \hat{\beta}_{FE}) \quad (5)$$

Hypotheses:

H_0: The random effects model is appropriate.

H_1: The fixed effects model is appropriate.

When $p < 0.05$, the fixed effects model is preferred.

The Modified Wald test is applied to examine whether the variance of the panel error terms is constant.

H_0: $\sigma_i^2 = \sigma^2$ In this case, the Wald statistic is expressed as follows:

N

$$W = \sum_{i=1} (\hat{\sigma}i^2 - \hat{\sigma}^2)^2/Vi \quad (6)$$

In addition, the presence of autocorrelation is tested using the Baltagi–Wu (LBI) and Durbin–Watson (DW) tests. The Durbin–Watson test statistic is given in Equation 7 (Baltagi, 2008: 95–96):

$$DW_p = \frac{\sum_{i=1}^{N}\sum_{t=2}^{T}(e_{it} - e_{i,t-1})^2}{\sum_{i=1}^{N}\sum_{t=2}^{T} e_{it}^2} \quad (7)$$

Here, e_{it} denotes the error term of the i-th cross-sectional unit in period t, whereas N represents the total number of units in the panel and T denotes the number of time periods for each unit. In the equation, the numerator corresponds to the sum of the squared differences between the error terms of consecutive periods, while the denominator represents the sum of the squared error terms. This ratio is used to test whether there exists first-order autocorrelation ($\rho \neq 0$) among the error terms. If;

If DWp ≈ 2 → no autocorrelation

If DWp < 2 → positive autocorrelation

If DWp > 2 → negative autocorrelation

The Baltagi–Wu LBI is known as the locally best invariant test and can also be used in unbalanced panels. The LBI test possesses the steepest power curve under the null hypothesis and has optimal power among invariant tests at the same significance level (Baltagi and Wu, 1999: 819). The LBI test can also be employed in models that contain AR (1) processes and exhibit serial correlation when estimating unequally spaced panel data models. According to the null hypothesis of the test, H_0: p = 0 (there is no autocorrelation), while the alternative hypothesis is H_1:|p| <1 (Baltagi and Wu, 1999: 819).

When conducting panel data analysis, it is also necessary to check whether multicollinearity is present in the model. For this purpose, the Variance Inflation Factor (VIF) test is frequently used. The variance inflation factor is calculated based on the R^2 values obtained from regression models in which each independent variable in the model is treated as the dependent variable, and the remaining variables are used as independent variables. The computation of the VIF is given as follows (Tatoğlu, 2021: 275):

$$VIF_i = 1/(1 - R_i^2) \quad (8)$$

In Equation 8, *i* denotes the auxiliary variables; the variance inflation factor (VIF) is interpreted as follows: "If the VIF value is less than 5, there is no multicollinearity; if the VIF value lies between 5 and 10, moderate multicollinearity is present; and finally, if the VIF value exceeds 10, multicollinearity is considered severe."

If the tests indicate the presence of autocorrelation, cross-sectional dependence, or heteroskedasticity, a new model should be constructed by incorporating the lagged values of all variables in the existing model to address these issues. In panel data models, when at least one of the problems—heteroskedasticity, autocorrelation, multicollinearity, or cross-sectional dependence—is present, estimation cannot be reliably performed using conventional methods. In such cases, robust estimation techniques or corrected standard errors must be employed to resolve these problems and obtain efficient estimates. Among these methods are stepwise (sequential) models. Depending on the type of issue encountered, techniques such as the robust least squares estimator, robust pooled least squares estimator, or feasible generalized least squares (FGLS) estimator may be applied.

One of the methods used to address such issues is the (FGLS) estimator, also known as the "extended least squares estimator—unit-specific Autoregressive Process (AR) (1) correlation" method (Tatoğlu, 2021: 340). The development of the FGLS panel data model began with Aitken's (1936) seminal work "On Least Squares and Linear Combinations of Observations," which laid the foundations of the Generalized Least Squares (GLS) approach. The systematic advancement of the FGLS methodology was subsequently undertaken by Parks (1967). Following these developments, the method was further refined and popularized through Kmenta's (1986) influential book *Elements of Econometrics*. Additionally, the study by Beck and Katz (1995) provided significant contributions to empirical applications in this field. The FGLS method is an important econometric approach that yields efficient estimates in the presence of heteroskedasticity and autocorrelation within panel data analysis (Parks, 1967: 500). By taking into account the variance–covariance structure of the error terms, the method produces more efficient estimates relative to OLS and has the flexibility to accommodate both balanced and unbalanced panel datasets (Beck & Katz, 1995: 634). Moreover, several practical conditions accompany its implementation, such as the requirement that the time dimension exceed the cross-sectional dimension (T>N) and the need for prior knowledge regarding the structure of the error terms (Kmenta, 1986: 619).

If autocorrelation is present, the residuals must be computed for the first-order autocorrelation AR (1) coefficient, and the model must be re-specified accordingly. On the other hand, because this method allows variation only across cross-sectional units, the variance is assumed to be constant, whereas the covariances are not equal to zero (Tatoğlu, 2021: 343–344). Panel FGLS is represented as

follows (Beck & Katz, 1995: 638):

$$\hat{\beta} = (X'\Omega^{-1}X)^{-1}X'\Omega^{-1} \quad (9)$$

In Equation 9, β̂ denotes the FGLS estimator, X represents the matrix of independent variables, and Ω denotes the variance–covariance matrix of the error terms. When the variance–covariance matrix of the error terms is unknown, the FGLS procedure first estimates this matrix and subsequently performs the Generalized Least Squares (GLS) transformation.

4.3. Stochastic Frontier Analysis

Stochastic Frontier Analysis (SFA) is a parametric method that statistically estimates the production frontier in order to measure the technical efficiency levels of production units. This approach assumes that the observed output contains deviations not only arising from random shocks but also from technical inefficiency, and therefore decomposes the error term into two components (Aigner et al., 1977, p. 22). The basic model of SFA is expressed as follows:

$$y_{(it)} = f(x_{(it)}, \beta) + v_{(it)} - u_{(it)} \quad (10)$$

The term $v_{(it)}$ represents the random error component and is distributed as $v_{it} \sim N(0, \sigma\_v^2)$, whereas u_{it} denotes the technical inefficiency component and follows the distribution $u_{it} \sim |N(0, \sigma\_u^2)|$. Technical efficiency is defined as $TE_{(it)} = \exp(-u_{(it)})$. The $u_{(it)}$ values obtained from the SFA model indicate the level of technical inefficiency for each port; as these values increase, the port is understood to deviate further from the frontier efficiency level. The TE coefficient derived from these inefficiency terms reflects the technical efficiency level for the corresponding period. A TE value approaching 1 implies that the port operates very close to the frontier efficiency, whereas a value approaching 0 indicates notable efficiency losses. Therefore, TE scores allow for the direct interpretation of relative technical performance differences among ports and enable the identification of which ports hold operational advantages or disadvantages.

5. RESULTS

The findings of the study were obtained through a two-stage analytical approach. In the first stage, a panel data model was estimated to analyze the economic and logistical factors determining container volumes at ports along the Mediterranean corridor. Using the fixed effects approach and the FGLS estimator—which corrects for heteroskedasticity and autocorrelation—the effects of per capita GDP, population, maritime connectivity (LSCI), trade balance, and crisis periods on TEU volumes were identified. In the second stage, independent of the panel model, the relative technical performance of the ports was evaluated through Stochastic Frontier Analysis (SFA) and the Fixed Effects model. This separation enabled the distinction between volume changes arising from economic determinants and

differences in operational efficiency across ports. The two-stage approach thus provides a comprehensive assessment of both the macro-determinants shaping TEU volumes and the technical efficiency levels of the ports.

5.1. Empirical Findings of the Panel Data Model

In this section, the empirical results obtained from the panel data analysis of container ports located along the Mediterranean corridor for the period 2005–2024 are presented. Before discussing the findings, the tests and analytical procedures forming the basis of the model estimation are briefly summarized. First, the cross-sectional dependence and stationarity properties of the series were examined using the Pesaran (2004) CD test and the second-generation unit root test (CIPS). Subsequently, the presence of heteroskedasticity and autocorrelation within the model was assessed through the Modified Wald and Durbin–Watson tests. In line with the results obtained, the Feasible Generalized Least Squares (FGLS) estimator—which accounts for the effects of heteroskedasticity and autocorrelation—was selected as the appropriate estimation method.

Within this framework, the logarithmic form of container handling volume was employed as the dependent variable, while the explanatory variables included GDP per capita, the Liner Shipping Connectivity Index, trade balance, and dummy variables representing crisis periods. The diagnostic tests for the panel data analysis are presented in this section. The analytical procedure begins with the evaluation of the fundamental assumptions of the model. Specifically, the distributional properties of the error terms were examined, and the validity of the normality assumption was tested. The results of the skewness and kurtosis tests conducted for this purpose are reported in Tables 2 and 3.

Table 2. Normality Test Results (Skewness and Kurtosis)

Test Statistic	Observed Coefficient	Bootstrap Std. Error	z	P>|z|	95% Confidence Interval
Skewness (e)	-0.0206	0.0152	-1.36	0.175	[-0.0503, 0.0091]
Kurtosis (e)	0.0205	0.0122	1.68	0.092	[-0.0034, 0.0445]
Skewness (u)	-0.1612	0.1176	-1.37	0.171	[-0.3917, 0.0693]
Kurtosis (u)	-0.0164	0.1280	-0.13	0.898	[-0.2673, 0.2345]

Notes: Number of obs = 260, Replications = 50 *(Replications based on 20 clusters in time)*

Table 3. Normality Test Results (Error Term and Unit Effects)

Test	chi2(2)	P > chi2
Normality for the Error Term (e)	4.68	0.0966
Normality for the Unit Effect (u)	1.89	0.3878

According to the normality tests conducted on the residuals of the panel data model and the unit effects using the bootstrap method (50 replications, 20 time clusters), the results indicate the following: As shown in Table 2, the skewness coefficient for the error term (e) is −0.0206 (p = 0.175), while the kurtosis coefficient is 0.0205 (p = 0.092). For the unit effects (u), skewness is measured as −0.1612 (p = 0.171) and kurtosis as −0.0164 (p = 0.898). All test statistics are statistically insignificant at the 5% significance level, indicating that neither the error terms nor the unit effects exhibit any meaningful deviation from the normal distribution. The joint normality tests presented in Table 3 support these findings. The joint normality test for the error term yields $\chi^2(2) = 4.68$ (p = 0.0966), while for the unit effects it yields $\chi^2(2) = 1.89$ (p = 0.3878). Both results indicate that the null hypothesis of normality cannot be rejected at the 5% significance level. These outcomes show that the error structure of the estimated panel data model satisfies the normality assumption, thereby confirming the reliability of the model estimates.

The Likelihood Ratio (LR) tests conducted to determine the structure of the panel data further confirm the presence of unit effects ($\text{chibar}^2(01) = 361.67$, $p < 0.001$). Conversely, the time effect is found to be statistically insignificant ($\text{chibar}^2(01) = 0.00$, p = 1.000). These findings imply that cross-sectional heterogeneity across ports must be controlled for within the model, whereas common shocks across years can be modeled through dummy variables (crisis_2008, euro_crisis, covid_2020) rather than through time fixed effects.

To select an appropriate unit root test in panel data analysis, the existence of cross-sectional dependence was first examined using the Pesaran (2004) Cross-sectional Dependence (CD) test. The test results indicate strong cross-sectional dependence across all variables (lnteu: CD = 42.36, p <0.001; lnimp: CD = 47.17, p <0.001; lnexp: CD = 47.58, p <0.001; lnpop: CD = 47.58, p <0.001; lsci: CD = 44.31, p <0.001; lngdp: CD = 47.43, p <0.001). The high correlation coefficients confirm that ports along the Mediterranean corridor are exposed to common shocks—such as the 2008 global financial crisis, the European sovereign debt crisis, and the COVID-19 pandemic—and share similar trade routes. These findings demonstrate that first-generation panel unit root tests assuming cross-sectional independence (LLC, IPS, Fisher-ADF) may lead to misleading inference. Therefore, the stationarity analysis was conducted using second-generation unit root tests that explicitly account for cross-sectional dependence, namely the Cross-sectionally Augmented IPS (CIPS) test.

Table 4. Panel Unit Root Test Results (CIPS)

Variable	CIPS Statistic	Critical Value (10%)	Critical Value (5%)	Critical Value (1%)
lnteu	-3.961***	-2.65	-2.77	-3.00
lnimp	-4.105***	-2.65	-2.77	-3.00
lnexp	-3.639***	-2.11	-2.22	-2.45
lsci	-3.461***	-2.11	-2.22	-2.45
lngdp	-2.866***	-2.11	-2.22	-2.45
Dlnpop	-2.646***	-2.11	-2.22	-2.45

Dtd	-2.333***	-2.11	-2.22	-2.45

Notes: CIPS = *Cross-sectionally Augmented IPS test* (Pesaran, 2007). H_0: *Homogeneous non-stationarity (unit root is present).* KD = *Critical values.* *** denotes rejection of the null hypothesis at the 1% significance level. The maximum lag length was set to 1, and the Bartlett Kernel bandwidth (BG lag) was also selected as 1.

After identifying the presence of cross-sectional dependence, the stationarity properties of the variables were examined using the CIPS (Cross-sectionally Augmented IPS) panel unit root test developed by Pesaran (2007). The CIPS test is a second-generation procedure that yields reliable results when units within the panel are influenced by common factors, thereby explicitly accounting for cross-sectional dependence. The test is based on individual Augmented Dickey–Fuller (ADF) regressions that are augmented with the cross-sectional averages of both the levels and first differences of the series. The maximum lag length was set to 1, and the optimal lag structure was selected using the general-to-specific approach based on F-tests. The results presented in Table 4 indicate that the variables lnteu (–3.961), lnimp (–4.105), lnexp (–3.639), lsci (–3.461), and lngdp (–2.866) are stationary at their levels at the 1 percent significance level. In contrast, the population (lnpop) and technological development (td) variables become stationary after first differencing (Dlnpop: –2.646; Dtd: –2.333).

Observed differences in the stationarity properties of the variables necessitate the use of appropriate transformations in the panel data model and require the investigation of long–run relationships through cointegration analysis. The existence of a long–run relationship among the variables was examined using the Pedroni (2004) cointegration test. The test results indicate that the null hypothesis of no cointegration is strongly rejected based on the Modified Phillips–Perron t-statistic, which is calculated as 4.9983 ($p < 0.001$). Therefore, it is concluded that a long–run equilibrium relationship exists between container throughput (lnteu) and the explanatory variables (trade balance, population, gross domestic product, and the logistics performance index). The identification of cointegration implies that the variables can be used in their level forms and that the model is not subject to the problem of spurious regression.

The presence of multicollinearity in the model was examined using the Variance Inflation Factor (VIF). The results show that the VIF values for all explanatory variables remain well below the critical threshold of 10 (VIF = 1.36). This finding indicates that there is no serious multicollinearity problem among the independent variables and that the estimated coefficients are reliable. To determine the appropriate specification between the fixed effects (FE) and random effects (RE) models, the Hausman (1978) test was conducted. The test results reveal systematic differences between the FE and RE estimators ($\chi^2(3) = 11.50$, $p < 0.001$). This outcome indicates that the individual effects are correlated with the explanatory variables and that the fixed effects model is the appropriate estimator. Structural differences across Mediterranean ports—such as hub versus gateway status, infrastructure capacity, and hinterland connectivity—are controlled for through the fixed effects structure.

Table 5. Diagnostic Test Results

Test	Statistic	p-value	Decision	Interpretation
Heteroscedasticity (Modified Wald)	chi2(20) = 4.71	0.9998	Accept H_0	No heteroskedasticity
Cross-sectional Dependence (Pesaran)	t = 41.804	0.0000***	Reject H_0	Cross-sectional Dependence exists
Cross-sectional Dependence (Friedman)	chi2 = 186.808	0.0000***	Reject H_0	Cross-sectional Dependence exists
Cross-sectional Dependence (Frees)	Q = 12.670	KD = 0.2838***	Reject H_0	Cross-sectional Dependence exists
Autocorrelation (Wooldridge)	F(1,19) = 38.810	0.0000***	Reject H_0	First-order autocorrelation exists
Autocorrelation (Durbin-Watson)	DW = 1.796	-	-	Positive autocorrelation detected
Autocorrelation (Baltagi-Wu LBI)	LBI = 1.916	-	-	Positive autocorrelation detected
Multicollinearity (Mean VIF)	VIF = 1.36	-	Accept H_0	No multicollinearity problem

Notes: *** denotes significance at the 1% level. KD = Critical Value. H_0 = Null hypothesis. DW = Durbin–Watson statistic. LBI = Baltagi–Wu Locally Best Invariant statistic.

The validity of the fundamental assumptions of the panel data model was examined through a series of diagnostic tests. The Modified Wald test results (chi2(20) = 4.71, p = 0.9998) indicate that there is no heteroskedasticity across panels, suggesting that the variance of the error terms is homogeneous for all units. The Pesaran test (t = 41.804, p < 0.001), Friedman test (chi2 = 186.808, p < 0.001), and Frees test (Q = 12.670) reveal strong cross-sectional dependence among the panels. This dependence may originate from the fact that ports along the Mediterranean corridor are exposed to common shocks (such as global crises and the pandemic) and share similar trade routes. The Wooldridge test (F (1,19) = 38.810, p <0.001), together with the Durbin–Watson statistic (1.796) and the Baltagi–Wu LBI statistic (1.916), demonstrates the presence of first-order positive autocorrelation in the error terms. This finding indicates that changes in port capacity exhibit persistence over time. The mean VIF value, calculated as 1.36, confirms the absence of multicollinearity among the explanatory variables.

As previously discussed, the results of the Hausman (1978) test indicate systematic differences between the fixed effects (FE) and random effects (RE) estimators (χ^2 (3) = 32.12, p <0.001). This finding confirms that the individual effects are correlated with the explanatory variables and that the fixed effects specification is the appropriate modeling choice. However, the presence of heteroskedasticity, cross-sectional dependence, and autocorrelation—identified through the diagnostic tests—implies that the standard fixed effects estimator would be inefficient and yield unreliable inference. In light of these findings, the Feasible Generalized Least Squares (FGLS) estimator, which

corrects for cross-sectional dependence and serial correlation, was selected as the appropriate estimation technique and adopted as the final model. The model was estimated allowing for cross-sectional correlation across panels (panels(corr)) and a common AR (1) autocorrelation structure for all units (corr(ar1)). In the analysis, container capacity (lnteu) is used as the dependent variable. The FGLS model accounts for cross-sectional correlation and heteroskedasticity across panels and is estimated under a panel-specific AR (1) autocorrelation structure. A separate AR (1) coefficient (rho) is estimated for each of the 12 panels, with the average rho value approximating 0.10, derived from the Durbin–Watson statistic (1.796) and the Baltagi–Wu LBI statistic (1.916). The analysis is conducted using a total of 240 observations, covering 12 groups over 20 time periods. Table 6 presents the FGLS estimation results.

Table 6. Panel FGLS Regression Results

Variable	Coefficient	Std. Error	z	P>|z|	95% Confident Interval
lnpop	-0.3328***	0.0369	-9.03	0.000	[-0.4050,0.2606]
lsci	0.0008***	0.0001	5.94	0.000	[0.0005, 0.0010]
lngdp	0.0612***	0.0163	3.77	0.000	[0.0294, 0.0931]
td	5.86e-07***	1.60e-07	3.65	0.000	[2.72e-07, 9.01e-07]
crisis_2008	-0.1342***	0.0251	-5.35	0.000	[-0.1833, 0.0850]
euro_crisis	-0.0180	0.0252	-0.72	0.474	[-0.0673, 0.0313]
covid_2020	0.1080***	0.0288	3.75	0.000	[0.0516, 0.1643]
post_covid	0.2059***	0.0363	5.67	0.000	[0.1347, 0.2771]
Constant Term	19.4117***	0.7522	25.81	0.000	[17.9375,20.8860]
Number of Observations	260				
Number of Groups	12				
Time Periods	20				
Wald chi2(8)	484.46				
Prob > chi2	0.0000				

Notes: *** significant at 1%, ** significant at 5%, * significant at 10%. lnpop = population (log), lsci = liner shipping connectivity index (log), lngdp = gross domestic product (log), td = trade balance. Dummy variables: crisis_2008 (global financial crisis), euro_crisis (European sovereign debt crisis), covid_2020 (COVID-19), post_covid (post-COVID-19 period).

The FGLS regression results reveal statistically significant relationships between container handling volumes and their determinants across 12 major Mediterranean ports over the 2005–2024 period. The overall model statistics indicate that the specification is highly significant as a whole. Based on the model estimation, the following results are obtained:

1. Population (lnpop): A 1% increase in population leads to a 0.33% decrease in port container capacity. In highly populated regions, land scarcity and urban pressure may restrict port expansion projects.

2. Liner Shipping Connectivity Index (lsci): A 1% improvement in the connectivity index results in a 0.08% increase in container handling volume. Higher levels of connectivity—through increased service frequency, ship calls, and route diversity—stimulate port capacity expansion and strengthen operational performance.

3. Gross Domestic Product (lngdp): A 1% increase in GDP per capita results in a 0.06% increase in port capacity. Economic growth positively influences trade volume and, consequently, port investment and operational expansion. When the population variable is excluded from the model, the effect of GDP on port capacity rises from 0.0612 to 0.1698. This inflation in the coefficient stems from the strong correlation between population and GDP. In models without population, the GDP coefficient captures both the effect of economic growth and the underlying population effect. Once population is included, the "true" impact of GDP is isolated, and the negative effect of population (–0.3328) is separated. Moreover, because high-GDP regions are typically also densely populated, omitting population leads GDP to reflect an overstated influence. When population is controlled for, a 1% increase in GDP raises port capacity by only 0.06%, whereas a 1% increase in population reduces capacity by 0.33%. This indicates that land constraints and urban pressure limit the potential for port expansion in densely populated areas.

4. Trade Balance (td): A one-unit increase in the trade balance (net exports) leads to a 5.86e–07 increase in port capacity. Ports with stronger export orientation demonstrate a greater tendency toward capacity expansion.

5. Global Financial Crisis of 2008 (crisis_2008): During the 2008 crisis period, container capacity at ports decreased by approximately 13.4%. The contraction in global trade volumes and the suspension of investment projects hindered capacity expansion across Mediterranean ports.

6. European Sovereign Debt Crisis (euro_crisis): The European sovereign debt crisis does not exhibit a statistically significant effect on port capacity. The regional impact of the crisis appears to have been limited, and Mediterranean ports continued their capacity investment activities during this period.

7. COVID-19 Period (covid_2020): The pandemic period led to a 10.8% increase in port capacity. The surge in e-commerce and the sudden rise in container demand likely intensified the need for capacity expansion.

8. Post-COVID Period (post_covid): In the post-pandemic period, port capacity increased by 20.6%. The restructuring of global supply chains and the recovery of international trade accelerated capacity investment across Mediterranean ports.

Constant Term (_cons): The constant term is estimated at 19.41 ($p < 0.001$), representing the expected level of port container capacity when all explanatory variables are equal to zero.

5.2. Efficiency Analysis of Ports Using Stochastic Frontier Analysis and Fixed Effects Models

In this section, two complementary approaches are employed to assess the container-handling performance of Mediterranean ports in terms of both efficiency levels and structural determinants. First, the Stochastic Frontier Analysis (SFA) measures the relative technical efficiency of ports with respect to the maximum attainable production frontier given their existing resources, thereby identifying ports operating close to the efficiency frontier versus those experiencing efficiency losses. Second, the Fixed Effects (FE) model isolates the effects of key macroeconomic and operational variables that determine TEU volumes, making it possible to reveal each port's inherent structural advantages or disadvantages through the estimated fixed-effect coefficients. The combined use of these two analytical frameworks enables a comprehensive assessment of port performance by jointly examining technical efficiency and the economic, demographic, and logistical factors shaping container throughput.

The fixed effects model estimates the port-specific constant term for each unit in the panel, capturing unobserved heterogeneity across ports. These fixed effects reflect structural differences that cannot be explained by the observed independent variables (such as vessel calls, berth length, or equipment capacity). A positive fixed-effect value indicates that the corresponding port performs above the level predicted by the model, whereas a negative value suggests performance below the expected output. Such differences typically arise from unobserved characteristics including strategic geographic location, infrastructure quality, government policies, or natural maritime advantages.

The Stochastic Frontier Analysis (SFA), in contrast, measures the technical efficiency of ports on a scale from 0 to 1. Values closer to 1 indicate that a port is utilizing its available inputs (berths, equipment, labor) with near-optimal efficiency relative to the estimated production frontier; lower values reveal that the port has the potential to generate higher output with the same input mix. SFA decomposes deviations from the frontier into stochastic noise and technical inefficiency, thereby enabling the identification of areas where operational improvements may be needed.

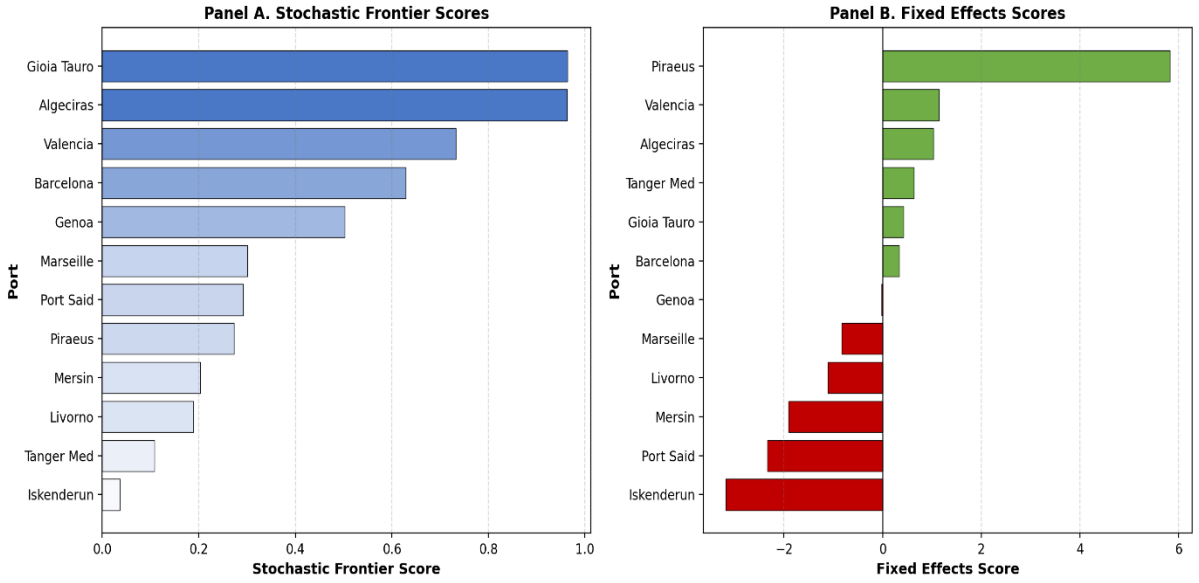
Table 7. Comparison of Efficiency Measures: Stochastic Frontier Analysis and Fixed Effects Model

Port	Fixed Effects Score	Fixed Effects Ranking	Stochastic Frontier Score	Stochastic Frontier Ranking
Algeciras	1.033	3	0.9629	2
Barcelona	0.340	6	0.6285	4
Genoa	-0.025	7	0.5025	5
Gioia Tauro	0.420	5	0.9643	1

Livorno	-1.113	9	0.1891	10
Marseille	-0.825	8	0.3005	6
Mersin	-1.908	10	0.2031	9
Piraeus	5.818	1	0.2728	8
Port Said	-2.337	11	0.2920	7
Tanger Med	0.634	4	0.1084	11
Valencia	1.144	2	0.7328	3
İskenderun	-3.180	12	0.0366	12

Note: The Fixed Effects (FE) model measures strategic advantage, while the Stochastic Frontier Analysis (SFA) measures operational efficiency. Ranking: 1 = best performance.

Figure 1. SFA and Fixed Effects Efficiency Scores



According to the fixed effects model results presented in Table 7 and Figure 1, substantial heterogeneity exists among Mediterranean ports. The Port of Piraeus exhibits the highest fixed effect score (+5.82), indicating a performance level that exceeds the model's predicted capacity and reflecting port-specific advantages unexplained by the included variables. Valencia (+1.14), Algeciras (+1.03), Tanger Med (+0.63), Gioia Tauro (+0.42), and Barcelona (+0.34) also display positive fixed effects, suggesting above-expected performance. Genoa (–0.02) appears nearly neutral. In contrast, Marseille (–0.83), Livorno (–1.11), Mersin (–1.91), Port Said (–2.34), and İskenderun (–3.18) present negative fixed effects, indicating that their observed capacity falls below the model's predicted values. These findings highlight the importance of port-specific characteristics—such as geographic location, infrastructure investment, and strategic positioning—in shaping capacity outcomes.

The Stochastic Frontier Analysis (SFA) results further complement these insights. Gioia Tauro ranks first with an efficiency score of 0.9643, demonstrating near-optimal efficiency in container

transshipment operations. Algeciras follows closely with a score of 0.9629, also reflecting high operational efficiency. Valencia (0.7328) ranks third, while Barcelona (0.6285) and Genoa (0.5025) show moderate efficiency levels. Marseille (0.3005), Port Said (0.2920), and Piraeus (0.2728) exhibit low efficiency scores, suggesting substantial room for operational improvement. Mersin ranks ninth with a score of 0.2031, and Livorno ranks tenth at 0.1891. Despite its strategic geographic position, Tanger Med falls to the eleventh rank with a score of 0.1084, indicating challenges related to operational experience or resource utilization. İskenderun ranks last with an efficiency score of 0.0366, indicating highly inefficient use of available inputs.

Because the two methods capture different analytical dimensions, notable discrepancies emerge between their results. The Port of Piraeus ranks first in the fixed effects model (+5.82), primarily due to its strategic advantages stemming from China's Belt and Road Initiative investments and its pivotal location along the Suez–Europe corridor (Liu & Davarinou, 2018). However, in the SFA model, Piraeus drops to the eighth position (0.27), which can be attributed to inefficiencies in its operational processes.

Conversely, the Port of Gioia Tauro exhibits the opposite pattern: it ranks first in the SFA model (0.96), indicating exceptionally high operational efficiency, yet only fifth in the fixed effects model. This contrast suggests that while Gioia Tauro may lack some of the structural or strategic advantages captured by the fixed effects model, it utilizes its operational resources with remarkable efficiency.

İskenderun Port ranks last in both models, with a fixed effects score of –3.18 and an SFA efficiency score of 0.04, indicating that it is both strategically disadvantaged and operationally inefficient.

In summary, the fixed effects model captures structural and strategic heterogeneity across ports, whereas the SFA model measures their operational efficiency. Using these two methods jointly enables a comprehensive assessment of both the strategic positioning and functional performance of ports. When combined with the FGLS estimation results, these three econometric approaches together provide a multidimensional and robust analytical framework for evaluating Mediterranean port performance.

6. CONCLUSION

Ports constitute one of the essential infrastructural components of the global trade system and have become key determinants shaping economic growth, the evolution of foreign trade, and the trajectory of regional development. Today, approximately 80% of world trade volume is transported by sea, making container ports a critical pillar of international logistics networks (www.unctad.org, 20.11.2025). Ports are not only logistical hubs that facilitate the movement of goods but also economic entities that generate employment, support industrial production, and contribute to regional competitiveness through their forward and backward linkages.

In this context, the Mediterranean Basin stands out as a strategic corridor located at the

intersection of major global trade routes. Connecting Europe, Asia, and Africa, the Mediterranean plays a decisive role in the continuity of global supply chains through the Suez Canal transits, energy and raw material flows, and major maritime routes.

Container ports in the Mediterranean region have transformed into competitive logistical centers at both regional and global scales, particularly over the past two decades, driven by increased trade volumes, industrialization trends, and connectivity-oriented infrastructure investments. However, the competitiveness of these ports is closely intertwined with processes of macroeconomic growth, the evolution of trade balances, and the operational efficiency of transport networks. Therefore, evaluating the performance of Mediterranean ports constitutes an important analytical basis for regional development strategies and trade policy formulation.

The present study investigates the economic and logistical determinants of container handling volumes at 12 major ports located along the Mediterranean corridor (Mersin, İskenderun, Piraeus, Valencia, Barcelona, Algeciras, Tanger-Med, Livorno, Gioia Tauro, Genoa, Marseille, and Port Said) using a balanced panel dataset covering the period 2005–2024. The analysis initially employed a fixed effects specification; however, the presence of heteroskedasticity, autocorrelation, and cross-sectional dependence necessitated the estimation of the model using the Feasible Generalized Least Squares (FGLS) approach. The empirical results clearly demonstrate that container throughput in Mediterranean ports is shaped primarily by population dynamics, trade balance, macroeconomic growth (GDP), and maritime connectivity (LSCI).

The econometric findings underscore the multidimensional nature of container capacity formation in the Mediterranean corridor. Results obtained through the FGLS estimator indicate that economic growth is among the strongest determinants of port capacity. A 1% increase in GDP per capita leads to a 0.06% rise in container throughput, suggesting a direct link between macroeconomic expansion and port infrastructure development. This outcome highlights that periods of economic growth tend to accelerate capacity enhancement efforts and that port development strategies must be aligned with national economic policies.

The Liner Shipping Connectivity Index emerges as a key driver of capacity expansion. A 1% improvement in the connectivity index increases container capacity by 0.08%. This result indicates that ports with a high level of integration into global maritime networks—such as Piraeus, Valencia, and Tanger-Med—continue to invest in capacity expansion, whereas ports with limited connectivity face competitive disadvantages. To strengthen the hub status of Mediterranean ports, policies promoting the establishment of new shipping services, increasing service frequency, and incentivizing transshipment activities are required.

The trade balance variable reveals that export-oriented ports tend to expand capacity more rapidly. Improvements in the trade balance positively affect port capacity. This finding shows that Mediterranean

ports require not only import-focused but also export-supporting logistical and infrastructural investments.

The negative effect of the population variable indicates that port expansion projects are constrained by land scarcity and urban pressure. A 1% increase in population leads to a 0.33% decrease in port capacity. In densely populated regions, the physical expansion of port areas becomes more difficult, making vertical capacity enhancement strategies (e.g., automation, high-stacking systems) increasingly necessary.

The effects of crisis periods on port capacity vary markedly. The 2008 global financial crisis caused a 13.4% decline in port capacity. The contraction in global trade volumes and the suspension of investment projects hindered capacity expansion during this period. By contrast, the European sovereign debt crisis did not produce a statistically significant effect, indicating that its regional impact remained limited. The COVID-19 pandemic and the post-pandemic period, however, generated positive effects: capacity increased by 10.8% during the pandemic and by 20.6% in the subsequent period. The surge in e-commerce, the sudden rise in container demand, and the restructuring of supply chains are likely the primary drivers of these increases.

In addition to the panel model findings, this study further assesses the functional efficiency of ports through Stochastic Frontier Analysis (SFA) and the fixed effects model. The efficiency scores reveal a pronounced divergence among ports along the Mediterranean corridor. The exceptionally high efficiency levels of Gioia Tauro and Algeciras indicate that these ports operate very close to their technical frontier with existing resources and thus enjoy a strong competitive advantage in the region. Intermediate-to-high levels of efficiency in ports such as Valencia and Barcelona are consistent with their robust hinterland connections and diversified network structures. Conversely, low efficiency scores in ports such as İskenderun, Tanger-Med, Livorno, and Mersin indicate that technical capacity is not being fully utilized and that operational constraints are limiting productivity.

The results of the fixed effects model corroborate this pattern: Piraeus, Valencia, Algeciras, and Gioia Tauro generate higher performance than predicted by the panel model, whereas Mersin, Port Said, Livorno, and İskenderun perform below expected levels. These findings suggest that competitive advantages within the Mediterranean are concentrated in a few strategic hubs, while other ports exhibit significant room for improvement in both technical efficiency and structural performance.

Therefore, future strategic planning should incorporate not only capacity expansion but also comprehensive policies aimed at operational efficiency enhancement, digitalization, strengthening connectivity, and improving hinterland integration.

The empirical findings demonstrate that the performance of Mediterranean ports is shaped not only by infrastructure investment but also by the interaction between economic growth, connectivity, and trade structure. In this context:

i. **Growth-oriented strategies** should strengthen hinterland connections and integrate port investments with industrial production. The positive effect of GDP growth on port capacity indicates that port infrastructure development must constitute an integral component of national economic development plans.

ii. **Connectivity-enhancing policies** should be supported through the allocation of new shipping services, higher service frequency, and incentives for transshipment activity. The strong influence of the Liner Shipping Connectivity Index highlights the necessity for Mediterranean ports to deepen their integration into global maritime networks.

iii. **Digitalization and automation investments** can increase operational efficiency and enhance port resilience during crisis periods. The land-use constraints resulting from population pressure may be mitigated through vertical capacity expansion and smart-port technologies.

iv. **Sustainable transport policies** should incorporate port electrification, energy-efficiency programs, and green infrastructure investments aimed at reducing carbon emissions. In line with global climate targets, Mediterranean ports must accelerate their transition toward environmentally friendly technologies.

v. **Regional cooperation mechanisms**—for example, along the Türkiye–Greece–Italy axis—may transform port competition into complementarity and strengthen the overall logistical competitiveness of the Mediterranean basin. Such coordination can prevent excess capacity, reduce duplication of investments, and promote more efficient resource allocation.

In conclusion, this study contributes to both the academic literature and regional policy design by identifying the economic and logistical determinants of container port capacity along the Mediterranean corridor. The findings confirm the strategic role of the Mediterranean in global maritime trade and highlight the necessity for Turkish ports, in particular, to accelerate investments in connectivity and digitalization. The 64% reduction in the GDP coefficient after controlling for population underscores the importance of variable interactions and suggests that future research should examine these interdependencies in greater depth. Future studies are encouraged to extend the analysis by incorporating indicators of port efficiency, carbon footprint, and digital competitiveness.

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ANALOGICAL VERSIONS OF MONEY DEMAND THEORIES IN THE CONTEXT OF THE UNCERTAINTY PRINCIPLE[5]

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ABSTRACT

This paper connects Heisenberg's uncertainty principle with Knight's idea of unmeasurable uncertainty to rethink money-demand theory. Heisenberg emphasizes the limits of measurement between knowledge and time, while Knight highlights the distinction between quantifiable risk and radical uncertainty (Dequech, 2000:36). From this synthesis, we propose— as a novel analytical contribution— the inequality $\Delta t.\Delta E \geq \theta$ *timing uncertainty in central-bank decisions* (Δt) *affects money demand only when combined macroeconomic volatility* (ΔE) *pushes the product beyond a behavioral threshold "*θ*". Using this framework, we reinterpret Cambridge, Keynesian, Friedman, Baumol–Tobin, and Post-Keynesian formulations of money demand.*

Empirically, our comparative review of the Federal Reserve, the European Central Bank, and the Central Bank of the Republic of Türkiye shows that irregular or unpredictable announcement strategies amplify uncertainty and undermine monetary stability. In short, money demand is shaped not only by income and interest rates but also by information asymmetries, timing risk, and behavioral responses. These findings underline the policy relevance of clear and predictable communication while offering an interdisciplinary bridge between physical and economic approaches.

Keywords: *Central Bank Timing, Heisenberg, Knight, Money Demand, Uncertainty Principle.*

JEL Codes: *E41, E52, D81.*

1.INTRODUCTION

The science of economics has historically been influenced by the natural sciences—particularly physics—and has shaped its theoretical frameworks through this interaction. The classical economic search for equilibrium parallels the deterministic universe of Newtonian mechanics, while neoclassical models were inspired by the mathematical formulations of thermodynamics (Mirowski, 1989:12; Smith, 1776:456; Newton, 1687:13). In the 20th century, however, uncertainty-oriented paradigms came to the

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forefront; quantum physics and probability theories guided new debates regarding the nature of economic thought (Heisenberg, 1927:172; Knight, 1921:19).

This study aims to reconceptualize the theory of money demand by synthesizing Heisenberg's uncertainty principle with Knight's notion of "immeasurable uncertainty." Heisenberg (1927:174–175) demonstrated that the position and momentum of a particle cannot be precisely measured simultaneously, grounding the inherent uncertainty of the measurement process in a scientific framework. Knight (1921:20–21), on the other hand, distinguished between risk and uncertainty in economic decision-making processes, arguing that risk can be measured through probabilistic calculations, whereas uncertainty is unmeasurable and radical in nature (Dequech, 2000:36). These two approaches indicate that economic behavior is shaped not only by rational assumptions but also within a framework of incomplete information, unpredictability, and behavioral dynamics.

The timing of central bank monetary policy decisions—particularly interest rate announcements—is critically important for expectation management and market stability in modern economies. However, timing uncertainty in policy announcements (Δt) and volatility in macroeconomic indicators (ΔE) profoundly affect the decision-making mechanisms of economic agents and lead to deviations of money demand from the predictions of traditional models (Begg et al., 2014:117; Soloviev and Saptsin, 2011:5). In this study, an original analytical framework is developed to explain such deviations.

Within this framework, the main research question of the study is formulated as follows: "How does uncertainty in central bank decision-making timing affect money demand, and how can this effect be modeled through the Heisenberg–Knight theoretical framework?"
In the research, the policy announcement patterns of the FED, ECB, and CBRT were examined comparatively; it was observed that irregular and unpredictable announcement strategies increase uncertainty and weaken monetary stability. Based on this, the inequality $\Delta t \cdot \Delta E \geq \theta$, proposed for the first time in this study, is used to explain the behavioral foundations of money demand under conditions of uncertainty—within the contexts of the Cambridge, Keynesian, Friedman, Baumol–Tobin, and Post-Keynesian money demand models (Avcı, 2025:111).

In conclusion, this article aims to offer an original contribution both theoretically and in terms of policy discussions by carrying the interdisciplinary interaction between economics and physics into monetary theory. In the following sections, the methodology and the extended money demand models will first be addressed, after which a general evaluation will be made in light of the literature, and the results and policy recommendations will be discussed.

2. METHODOLOGY

2.1. Heisenberg Uncertainty Principle

The Heisenberg Uncertainty Principle is one of the fundamental pillars of quantum mechanics and was introduced by the German physicist Werner Heisenberg in 1927. According to the principle, conjugate variables such as position and momentum cannot be precisely measured simultaneously; the product of their measurement uncertainties cannot fall below a certain lower bound (Heisenberg, 1927:47). Mathematically:

$$\Delta x \cdot \Delta p \geq \hbar/2 \quad (1)$$

Here,

Δx: the measurement uncertainty in the particle's position,

Δp: the measurement uncertainty in the particle's momentum,

$\hbar$: the reduced Planck constant ($\hbar = h/2\pi$).

Similarly, the uncertainty between energy and time is expressed by the following formula:

$$\Delta t \cdot \Delta E \geq \hbar/2 \quad (2)$$

Here,

Δt: the uncertainty in time,

ΔE: the uncertainty in energy.

Heisenberg's uncertainty principle is not merely a limitation arising from the technical imperfections of measurement instruments; it is also considered an expression of a fundamental uncertainty inherent in nature itself. As Goldhaber (2016:144–145) notes, this shifts the discussion beyond the epistemological question of "what do we know?" to the ontological question of "what can we never know?" Thus, uncertainty is treated not as a lack of knowledge but as a structural property of nature. In this sense, the question "what can I not know?" reveals that we may not even know what—and how much—we must know. This approach highlights the importance of interdisciplinary studies; one of the most striking examples is the adaptation of the Heisenberg uncertainty principle to the economic dimension (Avcı, 2025:110).

2.2. Economic Adaptation

The view that the uncertainty principle can be adapted to the social sciences — that is, "the uncertainty principle may operate not only in physical systems but also analogically in social systems" — was first proposed by Soloviev and Saptsin (2011), who emphasized that economic variables may also exhibit uncertainty relationships similar to conjugate variables. In this study, the principle is

reformulated to explain the relationship between the timing of central bank interest rate announcements and the volatility generated by these announcements in the market.

Within this framework, the interaction between decision-making timing in the economic system and the system's reaction to this timing is formulated through the following original inequality developed in the study:

$$\Delta t \cdot \Delta E \geq \theta \tag{3}$$

Here,

Δt: The uncertainty in the timing of the central bank's interest rate announcement (the more uncertain the announcement time, the larger Δt becomes). This parameter is directly related to transparency in the decision-making and announcement process, the timing of the announcement, and market expectations.

ΔE: The magnitude of the volatility in market variables (such as the exchange rate, short-term interest rates, and commodity prices) that emerges after the central bank announces its interest rate decision. It reflects the level of uncertainty in the perception and reaction process to the decision.

θ: The minimum uncertainty bound inherent in the nature of the economic system. Regardless of how well the systemic structure is designed, it cannot fall below a certain lower threshold.

2.3. Analogical Interpretation

This approach suggests that, similar to how the measurement process in quantum physics alters the system itself, there exists an interaction between the timing of central bank decisions and market responses (Uçar, 2020:78–79). If the central bank delays its announcement (high Δt), the immediate effects on the market decrease (low ΔE); conversely, if the decision is announced early and clearly (low Δt), market effects and volatility (ΔE) increase. In other words, there is an inverse relationship — along with an uncertainty bound θ — between the timing of the central bank decision and the magnitude of the market reaction. Thus, the timing of the decision is not merely a passive transmission of information but an active factor that directly reshapes the system itself.

2.4. Application and Limitations of the Model

The inequality $\Delta t \cdot \Delta E \geq \theta$ proposed in this study aims to explain the interaction between central bank decision timing (Δt) and macroeconomic fluctuations (ΔE) within an interdisciplinary framework. The model is derived from the combination of Heisenberg's uncertainty principle (Heisenberg, 1927:172) and Knight's concept of unmeasurable uncertainty (Knight, 1921:19; Dequech, 2000:36), enabling an analytical reinterpretation of money demand theories. In this context, the inequality transforms parameters that traditional models typically assume to be fixed into dynamic and variable

elements under uncertainty. Thus, it suggests that money demand is shaped not only by income and interest rates but also by information asymmetries, timing uncertainties, and behavioral factors (Soloviev and Saptsin, 2011:7).

The most significant contribution of the model is its analytical formulation of the transformative role played by central bank communication strategies and decision announcement timing in macroeconomic volatility. This approach allows for a comparative analysis of the distinct policy announcement patterns of institutions such as the FED, ECB, and CBRT. In this framework, it is theoretically shown that irregular and unpredictable announcements increase uncertainty, while consistent and transparent communication strengthens market stability (Begg et al., 2014:117; Blinder et al., 2008:5).

However, the model inevitably carries certain limitations. First, the parameter θ represents a behavioral threshold and cannot be directly measured empirically. Therefore, the inequality offers an analogical and conceptual framework rather than precise quantitative estimates. Second, although the analogy drawn from the physical sciences to economics serves as an explanatory tool, it does not claim to establish a one-to-one causal relationship (Goldhaber, 2016:144–145). This necessitates cautious interpretation of the model's results. Third, the model has not yet been empirically tested, meaning that its findings remain theoretical at this stage.

In conclusion, while the inequality $\Delta t \cdot \Delta E \geq \theta$ introduces an interdisciplinary innovation to money demand theories, its applicability remains confined to conceptual explanation and theoretical modeling. Within this framework, the model aims to make the phenomenon of uncertainty in the economy more visible, broaden the analytical scope of monetary policy decisions, and provide an original starting point for future empirical research.

3. MONEY DEMAND MODELS UNDER UNCERTAINTY

3.1. The Cambridge Approach: The Uncertainty-Extended Model

The Cambridge approach is based on the idea that individuals tend to hold a certain proportion of their income as cash, and it is classically formulated as:

$$M^d = k \cdot P \cdot Y \tag{4}$$

Where M^d denotes real money demand, $k$is the Cambridge coefficient, P is the price level, and Y is real income. When linked to the quantity theory of money, the model incorporates the velocity of circulation v and is rewritten as:

$$M^d = k \cdot \frac{P \cdot Y}{v} \tag{4a}$$

The traditional Cambridge model relies solely on income and the price level, overlooking elements such as timing uncertainty (Δt_t) and economic volatility (ΔE_t), which have become central in modern economies. Therefore, the model is extended in the light of Knight's (1921:20) concept of unmeasurable uncertainty and Heisenberg's (1927:174) uncertainty principle.

The basic inequality adapted from Heisenberg is expressed as:

$$\Delta t_t \cdot \Delta E_t \geq \theta \tag{3}$$

This inequality indicates that the product of central bank decision timing uncertainty (Δt_t) and economic volatility (ΔE_t) represents a critical threshold value (θ) that must be surpassed in order to alter individual behavior.

Thus, the Cambridge coefficient is no longer treated as a fixed parameter but as a variable sensitive to uncertainty:

$$k = k(\Delta t_t, \Delta E_t) \tag{5}$$

or, more explicitly:

$$k = k_0 + \theta(\Delta t_t \cdot \Delta E_t) \tag{6}$$

Here, $k_0$represents the normal cash-holding ratio, and θ denotes sensitivity to uncertainty components. As economic uncertainty rises, the tendency to hold cash increases, which can be analytically expressed as:

$$\Delta t_t \cdot \Delta k_t \geq \theta \tag{7}$$

In the final step, the uncertainty-augmented Cambridge model is proposed as follows:

$$M_t^d = \frac{k \cdot P_t \cdot Y_t}{v} + \lambda \cdot (\Delta t_t \cdot \Delta E_t) \tag{8}$$

where λ measures the strength of the impact of uncertainty components on money demand.

The macroeconomic volatility indicator is defined as the sum of fluctuations in interest rates, exchange rates, and commodity prices:

$$\Delta E_t = \sigma_{i_t} + \sigma_{ER_t} + \sigma_{C_t} \tag{9}$$

σ_{i_t}: interest rate volatility

σ_{ER_t}: exchange rate volatility (e.g., TL/USD, TL/Euro)

σ_{C_t}: commodity price volatility (gold, silver, copper, etc.)

Through this structure, it is analytically demonstrated that money demand is determined not only by income and the price level but also by factors such as central bank decision timing, market volatility, and behavioral threshold values.

With this study, the Cambridge model is transformed from a constant k parameter into a dynamic function, thereby explaining the behavioral foundations of money demand under uncertainty.

3.2. Keynesian Money Demand Model: An Uncertainty-Expanded Approach

The Keynesian money demand model explains money holding through three main components: transactions, precautionary, and speculative motives. The basic formulation is expressed as:

$$M_t^d = f(Y_t, i_t) \quad \text{or} \quad M_t^d = L_1(Y_t) + L_2(i_t) \tag{10}$$

Here, M_t^d denotes nominal money demand;

$L_1(Y_t)$ reflects transaction and precautionary demand proportional to income;

$L_2(i_t)$ represents speculative demand based on the interest rate;

Y_t is real income, and i_t is the nominal interest rate.

However, the classical model does not take into account contemporary uncertainty factors (income volatility, central bank timing risk, etc.) that shape money demand today. Fluctuations in income, interest rate volatility, and uncertainty surrounding central bank decision timing have become key determinants of individuals' money-holding behavior. For this reason, the model is expanded in light of Knight's (1921: 21) concept of unmeasurable uncertainty and Heisenberg's (1927: 174) uncertainty principle.

Transaction demand for money is directly proportional to income:

$$L_T = f(Y_t) \tag{11}$$

Precautionary money demand depends not only on the level of income but also on its volatility:

$$L_P = f\left(Y_t, \sigma_{Y_t}\right) \tag{12}$$

where σ_{Y_t} represents uncertainty in real income. As income volatility increases, individuals tend to hold more cash to buffer against unexpected expenditures.

Speculative money demand is classically inversely related to the interest rate (i_t). Under uncertainty, however, individuals' decisions depend not only on the level of interest rates but also on interest rate volatility (Δi_t), uncertainty in the timing of central bank decisions (Δt_t), overall economic volatility (ΔE_t), and a behavioral threshold parameter (θ). The parameter θ captures individuals' tolerance for uncertainty, shaped by economic conditions, confidence levels, and past experiences.

At this point, the following inequality—adapted from Heisenberg's uncertainty principle—comes into play:

$$\Delta t_t \cdot \Delta E_t \geq \theta \tag{3}$$

This economic adaptation of the Heisenberg principle highlights the multiplier effect between uncertainty in central bank decision timing and market volatility. When the product of Δt_t and ΔE_t exceeds the threshold θ, individuals exhibit significant behavioral adjustments, leading to observable changes in money demand.

Within this framework, speculative demand is defined as:

$$L_S = f(i_t, \Delta i_t, \Delta t_t, \Delta E_t, \theta) \tag{13}$$

where:

i_t: interest rate

Δi_t: interest rate volatility

Δt_t: uncertainty in central bank decision timing

ΔE_t: macroeconomic volatility

θ: behavioral threshold parameter

Finally, combining all components, the uncertainty-augmented Keynesian money demand model can be written as:

$$M_t^d = L_T(Y_t) + L_P(Y_t, \sigma_{Y_t}) + L_S(i_t, \Delta i_t, \Delta t_t, \Delta E_t, \theta) \tag{14}$$

This model goes beyond the classical Keynesian approach by incorporating income fluctuations, interest rate volatility, central bank timing uncertainty, and overall macroeconomic variability. It presents money demand not only as a function of income and interest rates but also as shaped by uncertainty and behavioral factors, offering a more realistic and dynamic framework.

3.3. The Friedman Modern Money Demand Model: An Uncertainty-Extended Approach

Friedman's modern money demand model explains individuals' decisions to hold money through macroeconomic variables such as real income, interest rates, and expected inflation. The classical model is defined as follows:

$$M^d = f(Y, r_b, r_e, \pi^e, u) \tag{15}$$

In its simplified form:

$$M_t^d = f(Y_t, i_t, \pi_t^e) \tag{16}$$

Here, M_t^d represents nominal money demand, Y_t denotes real income, i_t the nominal interest rate, and π_t^e the expected inflation rate.

The classical Friedman model relies on the assumptions of full information and rational expectations. However, in contemporary economies, individuals decisions are affected not only by income, interest rates, and inflation, but also by interest rate volatility, the uncertainty in central bank policy timing, and overall market volatility. For this reason, the model is extended within the framework of Knight's (1921: 21) concept of unmeasurable uncertainty and Heisenberg's (1927: 174) uncertainty principle.

The inequality adapted from Heisenberg's uncertainty principle is expressed as follows:

$$\Delta t_t \cdot \Delta E_t \geq \theta \tag{17}$$

Here, θ represents the psychological threshold at which individuals begin to perceive uncertainty. Unless the product of central bank policy timing uncertainty (Δt_t) and macroeconomic volatility (ΔE_t) exceeds this threshold, no significant change in money demand is observed.

In this context, the extended Friedman model is defined as follows:

$$M_t^d = f(Y_t, i_t, \pi_t^e, \Delta i_t, \Delta t_t, \Delta E_t, \theta) \tag{18}$$

Where:

Δi_t: interest rate volatility,

Δt_t: uncertainty regarding the timing of central bank policy decisions, which may lead to sudden changes in money demand,

ΔE_t: overall macroeconomic volatility ($\sigma_{i_t} + \sigma_{ER_t} + \sigma_{C_t}$),

θ: the threshold representing individuals' sensitivity to uncertainty; uncertainty affects money demand only when it exceeds this level.

In this model, both micro-level responses of individuals to short-term interest rate volatility (Δi_t) and macro-level market conditions reflected by overall volatility (σ_{i_t}) are taken into account simultaneously.

In conclusion, the extended Friedman model adopts a more comprehensive and dynamic structure by incorporating uncertainty and behavioral factors, rather than relying solely on income, interest rates, and inflation expectations in explaining money demand.

3.4. The Baumol–Tobin Money Demand Model: An Uncertainty-Extended Approach

The Baumol–Tobin model is a microeconomic approach that assumes individuals' cash-holding preferences are determined by transaction costs and the opportunity cost of interest rates. The classical model is defined as follows:

$$M^d = \sqrt{\frac{cY}{2i}} \tag{19}$$

Here, M^d represents real money demand, Y denotes real income or expenditure level, i the nominal interest rate (the opportunity cost of holding cash), and c the cost of going to the bank or the transaction cost (a fixed cost).

In the classical model, the transaction cost $c$is assumed to be constant, and full information is presumed. However, in reality, elements such as interest rate volatility, income uncertainty, and central bank decision-timing can directly affect transaction costs. Therefore, the model is extended based on Knight's concept of unmeasurable uncertainty and Heisenberg's uncertainty principle.

The inequality adapted from Heisenberg is defined as follows:

$$\Delta t_t \cdot \Delta E_t \geq \theta \tag{3}$$

This inequality indicates that the uncertainty arising from the interaction of central bank decision-timing uncertainty (Δt_t) and market volatility (ΔE_t) increases transaction costs once the critical threshold $\theta$is exceeded.

Thus, the transaction cost ceases to be constant and becomes variable depending on uncertainties:

$$c_t = c_0 + \theta(\Delta t_t \cdot \Delta E_t) \tag{20}$$

Here, c_0 is the baseline fixed cost, and θ represents the effect of uncertainty on transaction costs.

In this case, the extended Baumol–Tobin model is defined as:

$$M_t^d = \sqrt{\frac{c_t Y_t}{2i_t}} + \lambda(\Delta t_t \cdot \Delta E_t) \quad (21)$$

Where:

M_t^d: real money demand in period t,

Y_t: real income in period t,

i_t: interest rate in period t,

c_t: transaction cost,

Δt_t: uncertainty regarding the timing of central bank policy announcements,

ΔE_t: macroeconomic volatility ($\sigma_{i_t} + \sigma_{ER_t} + \sigma_{C_t}$),

λ: the coefficient measuring the effect of the uncertainty component on money demand.

In this model, ΔE_t has both an indirect effect through transaction costs and a direct effect on money demand. Thus, uncertainties shape individuals' cash-holding behavior in a dual manner.

In conclusion, the extended Baumol–Tobin model becomes sensitive not only to income and interest rates but also to central bank timing uncertainty and market volatilities, thereby explaining money demand more realistically during periods of uncertainty.

3.5. The Post–Keynesian Money Demand Model: An Uncertainty-Extended Approach

The Post-Keynesian approach does not limit the explanation of money demand to classical variables such as income and the interest rate; it also places liquidity preference, radical uncertainty, and insecurity about the future at the center. The basic function is expressed as follows:

$$M^d = f(Y, i, uncertainty) \quad (22)$$

With this perspective, the updated form of the model is written as:

$$M_t^d = f(Y_t, i_t, L_t) \quad (23)$$

Here, M_t^d denotes nominal money demand, $Y_t$real income, $i_t$the nominal interest rate, and $L_t$the behavioral component reflecting liquidity preference and perceived uncertainty. Liquidity preference (L_t) reflects individuals' behavior in the face of insecurity about the future and radical uncertainty. However, since this variable is generally considered exogenous, its measurability is limited. At this point, the inequality adapted from Heisenberg's uncertainty principle comes into play:

$$\Delta t_t \cdot \Delta E_t \geq \theta \tag{3}$$

The product of uncertainty in the timing of central bank policy announcements (Δt_t) and economic volatility (ΔE_t) represents a critical threshold θthat must be exceeded for individuals to change their behavior. When this threshold is not exceeded, the effect of uncertainty on money demand and liquidity preference remains limited. However, once the threshold is surpassed, economic agents strengthen their perceptions of unpredictability and insecurity about the future, leading them to make significant changes in liquidity preference and cash-holding behavior.

Thus, in the Post-Keynesian model, uncertainty is treated not merely as a continuous variable but as a dynamic threshold that affects economic decisions when exceeded. This allows for a more realistic modeling of radical uncertainty and behavioral responses, which are neglected in classical approaches.

The extended version of the model is formulated as follows:

$$M_t^d = f(Y_t, i_t, L_t) + \lambda(\Delta t_t \cdot \Delta E_t) \tag{24}$$

Where:

Y_t: real income

i_t: nominal interest rate

Δt_t: uncertainty regarding the timing of central bank interest rate decisions

ΔE_t: macroeconomic volatility in period $t(\sigma_{i_t} + \sigma_{ER_t} + \sigma_{C_t})$

λ: individuals' sensitivity to these uncertainties (Knight-type sensitivity coefficient)

Here, λ represents the coefficient of individuals' sensitivity to uncertainty. This extended model adapts the classical notion of liquidity preference to today's high-uncertainty environment and demonstrates that money demand is shaped not only by traditional variables such as income and the interest rate but also by timing risk (Δt_t) and market volatility (ΔE_t). In this way, the increase in cash-holding tendencies during periods of heightened uncertainty becomes a critical behavioral factor directly affecting the effectiveness of monetary policy.

4. LITERATURE REVIEW

The theoretical foundation of this study is based on classical money demand models and the uncertainty literature, shaped by Heisenberg's uncertainty principle and Knight's concept of unmeasurable uncertainty. The limited number of sources makes the original contribution of the study more visible.

Uncertainty and Decision Timing: Pindyck (1988) analyzed the irreversibility of investment decisions and the option value of waiting under uncertainty, emphasizing the economic implications of decision timing. Begg et al. (2014) clarified the concepts of uncertainty and variability, contributing to economic modeling.

Physical and Quantum Economic Approaches: Soloviev and Saptsin (2011) adapted Heisenberg's principle to economic models; Harin (2006) and Vukotic (2011) examined economic uncertainty from a quantum economics perspective; and Gonçalves (2012) analyzed risk and returns using quantum-based financial models.

Keynesian and Post-Keynesian Perspectives: Dequech (2000) systematically defined fundamental uncertainty, while Davidson (1991) emphasized the significance of Keynes's concept of true uncertainty. These approaches show that uncertainty is a fundamental element shaping the behavior of economic agents.

Macroeconomic Uncertainty: Cesa-Bianchi and Pesaran et al. (2018) conducted a comparative analysis of multi-country macroeconomic uncertainty shocks and their effects on growth, investment, and employment. These findings demonstrate that uncertainty shapes economic decisions not only nationally but also on a global scale.

Money Demand Theories: Laidler (1993) compared classical, Keynesian, and monetarist models; Baumol (1952) and Tobin (1956) provided a microeconomic framework through liquidity preference theory; and Friedman (1956) approached modern money demand from an asset demand perspective. However, since these theories largely rely on the assumption of full information, different dynamics emerge when uncertainty is incorporated.

In conclusion, this literature review presents the key sources for extending money demand models through the perspectives of uncertainty and behavioral finance. The model of Svirina and Parfenova et al. (2015) demonstrates the applicability of the Heisenberg principle in measuring economic performance, emphasizing that uncertainty exists not only externally but also internally within the measurement processes of economic systems. Thus, the integration of physical principles into economic models offers a new perspective to the fields of money demand and decision timing and provides a theoretical basis for their reinterpretation.

5. ANALYSIS AND DISCUSSION

In this article, money demand theories are reinterpreted in the light of Heisenberg's uncertainty principle and Knight's concept of unmeasurable uncertainty. The proposed inequality $\Delta t_t . \Delta E_t \geq \theta$ reveals that the product of uncertainty in central bank decision timing (Δt_t) and macroeconomic fluctuations (ΔE_t) affects economic behavior only when a critical threshold "θ" is exceeded. Applying this framework to the Cambridge, Keynesian, Friedman, Baumol–Tobin, and Post-Keynesian models

demonstrates that the stability of traditional parameters is replaced by a dynamic structure under uncertainty.

The comparative evaluation of the models shows that the effect of uncertainty on money demand emerges through different channels: the cash-holding ratio in the Cambridge model, income and interest rate volatility in the Keynesian model, inflation expectations in the Friedman model, transaction costs in the Baumol–Tobin model, and liquidity preference in the Post-Keynesian model. This diversity confirms that uncertainty is not a one-dimensional but a multi-layered dynamic.

The original contribution of the study is to reformulate the uncertainty factor through an economics–physics analogy and to reconceptualize money demand theories. This approach shows that the communication strategies of central banks are not merely mechanisms for transmitting information but also mechanisms that can increase or decrease uncertainty.

However, the impossibility of empirically measuring the parameter "θ" and the use of the analogy as an explanatory bridge between physics and economics constitute the limitations of the model. Therefore, the inequality provides a theoretical and rhetorical framework rather than a quantitative estimation.

In conclusion, this article reconstructs money demand theories within the context of the uncertainty principle and makes the critical role of central bank decision timing on economic behavior visible through an interdisciplinary perspective.

6. CONCLUSION

With the intersection of physics and the social sciences, concepts such as uncertainty, information gaps, and behavioral thresholds have been incorporated into the economics literature at both theoretical and mathematical levels. This study reveals the multidimensional impact of uncertainty on economic decisions and its critical role in central bank policy implementation. Knight's concept of "unmeasurable uncertainty" and Heisenberg's uncertainty principle show that economic agents make decisions not only based on rational data but also in response to information gaps and psychological thresholds.

Within this framework, the Cambridge, Keynesian, Friedman, Baumol–Tobin, and Post-Keynesian money demand models were restructured by integrating elements of uncertainty, and the effects of central banks' interest rate decisions—both in terms of their magnitude and their announcement timing—were analyzed through the parameters Δt_t (decision-timing uncertainty) and ΔE_t (macroeconomic volatility). When certain thresholds are exceeded, breaks occur in money demand behavior, which increases market volatility and economic unpredictability ($\Delta t_t . \Delta E_t \geq \theta$).

Differences in decision timing create information gaps in the markets, deepening uncertainty and making the expectations and positions of economic agents unpredictable. This situation, analogous to the Heisenberg principle, underscores the importance of measurement and timing boundaries in the

economy. At the macro level, the psychological effects of economic policy uncertainty and market volatility should also not be overlooked (Baker and Bloom, 2016; Bloom, 2009; Bernanke, 1983; Jurado et al., 2015).

Implications for policymakers include predictability in the timing of interest rate decisions, transparent communication, perception and expectations management, the integration of uncertainty indicators, flexible mechanisms during crises, international coordination, and improving financial literacy. These elements strengthen uncertainty management and support market stability and economic performance.

In conclusion, the model developed in this study treats uncertainty not merely as an external factor but as an inherent feature of economic systems, providing a new perspective on both the theoretical and practical dimensions of central bank policies. Managing uncertainty in interest rate announcement processes is of critical importance for economic stability and for understanding the behavior of economic agents.

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