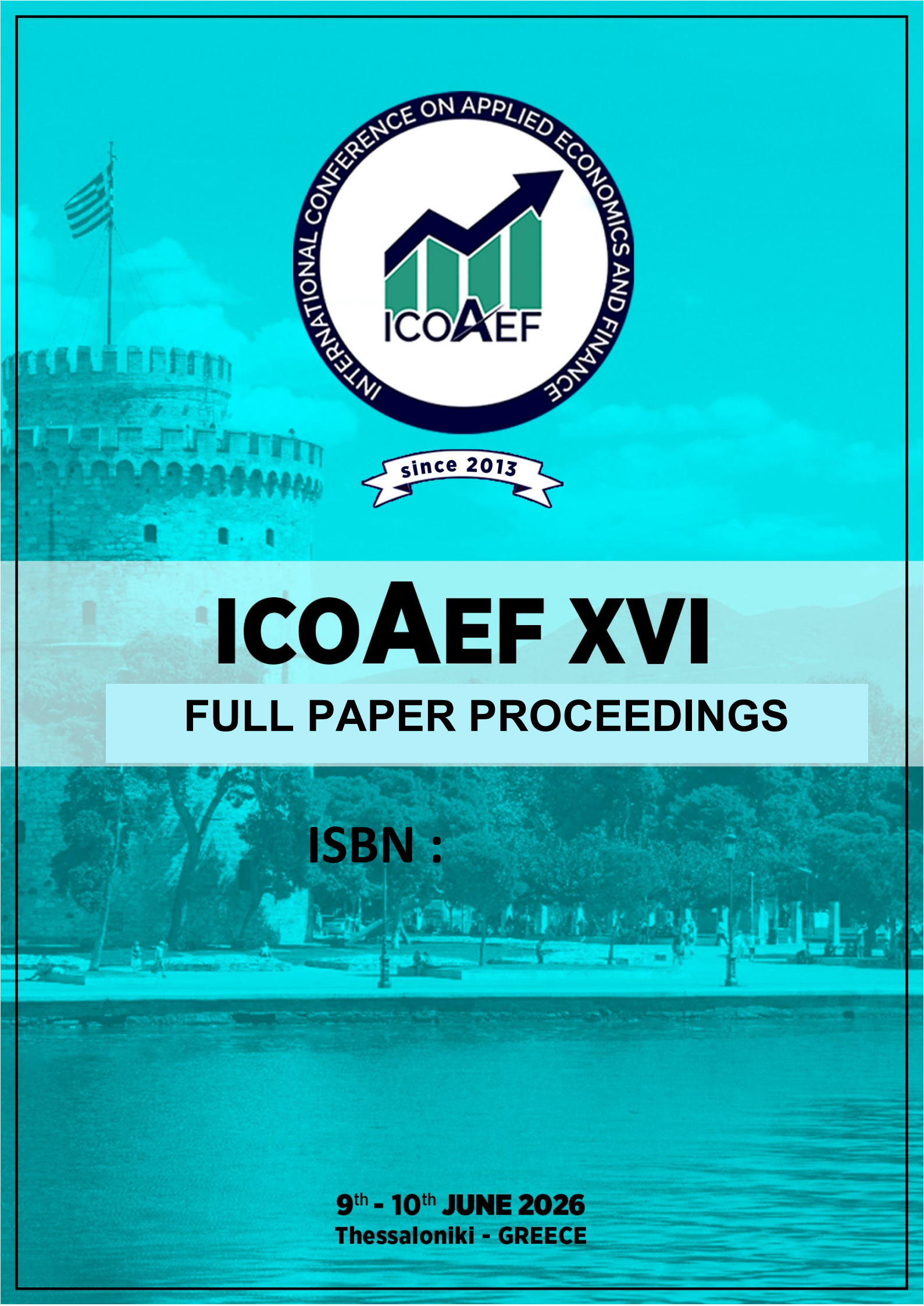

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ICOAEF XVI

INTERNATIONAL CONFERENCE ON APPLIED ECONOMICS AND FINANCE

WELCOME MESSAGE

International Conference on Applied Economics and Finance (ICOAEF XVI) held on 9th-10th June, 2026 in Blacksea Trade and Development Bank Thessaloniki-Greece. We are glad ICOAEF-XVI gathered many successful academics and professionals around the World. 67 papers were submitted, and 58 papers presented during ICOAEF-XVI from 16 different countries.

This conference provided as a well-fitted platform for discussions about the researches. This conference full paper proceeding contains 17 papers presented both online and in person. ICOAEF-XVI participants consisted of from 17 different countries, 16 Turkish universities. Scientific board rejected 9 papers directly due to the inconvenience of conference topics, theme and structure of ICOAEF-XVI. Scientific committee also requested some revisions to 13 different papers then these papers accepted and presented during the conference. All submissions for ICOAEF-XVI scientifically reviewed and evaluated by scientific committee members.

We believe that ICOAEF-XVI 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 (4), Azerbaijan (1), Central African Republic (2), Cyprus (1), Denmark (1), Ethiopia (1), France (1), Greece (3), Hungary (1), Indonesia (1), Italy (2), Kyrgyzstan (2), Lebanon (1), Malaysia (3), Romania (3), Saudi Arabia (1), South Africa (1), Türkiye (26), United States (3). Finally, we would like to thank Blacksea Trade and Development Bank, Aristotle University, Anatolia American University, and our esteemed ICOAEF-XVI participants who shared their deep knowledge and experience at ICOAEF-XVI. We would like to be together in our following organizations.

On behalf of Conference Organization Committee

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CONTENTS OF FULL PAPER PROCEEDINGS

DETERMINANTS OF CARBON INTENSITY IN TÜRKİYE: ENERGY INTENSITY AND

Asst. Prof. Dr. Ayşegül UÇKUN ÖZKAN*

ABSTRACT

This study analyses the short-term and long-term effects of energy intensity and capital deepening on carbon intensity in Türkiye during the period 1965-2023 using an ARDL model. Carbon intensity is a critical indicator in combating climate change and in the process of aligning with the European Union's Carbon Border Adjustment Mechanism (CBAM), directly affecting Türkiye's export competitiveness. The findings show that a 1% increase in energy intensity increases carbon intensity by 0.43% in the short term and 1.04% in the long term. Capital deepening exerts a statistically significant negative effect on carbon intensity in both the short and long run. Specifically, a 1% increase in capital deepening is associated with a 0.048% reduction in carbon intensity in the short term, with this effect intensifying to 0.12% in the long term. Nevertheless, despite the persistent and substantial increase in Türkiye's capital deepening over the period under examination, energy and carbon intensity have not decreased to the expected level. This finding suggests that capital deepening alone cannot be relied upon as a sufficient mechanism for reducing carbon intensity. However, the capital accumulation directed towards renewable energy investments with the Renewable Energy Resources Support Mechanism (YEKDEM) regulations after 2011 shows that the correct incentive design is crucial. The study emphasizes that energy efficiency and incentive policies should be considered together in Türkiye's decarbonization process.

Keywords: *Carbon Intensity, Energy Intensity, Capital Deepening, ARDL, Türkiye.*

JEL Codes : *Q43, J21, H54.*

1. INTRODUCTION

While the origins of scientific discussions on climate change can be traced back to the 19th-century work of Joseph Fourier[1], who first described the greenhouse effect, it was only in the mid-20th century that the issue became a global concern. Considered a precursor to climate policies and the concept of sustainable development, "*Limits to Growth*[2]", developed by the Club of Rome[3], is one of the most influential early works forming the socio-economic basis of climate change discussions. This work also laid the foundation for the concept of *"sustainable development"* worldwide and formed the basis for scenarios produced by the 1987 Brudtland Report (Our Common Future), the 1992 Rio

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[1] Fourier was the first to discover the greenhouse effect, demonstrating in his 1824 paper that gases in the atmosphere increase the Earth's temperature (Lynch, 2019).

[2] It has been translated into Turkish as "The Limits to Economic Growth (Ekonomik Büyümenin Sınırları)".

[3] The Club of Rome was founded in 1968 to examine the relationships between industry, economics, and the environment on a global scale.

Summit, the United Nations Climate Convention (UNFCCC), and the 1988 Intergovernmental Panel on Climate Change (IPCC). With the establishment of the IPCC in 1988, climate change began to be discussed at the global policy level. This marks a turning point in climate change studies.

Over the last quarter century, global climate change has evolved from being merely an environmental problem to a key determinant of economic growth, trade, and international competitiveness. This is because climate change alters transportation routes, infrastructure, production, and areas of specialization, weakening the trade position of some countries while increasing the competitiveness of others (Dellink, 2017). The rapid increase in industrial greenhouse gas (GHG) emissions since the Industrial Revolution is causing global warming and climate change. Carbon dioxide (CO_2) emissions accounted for 74% of total GHG emissions in 2024 (Ge, Friedrich and Vigna, 2024). Therefore, such high CO_2 emission levels are considered the main cause of global warming, and reducing CO_2 emissions is regarded as one of the most urgent issues for global economies (Liu and Wang, 2022). Global studies have shown that every 1°C increase in daily temperature fluctuations is associated with a 5% decrease in regional economic growth in a given year (Khurshid, Fiaz, Khurshid and Ali, 2022). Accordingly, under the Paris Agreement, which entered into force in 2016 and has been accepted by 195 signatory countries, countries have been submitting their own climate action plans, known as National Contribution Declarations (NDCs), since 2020. The agreement adopts a bottom-up mitigation strategy that encourages countries to reduce emissions globally and takes regional differences into account (Zhang, Yao, Qian, Zhang, Liang and Wei, 2024; UNFCCC, 2025).

The Carbon Border Adjustment Mechanism (CBAM), developed by the European Union (EU) in May 2023, is an environmental policy tool aimed at ensuring fair carbon emission pricing. Fully implemented in January 2026, following a transition period[4] between 2023-2025, this mechanism aims to support the decarbonization process of EU industry. CBAM aims to encourage cleaner and more sustainable industrial production in countries outside the EU by imposing a fair cost on emissions generated during the production of carbon-intensive products (European Commission, 2025a). Türkiye, due to its strong trade ties[5] with the EU based on the Customs Union, is among the countries that will be directly affected by this regulation. Considering that additional taxation will be applied to imported products based on their carbon content under CBAM, understanding the factors determining carbon intensity is critical for Türkiye's export competitiveness. Carbon intensity is a key indicator showing how much carbon emissions an economy produces per unit of economic output and is one of the most important parameters to be reduced during the CBAM compliance process.

[4] No financial obligations arise during the transition period (Republic of Türkiye Ministry of Trade, 2025).
[5] EU-Türkiye trade relations are based on the Association Agreement signed in 1963 and the Customs Union Agreement which entered into force in 1995. With a trade volume of €210 billion as of 2024, Türkiye is the EU's fifth largest trading partner in total goods trade. As of 2024, 41% of Türkiye's exports are to the EU, while 32.1% of its imports originate from the EU (European Commission, 2025b).

One of the most important determinants of carbon intensity is energy intensity (energy consumption per unit of GDP). Energy intensity can be reduced either through the use of less energy-intensive equipment and technologies or by moving away from energy-intensive activities (Metcalf, 2008; Hajiyev, Guliyev, Abdullayeva and Abdullayeva, 2023). However, capital deepening (capital stock per worker) is also theoretically predicted to be a determining factor in carbon intensity. Capital deepening can reduce carbon intensity by facilitating the transition to cleaner and more efficient technologies, but it can also have the opposite effect if capital accumulation occurs through fossil fuel-based and low-efficiency technologies. This indicates that the environmental consequences of capital deepening can vary from country to country and depending on the policies implemented.

In this context, the main objective of this study is to analyse the short- and long-term effects of energy intensity and capital deepening on carbon intensity in Türkiye during the period 1965-2023 using the ARDL approach. The ARDL model is preferred because it provides reliable results even when the variables have different degrees of stationarity, and because it allows for the interpretation of long-term relationships by separating them from short-term dynamics.

2. LITERATURE REVIEW

In line with net-zero carbon emission targets, there is a vast literature on carbon emissions, and the subject is addressed from various perspectives. However, studies focusing on carbon intensity, which stands out as one of the key determinants of emission reduction performance, appear to be relatively limited. The current literature includes studies investigating the key determinants of carbon intensity (Huang, 2018; Xu, Zhu, Li, Wu and Deng, 2024; Ke, Chen and Cheng, 2024), as well as research examining the relationship between renewable energy and carbon intensity (Yu, Hu, Li and Chen, 2020; Mirziyoyeva and Salahodjaev, 2022; Kongkuah and Alessa, 2025).

A low carbon intensity value indicates that a country achieves greater economic output with less carbon emissions and makes significant progress in energy conservation and emission reduction (Zhou and Zhong, 2025). In this context, energy intensity stands out as a significant driving force in reducing carbon intensity (Ling, Xia, Cao, He, Lim, Sukumar, Yi and Qian, 2021). However, the number of studies directly focusing on the interaction between carbon intensity and energy intensity is quite limited (Yu, Hu, Li and Chen, 2020; Tudor, Horobet, Mnohoghithei, Sova and Belascu, 2023; Zhou and Zhong, 2025). Conversely, research investigating the impact of energy intensity on the mitigation of carbon emissions (Shahbaz, Solarin, Sbia and Bibi, 2015; Rahman, Sultana and Velayutham, 2022; Li, Zheng, Li, Peng and Irfan, 2023) holds a more significant position in literature. Furthermore, the literature includes studies investigating the correlation between energy intensity and economic performance or growth (Diaz, Marrero, Puch and Rodriquez, 2019; Hajiyev, Guliyev, Abdullayeva and Abdullayeva, 2023; Kazemzadeh, Fuinhas, Shirazi, Koengkan and Silva, 2023; Sueyoshi and Goto, 2023), as well as

those analyzing the relationship between energy prices and energy intensity (Metcalf, 2008; Aterido, Iootty and Melecky, 2025).

The interaction between energy intensity and carbon intensity discussed above is largely determined by the structure and quality of capital used in production processes. In other words, a point often neglected in the literature on energy and carbon intensity is the underlying capital-labor dynamics. This is where the concept of capital deepening comes into play, i.e., the increase in the capital stock per worker, which has the potential to directly affect both energy use efficiency and carbon intensity. Capital deepening is defined as an increase in the capital-labor ratio resulting from capital growing faster than labor; this process increases labor productivity and economic growth. In other words, capital deepening, which means each worker having more or better machinery and equipment, is the main driving force behind higher production, usually supported by technological advancements or high savings and investment rates (Owyang and Shell, 2018). A review of the literature reveals that studies focusing on capital deepening can be grouped into three main categories: (i) Capital deepening and the agricultural sector: These studies examine the interaction between total factor productivity (TFP), labor productivity, and productivity indicators in the agricultural sector and capital deepening (Sheng, Ball, Erickson and Mesonada, 2022; Shen, Liang and Shi, 2023; Hong, Sun and Zhao, 2024; Sheng, 2025; Wu, Wu, Liu and Zhang, 2025; Du, Baskaran and Chandran, 2025). (ii) Capital deepening and the environment: These studies address the relationship between capital deepening and environmental indicators such as environmental efficiency, energy transition, climate change, and green total factor productivity (GTFP); generally emphasizing the role of environmental regulations in this relationship (Chen and Golley, 2014; Fan, Shao and Yang, 2015; Wang, Zhou, Ding and Wang, 2019; Xiao, 2022; Zhao, Hu and Jin, 2023). (iii) Capital deepening and macroeconomic indicators: This category investigates the relationship between capital deepening and macroeconomic variables such as aggregate factor productivity, trade, labor contracts, economic growth, foreign direct investment (FDI), and technological development (Kumar and Russell, 2002; Acemoğlu and Guerrieri, 2008; Madsen, 2010; Özay, 2015; Owyang and Shell, 2018; Chen, 2020; Zhang, 2020; Glover and Short, 2020; Ding and Zhou, 2021; Wang and Qiao, 2022). Despite the rich literature in these three categories, it is noteworthy that studies directly examining the relationship between carbon intensity and capital deepening are quite limited. In this context, Zhang, Song, Fan, Huang, Yang, Shao and Geng (2025) examine the relationship between carbon intensity and capital deepening; Shao, Luan, Yang and Li (2016) focus on the relationship between capital deepening and carbon emission performance; and Hao and Wang (2025) focus on the relationship between total factor carbon emission efficiency and capital deepening.

A review of the current academic literature reveals that studies specifically on this subject in Türkiye are quite limited. Looking at research conducted in Türkiye in general, it is noteworthy that researchers mostly focus on examining the interaction between carbon emissions, economic growth, and energy consumption (Çetin, Kırcı, Saygın and Alaşahan, 2018; Gokmenoglu, 2021; Doğanlar, Mike,

Kızılkaya and Karlılar, 2021; Adebayo, Agyekum, Kamel, Zawbaa and Altuntaş, 2022; Yıldız, 2023; Yücel and Kaplan, 2025; Kara, 2026). These studies contribute to the evaluation of Türkiye within the context of the environmental Kuznets curve hypothesis. Examining the limited number of studies on energy intensity and carbon intensity, Can (2025) focuses on the distributional factors of carbon emissions in Türkiye, particularly how household income and consumption patterns affect carbon footprints, addressing this through carbon intensity and energy intensity; Rahman, Sultana and Velayutham (2022) examines the relationship between carbon intensity, energy intensity, industrialization, renewable energy consumption, and urbanization; Akal (2016) investigates the impact of per capita oil energy use, world energy prices, and per capita GDP on energy intensity; Demiralp (2025) examines the relationship between energy intensity, carbon emissions, and economic growth; Çermikli and Tokatlıoğlu (2015) investigate the relationship between technological development and energy intensity; and Naimoğlu and Özbek (2022) examine the effects of energy prices and industrialization on energy intensity. Regarding carbon intensity, İlkdoğan and Sakarya (2025) examine the effect of carbon intensity on firm value; Durgun (2025) investigates the impact of income inequality, FDI, human development, corporate quality, and renewable energy consumption on carbon intensity; and Demiralp (2024) explores the relationship between energy consumption and carbon intensity. Eken and Yazıcı (2024) examine the potential effects of the carbon emission factor of production and the carbon emission intensity of exports on Türkiye's exports to the EU via CBAM. However, the vast majority of these studies address energy intensity or carbon intensity separately, with very few studies examining both indicators within the same analytical framework. Therefore, this study aims to fill this gap in literature.

Studies directly addressing the phenomenon of capital deepening in Türkiye are quite limited. In this limited literature, for example, Özay (2015) examines the effects of capital deepening on gender equality; while Bostan and Karadağ (2022) investigate the effects of international technology diffusion channels on the innovation performance of firms operating in the Turkish manufacturing industry, including capital intensity (K/L) only as a control variable in the model. In contrast, the concept of TFP is frequently used in the Turkish literature. However, unlike capital deepening, TFP is a productivity indicator that measures an economy's ability to generate income from inputs, in other words, its power to do more with less (Zynek, 2024); it explains the quantity of output obtained using factors of production such as labor and capital. It is noteworthy that there are relatively many studies in Türkiye examining the relationship between TFP and energy and the environment. Şimşek (2011) and İskender and Sözen (2016) focused on the relationship between energy efficiency and TFP; Demirsoy and Sözen (2025) examined the TFP of buildings in terms of energy efficiency. Tuğcu (2013) evaluated the relationship between energy consumption and TFP, while Tzeremes (2020) investigated the effect of energy consumption and TFP on CO_2 emissions, and Mukhtarov (2024) investigated whether renewable

energy and TFP reduce CO_2 emissions. Altınöz, Vasbieva and Kalugina (2021) analyzed the effects of information and communication technologies and TFP on CO_2 emissions.

Accordingly, the aim of this study is to analyze the interactions and short- and long-term dynamics between energy intensity and capital deepening, which are the main determinants of carbon intensity in Türkiye, using the ARDL model; and to fill three main gaps in the existing literature: The limited treatment of the carbon-energy intensity relationship in Türkiye, the lack of direct examination of the relationship between carbon intensity and capital deepening, and the lack of systematic research into the impact of capital deepening on carbon intensity specifically in Türkiye.

3. MODEL, DATA SET, AND METHODOLOGY

3.1. Variables and Data Sources

This study uses annual data covering the period 1965-2023. The dependent variable, carbon intensity (CI), is defined as the ratio of total CO_2 emissions to real GDP. The independent variables are energy intensity (EI) (the ratio of total energy consumption to real GDP) and capital deepening (KL) (the ratio of capital stock to total employment). While carbon intensity and energy intensity play a direct determinant role in greenhouse gas emissions, their effects on emissions can be both concordant and inverse (Tudor, Horobet, Mnohoghithei, Sova and Belascu, 2023). Based on this comprehensive relationship, this study, conducted specifically for Türkiye, included the energy intensity variable, which is considered one of the possible determinants of carbon intensity, in the analysis. Thus, the aim is to reveal the direction and strength of the effect of this variable on carbon intensity. All variables were converted to natural logarithmic form and included in the analysis. The variables included in the analysis are shown in Table 1.

Table 1. Variables Included in the Analysis

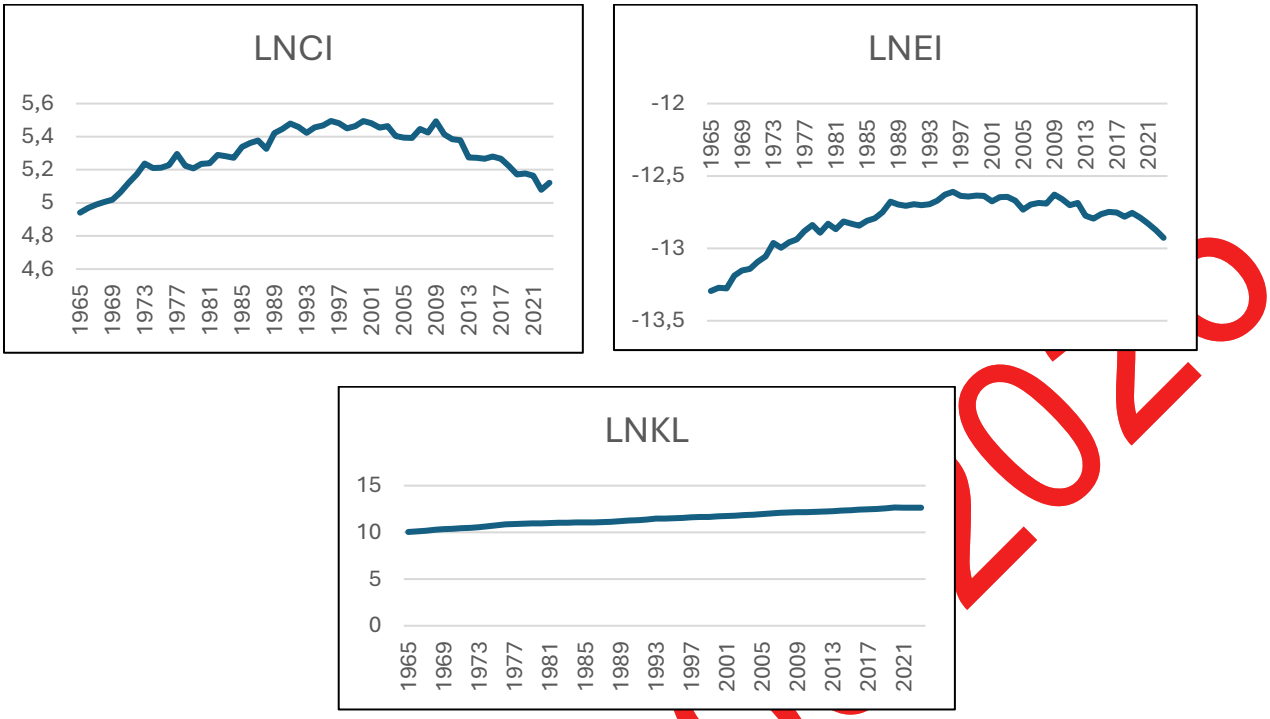
Variable	Definition	Explanation	Source
LNCI	Carbon intensity	CO_2/GDP	Carbon dioxide (CO_2) emissions were obtained from Our World in Data (OWID).
			Real GDP data at constant national prices was obtained from FRED (Federal Reserve Bank of St. Louis).
LNEI	Energy intensity	Total energy consumption/GDP	Energy consumption data was obtained from the BP Energy Institute.
LNKL	Capital deepening	Total capital stock (K) / Number of employees (L)	Capital stock (K) at constant national prices was obtained from FRED.
			The number of employees (L) was obtained from FRED.

Figure 1 shows the changes in the variables included in the analysis over the years. Carbon intensity is seen to have increased during the 1965-1975 period. The main reason for this increase is the

emphasis on investments in the production of iron and steel, petrochemicals, and other intermediate goods within the framework of the mixed economic system prevalent in the 1960s. During this period, manufacturing industry experienced average annual growth rates of 10%, while the general economy experienced growth rates of up to 6% (Pamuk, 2017). In other words, the acceleration of industrialization and the dominance of energy-intensive sectors during the import substitution period explain the increase in carbon intensity. The 1980s are considered a turning point for Türkiye in economic terms (Şenses, 2014). With the economic liberalization program announced on January 24, 1980, export-oriented industrialization was targeted (Pamuk, 2017). Accordingly, it is observed that carbon intensity continued to increase during the 1980-2000 period. After 2000 (excluding the 2009 economic crisis), a downward trend in carbon intensity is observed. The main reason behind this decrease can be attributed to the approximately tenfold increase in total energy supply from renewable sources from 2000 to the present (BP, 2025). However, when evaluated generally, although a relative improvement is observed in the post-2000 period, it cannot be said that Türkiye has been successful in reducing its carbon intensity. Indeed, in the long term, carbon intensity has not fallen below the 1965 level and has even continued to remain above this level. This result is supported by the studies of Gül and İnal (2017) and Baştan Töke (2025). In the study covering the EU and Türkiye, Baştan Töke (2025) observes that the environmental Kuznets curve hypothesis is not valid for Türkiye because Türkiye has not yet reached its peak, and therefore economic growth increases carbon emissions. When evaluated in terms of energy intensity, it is observed that energy intensity increased during the 1965-1980 period due to the structure of industry in energy-intensive sectors and the growth of industrialization without achieving energy efficiency. In the post-1980 period, the adoption of neoliberal policies led to even more intensive industrialization, resulting in a rapid increase in energy intensity. While the rate of increase in energy intensity slowed down during the 2015-2023 period, the values are still well above the 1965 level. Overall, Türkiye has continuously increased its energy intensity throughout its development process; in other words, more energy has been used per unit of GDP. This situation reveals the existence of an energy efficiency problem in Türkiye's production structure. Capital deepening (K/L) shows a continuous and strong increase. This indicates that capital deepening has been successfully achieved in Türkiye. However, despite the success of capital deepening, the fact that energy and carbon intensity have not decreased shows that Türkiye is achieving capital accumulation with low-efficiency and fossil fuel-based technologies. Looking at Türkiye's energy profile, as of 2024, 33.7% of the total energy supply consists of oil, 26% of natural gas, 25.6% of coal, 3.8% of hydroelectricity, and 10.6% of renewable energy (BP, 2025). In light of this data, 85% of Türkiye's energy supply consists of fossil fuels, which significantly increases CO_2 emissions[6].

[6] As of 2024, Türkiye ranks 67th out of 138 countries in air pollution (IQAir, 2025).

Figure 1. Changes in the Variables Included in the Analysis over the Years



3.2. Methodology

In this study, the relationship between carbon intensity, energy intensity and capital deepening in Türkiye was empirically analyzed. In the analysis, all variables were converted to natural logarithmic form. The basic linear regression model is expressed by equation (1):

$$lnCI_t = \beta_0 + \beta_1 lnEI_t + \beta_2 lnKL_t + \varepsilon_t \quad (1)$$

The model is based on annual time series data and covers the period t=1,...,T. The dependent variable, *lnCI*, represents the natural logarithm of carbon intensity. The explanatory variables, *lnEI* and *lnKL*, represent the natural logarithm of energy intensity and capital deepening respectively. ε_t, represents the error term of the model.

To test the long-term relationship between variables, the ARDL bounds test approach developed by Pesaran, Shin and Smith (2001) was used. The advantage of the ARDL model is that it gives valid results when the variables are I(0) or I(1) and is reliable in small samples. The log-linear ARDL specification based on Eq. (1) is expressed as follows:

$$lnCI_t = \alpha_0 + \sum_{i=1}^{p} \tau_i \, lnCI_{t-i} + \sum_{j=0}^{q^1} \omega_j lnEI_{t-j} + \sum_{j=0}^{q^2} \mu_j lnKL_{t-j} + \varepsilon_t \quad (2)$$

Here, p and q represent the optimal lag lengths chosen for the dependent variable (*lnCI*) and independent variables (*lnEI*, *lnKL*), respectively.

To determine whether there is a long-term equilibrium relationship between the series, the ARDL bounds test approach developed by Pesaran, Shin and Smith (2001) is used. In this context, Eq.(2) is

reconstructed into an error correction model (ECM) form that allows examining both short-term dynamics and long-term relationships simultaneously.

$$\Delta lnCI_t = \alpha_0 + \sum_{i=1}^{n} \beta_1 \Delta lnCI_{t-i} + \sum_{i=0}^{n} \beta_2 \Delta lnEI_{t-i} + \sum_{i=0}^{n} \beta_3 \Delta lnKL_{t-i} + \delta_1 lnCI_{t-1} + \delta_2 lnEI_{t-1} + \delta_3 lnKL_{t-1} + \varepsilon_t \quad (3)$$

In this equation, Δ represents the first differences of the series, α is the slope coefficient, $\beta_1, \beta_2, \beta_3$ represent the short-term relationship between the variables, and $\delta_1, \delta_2, \delta_3$ represent the long-term relationship between the variables.

In the bounds test approach developed by Pesaran, Shin and Smith (2001), the existence of a long-term cointegration relationship within the framework of Eq. (3) is tested with the null hypothesis *H0: δ1 = δ2 = δ3 = 0* (no cointegration). Pesaran, Shin and Smith (2001) offer two different critical values (lower and upper limits) depending on whether the explanatory variables are I(0) or I(1). If the calculated F-statistic is below the lower limit, the null hypothesis cannot be rejected; if it is above the upper limit, the null hypothesis is rejected, and the existence of a cointegration relationship is accepted. If the F-statistics fall between these two limits, the test result is considered inconclusive.

If a cointegration relationship is detected between the variables, Eq. (4) is re-estimated by adding an unrestricted error correction term (θECM_{t-1}) to the equation in order to model the convergence process to long-term equilibrium.

$$\Delta lnCI_t = \alpha_0 + \sum_{i=1}^{n} \beta_1 \Delta lnCI_{t-i} + \sum_{i=0}^{n} \beta_2 \Delta lnEI_{t-i} + \sum_{i=0}^{n} \beta_3 \Delta lnKL_{t-i} + \theta ECM_{t-1} + \varepsilon_t \quad (4)$$

The Δ operator represents the first differences of the variables, enabling the analysis of short-term dynamics, while the error term ε_t, represents the white noise process without autocorrelation. The term ECM_{t-1} in the equation shows the deviation of the carbon intensity ($\Delta lnCI_t$) from the long-term equilibrium value. The coefficient θ for this term captures the adjustment mechanism that corrects this deviation and returns the system to equilibrium. For the system to effectively return to its long-term equilibrium, the coefficient θ is expected to be negative and statistically significant.

4. FINDINGS

4.1. Unit Root Tests

One of the fundamental assumptions in time series analysis is that the variables used are stationary; therefore, stationarity tests are of critical importance. For the ARDL bounds test to be applicable, the series must be stationary at the level (I(0)) or at the first difference (I(1)). However, if the series becomes stationary at the second difference (I(2)), the ARDL bounds test cannot be used (Pesaran, Shin and Smith, 2001). In this context, the ADF (Augmented Dickey-Fuller) and PP (Phillips-Perron) stationarity tests were applied in this study; the series were examined both at the level and at

their first differences. The analysis results show that not all series are stationary at the level, but they become stationary when their first differences are taken, and these findings are presented in Table 2.

Table 2. Unit Root Test Results

ADF unit root test		
	Constant	Trend + Constant
LNCI	-2.134	-0.915
LNEI	-3.156	-0.737
LNKL	-2.187	-2.913
ΔLNCI	-7.516***	-9.063***
ΔLNEI	-7.256***	-9.473***
ΔLNKL	-5.441***	-5.626***
PP unit root test		
	Constant	Trend + Constant
LNCI	-2.132	-0.497
LNEI	-3.226	-0.272
LNKL	-1.846	-2.771
ΔLNCI	-7.521***	-11.215***
ΔLNEI	-7.341***	-11.183***
ΔLNKL	-5.409***	-5.607***

Note: In the ADF and PP unit root test, the critical values for the constant model at the 1%, 5% and 10% statistical significance levels are -3.548, -2.912, -2.594 respectively, while for the trend and constant models they are -4.124, -3.489, -3.173. In their first differences, the values are -3.550, -2.913, -2.594 for the constant model and -4.127, -3.490, -3.173 for the trend and constant models. Accordingly, each variable is stationary in its first differences (I(1)) at the 1% significance level.

4.2. ARDL Bound Test

In the ARDL bounds test model examining the effect of energy intensity and capital deepening on carbon intensity in Türkiye, the adjusted-R^2 value of the estimated model reached a high level of approximately 94%. In other words, energy intensity and capital deepening explain approximately 94% of the variations in carbon intensity. Diagnostic tests of the model showed that, according to the Breusch-Godfrey series correlation test, there was no autocorrelation up to the fourth order in the model residuals (LM = 0.578, p = 0.966). The ARCH LM test indicated that there was no conditional heteroskedasticity effect in the residuals (χ^2 = 10.184, p = 0.600). The Jarque-Bera normality test revealed that the hypothesis that the model residuals follow a normal distribution could not be rejected (χ^2 = 4.681, p = 0.096). According to the Ramsey RESET test result, there was no specification error in the model; This finding indicates that the established model is appropriate in terms of functional form (F = 0.945, p = 0.395).

The F statistics (F=10.276) obtained from the bounds test applied to examine the existence of a long-term cointegration relationship between the variables exceeds the upper critical limit value (4.61) at the 1% significance level determined by Pesaran, Shin and Smith (2001) for k=2. This finding

indicates the existence of a long-term cointegration relationship between carbon intensity, energy intensity, and capital deepening; thus, it allows for the estimation of ARDL long-term coefficients.

Table 3. ARDL Results

Panel A: Bounds Test		
F-statistics	10.276***	
Selected ARDL model	ARDL(1, 0, 0)	
Critical values (k=2) of Pesaran, Shin and Smith (2001)	**Lower Limit I(0)**	**Upper Limit I(1)**
%1	3.88	4.61
%5	3.23	3.83
%10	2.72	3.28
Panel B: Short-Term Coefficients		
Variable	**Coefficient**	**Std. error**
Constant	8.318***	1.971
$LNCI_{t-1}$	0.582***	0.101
LNEI	0.433***	0.107
LNKL	-0.048***	0.010
Panel C: Long-Term Coefficients		
Sabit	19.912***	1.265
LNEI	1.037***	0.085
LNKL	-0.116***	0.024
Panel D: Error correction model (ECM)		
ECT	-0.418***	0.074
Panel E: Diagnostic Tests		
R^2	0.949	
Adjusted-R^2	0.946	
F-statistics	333.880 (0.000)***	
Breusch-Pagan-Godfrey	3.271 (0.352)	
Breusch-Godfrey LM	0.578 (0.966)	
Jarque-Bera	4.681 (0.096)	
ARCH LM	10.184 (0.600)	
Ramsey RESET	0.945 (0.395)	
CUSUM / $CUSUM^2$	Stable/ Stable	

Note: Values in parentheses indicate p-values. ***, **, and * indicate significance levels of 1%, 5%, and 10%, respectively. k indicates the number of independent variables.

In Table 3, Panel B provides short-term coefficients, while Panel C provides long-term coefficients. Examining the short-term estimation results, it is observed that the short-term effect of

energy intensity on carbon intensity is statistically significant and positive (β=0.433, p<0.001). Accordingly, a 1% increase in energy intensity increases carbon intensity by approximately 0.43% in the short term. The short-term coefficient for capital deepening, however, is negative and statistically significant (β=−0.048, p<0.001). This finding indicates that capital accumulation plays a role in reducing carbon intensity in the short term.

When the long-term estimation results are examined, it is seen that the effect of energy intensity on carbon intensity is positive and statistically significant (β=1.037, p<0.001). This finding indicates that a 1% increase in energy intensity increases carbon intensity by approximately 1.04% in the long term. This finding is consistent with the results of Shahbaz, Solarin, Sbia and Bibi (2015) and Rahman, Sultana and Velayutham (2022). Indeed, Rahman, Sultana and Velayutham (2022), in their model developed specifically for Türkiye, found that a one-unit increase in energy intensity increased carbon intensity by 2.616 units. In that study, similar to the current research, it is observed that the short-term effects are lower compared to the long-term effects; since Rahman, Sultana and Velayutham (2022) found a positive relationship between energy intensity and carbon intensity in the short term, represented by a coefficient of 0.811, and this value is below the long-term coefficient. This finding indicates that the effect of changes in energy intensity on carbon intensity continues to strengthen over time. The long-term coefficient of capital deepening was found to be negative and statistically significant (β=−0.116, p<0.001). This result indicates that capital accumulation reduces carbon intensity in the long run, and therefore, capital deepening contributes to the relative reduction of carbon emissions in Türkiye. In other words, when capital deepening increases by 1% in the long run, carbon intensity decreases by 0.12%. One possible reason for this is that capital deepening facilitates the adoption of cleaner and more sustainable production technologies. Such technologies improve environmental performance by reducing carbon emissions per unit of output. Indeed, the study by Guerini, Marin and Vona (2025) empirically shows that loosening financial constraints (i.e., policies that encourage capital deepening by lowering the cost of capital) significantly reduces emissions, especially in small and medium-sized enterprises. These findings demonstrate that the emissions reduction caused by financial easing is driven by mechanisms such as increased energy efficiency and a cleaner energy mix. Therefore, the evidence presented by Guerini, Marin and Vona (2025) empirically confirms the importance of adopting cleaner and more sustainable production technologies and that access to credit and cost of capital play a decisive role in this process. Cole and Elliott (2003) conceptualize this process using scale effect, technical effect, and composition effect. According to the scale effect, emissions increase as the economy grows. Therefore, capital deepening increases production, which alone has an emission-increasing effect. According to the technical effect, as income increases, environmental regulations tighten and trigger the transition to clean technologies. In other words, capital deepening, accompanied by the right policy framework, facilitates the transition to clean technologies. The composition effect refers to the specialization of countries according to their comparative advantages. In this context, two opposing

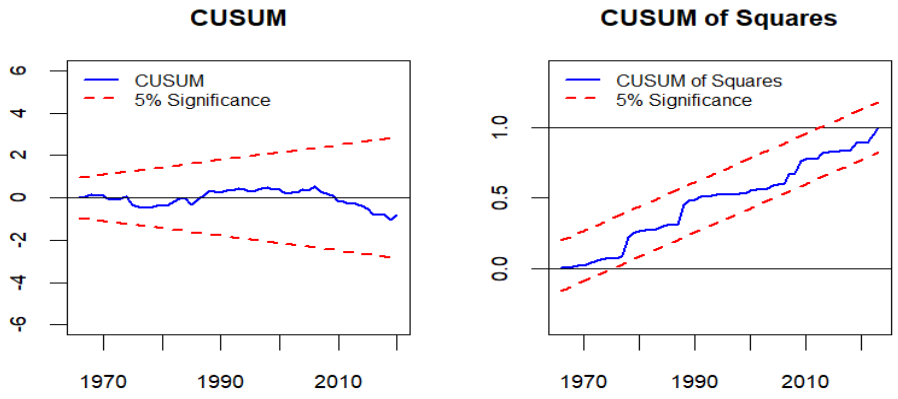
forces have been identified: The Capital-Labor Effect (KLE) leads capital-intensive countries to specialize in polluting production, while the Environmental Regulation Effect (ERE) enables countries with high environmental standards to specialize in clean production. In this framework, since pollution-intensive sectors are also capital-intensive, capital deepening alone does not reduce carbon intensity. On the contrary, for a reduction to occur, the technical effect (transition to clean technology) must be stronger than the composition effect, and capital must be directed towards the right technologies.

From Türkiye's perspective, it is observed that in the period before 2015, the composition (in the direction of the KLE) was dominant; in other words, despite the increase in capital deepening, there was no significant decrease in carbon intensity due to the predominance of capital-intensive polluting sectors. However, in the period after 2015, it is noteworthy that carbon intensity began to decrease while capital deepening continued to increase (See Fig. 1). The main reason for this transformation is that policies such as the Renewable Energy Resources Support Mechanism (YEKDEM) strengthen the technical effect, directing capital towards clean technologies and thus balancing the negative impact of the composition effect.

In Türkiye, the differentiated feed-in tariff incentives in US dollars, provided under the YEKDEM (2011 regulation with Law No. 6094), have significantly increased renewable energy investments, especially in solar energy. Indeed, the total number of applications to YEKDEM increased from 234 in 2015 to 1034 in 2022 (EPDK, 2025). This increase demonstrates the effective role of incentive policies in directing capital towards clean technologies. In light of this periodic data, it can be said that capital deepening in Türkiye, especially after 2015, accompanied by appropriate policy incentives (YEKDEM), has facilitated the transition to cleaner production technologies and thus contributed to a reduction in carbon intensity. This finding is consistent with the theoretical prediction of Cole and Elliott (2003) (that ERE can balance KLE) and Guerini, Marin and Vona (2025) empirically demonstrates a financial easing channel, which is supported specifically for Türkiye.

The results obtained from the error correction model (Table 3, Panel D) reveal that the coefficient of the error correction term (ECT) is negative and statistically significant ($\beta=-0.418$, $p<0.001$). This finding confirms the existence of a long-term equilibrium relationship and indicates that imbalances occurring in the short term are corrected over time. The magnitude of the coefficient shows that approximately 41.8% of the imbalance that occurred in the previous period is corrected in the following period, in other words, the convergence time to long-term equilibrium is approximately 2.4 years.

Figure 2. CUSUM and CUSUMSQ



Note: The horizontal axis shows the observation period, and the vertical axis shows the cumulative value of the CUSUM and CUSUMSQ test statistics. Dashed lines represent the critical limits at the 5% significance level.

To assess the structural stability of the model parameters, CUSUM and CUSUM of Squares tests were applied. In both tests, the statistical values remained within the critical limits at the 5% significance level throughout the sample period. These findings indicate that the model coefficients and variance exhibit structural stability throughout the relevant period and that there is no structural break in the model.

5. CONCLUSION

This study aims to analyse the short- and long-term effects of energy intensity and capital deepening on carbon intensity in Türkiye during the period 1965-2023 using the ARDL approach.

The analysis results show that energy intensity positively and significantly affects carbon intensity in both the short and long term. In the short term, a 1% increase in energy intensity increases carbon intensity by 0.43%, while this effect increases to 1.04% in the long term. The findings indicate an almost complete pass-through from energy intensity to carbon intensity, consistent with Shahbaz, Solarin, Sbia and Bibi (2015) and Rahman, Sultana and Velayutham (2022). This result confirms the existence of an energy efficiency problem in Türkiye's production structure; as stated in the literature by Hajiyev, Guliyev, Abdullayeva and Abdullayeva (2023) and Metcalf (2008), reducing energy intensity is possible either by switching to less energy-intensive technologies or by moving away from energy-intensive activities. In the case of Türkiye, the long-term increase in energy consumption per unit of GDP shows that these channels are not functioning sufficiently.

The empirical analysis further indicates that capital deepening exerts a statistically significant negative effect on carbon intensity in both the short and long run. Specifically, a 1% increase in capital deepening is associated with a 0.048% reduction in carbon intensity in the short term, with this effect intensifying to 0.12% in the long term. Nevertheless, despite the persistent and substantial increase in

Türkiye's capital deepening over the period under examination, energy and carbon intensity have not decreased to the expected level. This divergence suggests that capital deepening alone cannot be relied upon as a sufficient mechanism for reducing carbon intensity; rather, the environmental outcome critically depends on the technological direction of investment. Indeed, Türkiye's energy profile (with 85% of its total energy supply consisting of fossil fuels as of 2024) and the fact that capital accumulation throughout the 1965-2023 period has largely occurred through low-efficiency and fossil fuel-based technologies explain this finding.

Findings carry significant implications for the design of future energy policies. Capital deepening, when complemented by well-designed incentive mechanisms, can facilitate the transition toward cleaner production technologies and thereby contribute to the reduction of carbon intensity. The case of Türkiye provides concrete evidence in this regard. Although the first YEKDEM, introduced in 2005, failed to achieve the expected effectiveness, the 2011 revision, which introduced technology-specific pricing and dollar-denominated purchase guarantees, triggered a substantial surge in investments, particularly in solar and wind power. The number of YEKDEM applications increased from 204 in 2011 to 1,034 in 2022, and with renewable sources projected to account for 62% of total installed capacity by 2025, it becomes evident that capital accumulation can indeed be steered toward clean technologies.

In conclusion, this study shows that energy intensity remains the most important determinant of Türkiye's carbon intensity, and energy efficiency policies should be central to decarbonization efforts. Furthermore, capital deepening neither automatically reduces nor inevitably increases carbon intensity; the environmental outcome of this process depends entirely on the technologies to which investments are directed. Properly designed incentive mechanisms can effectively direct capital accumulation towards clean technologies. Finally, Türkiye's post-2011 YEKDEM experience contains important lessons for developing countries regarding the integration of capital deepening with environmental sustainability.

REFERENCES

Acemoğlu, D., & Guerrieri, V. (2008). Capital deepening and non-balanced economic growth. *Journal of Political Economy, 116*(3), 467–498.

Adebayo, T. S., Agyekum, B. E., Kamel, S., Zawbaa, H. M., & Altuntaş, M. (2022). Drivers of environmental degradation in Turkey: Designing an SDG framework through advanced quantile approaches. *Energy Reports, 8*(29), 2008–2021.

Akal, M. (2016). Modeling of energy intensity in Turkey. *Energy Sources, Part B: Economics, Planning, and Policy, 11*(9), 807–814.

Altinöz, B., Vasbieva, D., & Kalugina, O. (2021). The effect of information and communication technologies and total factor productivity on CO2 emissions in top 10 emerging market economies. *Environmental Science and Pollution Research, 28*, 63784–63793.

Aterido, R., Iootty, M., & Melecky, M. (2025). *Energy prices, energy intensity, and firm performance* (Policy Research Working Paper 11069). World Bank Group.

Baştan Töke, L. (2025). *EKC hipotezi çerçevesinde enerji piyasası ile enerji, çevre ve ekonomi ilişkisi: Avrupa Birliği ve Türkiye için panel veri analizi*. Necmettin Erbakan Üniversitesi Sosyal Bilimler Enstitüsü.

Bostan, F., & Karadağ, M. (2022). The decisive role of sectoral technology intensity in the impact of international technology diffusion on innovation performance: An empirical application on the Turkish manufacturing industry. *Doğuş Üniversitesi Dergisi, 23*(2), 379–399.

British Petroleum (BP). (2025). *2025 statistical review of world energy*. https://www.energyinst.org/statistical-review

Can, Z. G. (2025). Distributional drivers of carbon emissions in Turkiye. *Sustainability, 17*, 4023.

Chen, C. (2020). Technology adoption, capital deepening, and international productivity differences. *Journal of Development Economics, 143*, 102388.

Chen, S. Y., & Golley, J. (2014). Green productivity growth in China's industrial economy. *Energy Economics, 44*, 89–98.

Cole, M. A., & Elliott, R. J. R. (2003). Determining the trade–environment composition effect: The role of capital, labor and environmental regulations. *Journal of Environmental Economics and Management, 46*(3), 363–383.

Çetin, M., Kırcı, B., Saygın, S., & Alaşahan, Y. (2018). Economic growth, financial development, energy consumption and foreign trade impact on the environmential: A causality analysis for Turkish economy (1960–2013). *Balkan Journal of Social Sciences, 7*(13), 26–43.

Dellink, R., Hwang, H., Lanzi, E., & Chateau, J. (2017). *International trade consequences of climate change* (OECD Trade and Environment Working Papers No. 2017/01).

Demiralp, A. (2024). Energy consumption and carbon intensity in Türkiye: Cointegration and causality approach. In E. Arı (Ed.), *Ekonometride ileri yaklaşımlar* (pp. 117–128). Yaz Yayınları.

Demiralp, A. (2025). CO2 emissions, energy intensity and economic growth: Cointegration and causality analysis for Türkiye. *Dicle University Journal of Economics and Administrative Sciences, 15*(30), 590–608.

Demirsoy, G., & Sözen, A. (2025). Binalarda enerji verimliliğinin toplam faktör etkinliği. *Journal of Polytechnic*.

Díaz, A., Marrero, G. A., Puch, L. A., & Rodríguez, J. (2019). Economic growth, energy intensity and the energy mix. *Energy Economics, 81*, 1056–1077.

Ding, J., & Zhou, Y. (2021). Did the Labor Contract Law affect the capital deepening and efficiency of Chinese private firms? *China & World Economy, 29*, 105–126.

Doğanlar, M., Mike, F., Kızılkaya, O., & Karlılar, S. (2021). Testing the long-run effects of economic growth, financial development and energy consumption on CO2 emissions in Turkey: New evidence from RALS cointegration test. *Environmental Science and Pollution Research, 28*, 32554–32563.

Du, S., Baskaran, A., & Chandran, V. G. R. (2025). The agriculture productivity puzzle: Capital deepening and agricultural productivity in China. *African Journal of Science, Technology, Innovation and Development, 17*(5), 767–779.

Durgun, B. (2025). The asymmetric effect of income inequality in reducing carbon intensity: Does institutional quality matter? *Fiscoeconomia, 9*(1), 656–685.

Eken, A. A., & Yazıcı, D. (2024). Possible effects of carbon border adjustment mechanism on Türkiye's EU export. *Başkent Üniversitesi Ticari Bilimler Fakültesi Dergisi, 8*(1), 1–15.

EPDK. (2025). *Elektrik piyasası yenilenebilir enerji kaynakları destekleme mekanizması (YEKDEM) listesi*. Enerji Piyasası Düzenleme Kurumu.

European Commission. (2025a). *Carbon border adjustment mechanism*. https://taxation-customs.ec.europa.eu/carbon-border-adjustment-mechanism_en

European Commission. (2025b). *EU trade relations with Türkiye: Facts, figures and latest developments*. https://policy.trade.ec.europa.eu/eu-trade-relationships-country-and-region/countries-and-regions/turkiye_en

Fan, M. T., Shao, S., & Yang, L. L. (2015). Combining global Malmquist-Luenberger index and generalized method of moments to investigate industrial total factor CO2 emission performance: A case of Shanghai (China). *Energy Policy, 79*, 189–201.

Ge, M., Friedrich, J., & Vigna, L. (2024). *Where do emissions come from? 4 charts explain greenhouse gas emissions by sector*. World Resource Institute.

Glover, A., & Short, J. (2020). Can capital deepening explain the global decline in labor's share? *Review of Economic Dynamics, 35*, 35–53.

Gokmenoglu, K. K., Taspinar, N., & Rahman, M. M. (2021). Military expenditure, financial development and environmental degradation in Turkey: A comparison of CO2 emissions and ecological footprint. *International Journal of Finance & Economics, 26*(1), 986–997.

Guerini, M., Marin, G., & Vona, F. (2025). *Can easing financial constraints reduce carbon emissions? Evidence from a large sample of French companies* (Grantham Research Institute on Climate Change and the Environment Working Paper No. 437). London School of Economics and Political Science.

Gül, E., & İnal, V. (2017). Hava kirliliği ve ekonomik büyüme ilişkisi: Zamanla değişen panel nedensellik analizi. *Sakarya İktisat Dergisi, 6*(2), 70–82.

Hajiyev, N., Guliyev, V., Abdullayeva, S., & Abdullayeva, E. (2023). Energy intensity of the economy in the context of rethinking growth within a limited planet. *Energy Strategy Reviews, 50*, 101246.

Hao, Z., & Wang, X. (2025). Total factor carbon emission productivity in China's manufacturing industry: A study considering indirect carbon emissions. *Frontiers in Environmental Science, 13*, 1517645.

Hong, H., Sun, L., & Zhao, L. (2024). Exploring the impact of digital inclusive finance on agricultural carbon emissions: Evidence from the mediation effect of capital deepening. *Sustainability, 16*(7), 3071.

Huang, J. (2018). Investigating the driving forces of China's carbon intensity based on a dynamic spatial model. *Environmental Science and Pollution Research, 25*(22), 21833–21843.

IQAir. (2025). *Air quality in Turkey*. https://www.iqair.com/turkey

İlkdoğan, S., & Sakarya, Ş. (2025). The impact of carbon intensity on firm value: An application in BIST Sustainability Index. *Pamukkale University Journal of Business Research, 12*(1), 1–17.

İskender, Ü., & Sözen, A. (2016). Total factor productivity change of Turkey's energy intensity. *Energy Sources, Part B: Economics, Planning, and Policy, 11*(2), 165–175.

Kara, F. (2026). The impact of renewable energy consumption on carbon emissions in Türkiye: An application of the augmented ARDL approach. *Turkish Journal of Agricultural and Natural Sciences, 13*(1), 113–128.

Kazemzadeh, E., Fuinhas, J. A., Shirazi, M., Koengkan, M., & Silva, N. (2023). Does economic complexity increase energy intensity? *Energy Efficiency, 16*(29).

Ke, N., Chen, J., & Cheng, T. (2024). The drivers of carbon intensity and emission reduction strategies in heavy industry: Evidence from nonlinear and spatial perspectives. *Ecological Indicators, 160*, 111764.

Khurshid, N., Fiaz, A., Khurshid, J., & Ali, K. (2022). Impact of climate change stocks on economic growth: A new insight from nonlinear analysis. *Frontiers in Environmental Science, 10*.

Kongkuah, M., & Alessa, N. (2025). Renewable energy and carbon intensity: Global evidence from 184 countries (2000–2020). *Energies, 18*, 3236.

Kumar, S., & Russell, R. R. (2002). Technological change, technological catch-up, and capital deepening: Relative contributions to growth and convergence. *American Economic Review, 92*(3), 527–548.

Li, G., Zheng, S., Li, T., Peng, Q., & Irfan, M. (2023). Analysing the effect of energy intensity on carbon emission reduction in Beijing. *International Journal of Environmental Research and Public Health, 20*, 1379.

Ling, Y., Xia, S., Cao, M., He, K., Lim, M. K., Sukumar, A., Yi, H., & Qian, X. (2021). Carbon emissions in China's thermal electricity and heating industry: An input-output structural decomposition analysis. *Journal of Cleaner Production, 329*, 129608.

Liu, L., & Wang, Q. (2022). Is the effect of human activity on air pollution linear or nonlinear? Evidence from Wuhan, China, under the COVID-19 lockdown. *Cities, 127*, 103752.

Lynch, P. (2019). How Joseph Fourier discovered the greenhouse effect. *The Irish Times*.

Madsen, J. B. (2010). Growth and capital deepening since 1870: Is it all technological progress? *Journal of Macroeconomics, 32*(2), 641–656.

Metcalf, G. E. (2008). An empirical analysis of energy intensity and its determinants at the state level. *The Energy Journal, 29*(3).

Mirziyoyeva, Z., & Salahodjaev, R. (2022). Renewable energy and CO2 emissions intensity in the top carbon intense countries. *Renewable Energy, 192*, 507–512.

Mukhtarov, S. (2024). Do renewable energy and total factor productivity eliminate CO2 emissions in Turkey? *Environmental Economics and Policy Studies, 26*, 307–324.

Naimoğlu, M., & Özbek, S. (2022). Do energy prices and industrialization affect energy intensity? The case of Turkey under structural breaks. *Bingol University Journal of Economics and Administrative Sciences, 6*(2), 275–294.

Owyang, M. T., & Shell, H. (2018). *How capital deepening affects labor productivity*. Federal Reserve Bank of St. Louis.

Özay, Ö. (2015). Is capital deepening process male-biased? The case of Turkish manufacturing sector. *Structural Change and Economic Dynamics, 35*, 26–37.

Pamuk, Ş. (2017). *Türkiye'nin 200 yıllık iktisadi tarihi* (7. basım). Türkiye İş Bankası Kültür Yayınları.

Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics, 16*(3), 289–326.

Rahman, M. M., Sultana, N., & Velayutham, E. (2022). Renewable energy, energy intensity and carbon reduction: Experience of large emerging economies. *Renewable Energy, 184*, 252–265.

Republic of Türkiye Ministry of Trade. (2025). *AB SKDM bilgi notu*.

Shahbaz, M., Solarin, S. A., Sbia, R., & Bibi, S. (2015). Does energy intensity contribute to CO2 emissions? A trivariate analysis in selected African countries. *Ecological Indicators, 50*, 215–224.

Shao, S., Luan, R., Yang, Z., & Li, C. (2016). Does directed technological change get greener: Empirical evidence from Shanghai's industrial green development transformation. *Ecological Indicators, 69*, 758–770.

Shen, D., Liang, H., & Shi, W. (2023). Rural population aging, capital deepening, and agricultural labor productivity. *Sustainability, 15*(10), 8331.

Sheng, Y. (2025). Technological change, capital deepening, and agricultural total factor productivity (TFP) growth: Cross-country comparison of 18 OECD countries. *Applied Economic Perspectives and Policy, 47*(5), 1848–1868.

Sheng, Y., Ball, E., Erickson, K., & Mesonada, C. S. J. (2022). Cross-country agricultural TFP convergence and capital deepening: Evidence for induced innovation from 17 OECD countries. *Journal of Productivity Analysis, 58*(2), 185–202.

Sueyoshi, T., & Goto, M. (2023). Energy intensity, energy efficiency and economic growth among OECD nations from 2000 to 2019. *Energies, 16*(4), 1927.

Şenses, F. (2014). Zor yıllarda sanayileşme: 1970'li yıllarda Türkiye deneyimi. In A. F. Barbaros & E. J. Zurcher (Eds.), *Modernizmin yansımaları: 70'li yıllarda Türkiye* (pp. 43–67). Efil Yayınevi.

Şimşek, N. (2011). Environmental efficiency and total factor productivity of Turkey: A comparative analysis. *Ege Academic Review, 11*(3), 379–396.

Tuğcu, C. T. (2013). Disaggregate energy consumption and total factor productivity: A cointegration and causality analysis for the Turkish economy. *International Journal of Energy Economics and Policy, 3*(3), 307–314.

Tudor, C. D., Horobet, A., Mnohoghithei, I., Sova, R., & Belascu, L. (2023). Decarbonization through carbon intensity mitigation: Evidence from global and income-based panels. *Economic Research-Ekonomska Istraživanja, 36*(3), 2188420.

Tzeremes, P. (2020). The impact of total factor productivity on energy consumption and CO2 emissions in G20 countries. *Economics Bulletin, 40*(3).

UNFCCC. (2025). *The Paris Agreement*. https://unfccc.int/process-and-meetings/the-paris-agreement

Wang, D., & Qiao, Z. (2022). The influence of capital deepening on regional economic development gap: The intermediary effect of the labor income share. *Sustainability, 14*(24), 16853.

Wang, D., Zhou, Y., Ding, J., & Wang, W. (2019). The role of capital deepening in China's energy transition. *Chinese Journal of Population Resources and Environment, 17*, 197–202.

Wu, Y., Wu, B., Liu, X., & Zhang, S. (2025). Digital finance and agricultural total factor productivity-from the perspective of capital deepening and factor structure. *Finance Research Letters, 74*, 106449.

Xiao, Z. (2022). *Labor exposure to climate change and capital deepening*. SSRN.

Xu, C., Zhu, Q., Li, X., Wu, L., & Deng, P. (2024). Determinants of global carbon emission and aggregate carbon intensity: A multi-region input-output approach. *Economic Analysis and Policy, 81*, 418–435.

Yıldız, M. (2023). The role of economic factors in Turkey's carbon neutrality target. *Journal of Research in Economics, Politics & Finance, 8*(1), 102–129.

Yu, S., Hu, X., Li, L., & Chen, H. (2020). Does the development of renewable energy promote carbon reduction? Evidence from Chinese provinces. *Journal of Environmental Management, 268*, 110634.

Yücel, M. E., & Kaplan, M. (2025). The impact of energy consumption composition on carbon emissions in Türkiye: An empirical ARDL analysis. *Journal of Academic Projection, 10*(2), 536–566.

Zhang, K., Yao, F. E., Qian, X. Y., Zhang, Y. F., Liang, Q. M., & Wei, Y. M. (2024). Could the EU Carbon Border Adjustment Mechanism promote climate mitigation? An economy-wide analysis. *Advances in Climate Change Research, 15*, 557–571.

Zhang, W. (2020). The dynamic correlation between capital deepening and total factor productivity in China. *Journal of Advanced Computational Intelligence and Intelligent Informatics, 24*, 524–531.

Zhang, X., Song, X., Fan, M., Huang, B., Yang, H., Shao, S., & Geng, Y. (2025). Toward carbon peak in China's manufacturing sector: Robot adoption and capital-embodied technological progress. *Journal of Industrial Ecology, 29*, 2429–2441.

Zhao, P., Hu, G., & Jin, P. (2023). Biased technical change, capital deepening, and efficiency of environmental regulations: Evidence from the Chinese provinces. *Technological Forecasting and Social Change, 191*, 122453.

Zhou, Z., & Zhong, S. (2025). Impact of legal commitments on carbon intensity: A multi-country perspective. *Journal of Environmental Management, 373*, 123696.

Zymek, R. (2024). *Total factor productivity: How can economies do more with less?* International Monetary Fund.

EVALUATION OF THE COMPLIANCE OF THE COURT OF ACCOUNTS REFORM IN TÜRKİYE WITH INTERNATIONAL STANDARDS

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ABSTRACT

The reform of the Court of Accounts in Türkiye was primarily shaped within the framework of the new Court of Accounts Law No. 6085, adopted in 2010. The reform process represents a transition from the traditional approach of compliance auditing to a system of performance and financial auditing aligned with international standards. Within the scope of international harmonization, the auditing approach of the Court of Accounts was restructured in accordance with the principles of transparency, accountability, and performance-oriented auditing promoted by the International Organization of Supreme Audit Institutions (INTOSAI) and the European Organization of Supreme Audit Institutions (EUROSAI). With the adoption of performance and system auditing, the Court of Accounts has evolved beyond merely examining whether public expenditures comply with legal and procedural requirements. It has become a supreme audit institution that evaluates public administrations in terms of economy, efficiency, and effectiveness. Through Law No. 6085, performance auditing was incorporated alongside regularity auditing as one of the principal components of the Court's auditing functions. One of the significant dimensions of the reform concerns judicial accountability in public financial management. The Court of Accounts possesses the authority to issue final judgments regarding public losses arising from the accounts and transactions of public officials. The reform process reorganized this judicial function through mechanisms designed to operate in a more independent, efficient, and internationally compatible manner. In this regard, structural changes introduced in the reporting processes of the Court of Accounts have facilitated public access to information and contributed to strengthening fiscal discipline within public administration. This study aims to examine the impact of the Court of Accounts reform in Türkiye on transparency and accountability through empirical data and to evaluate the outcomes of the reform process. Secondary data obtained from the official reports of the Turkish Court of Accounts will be utilized to assess the extent to which the reform has implemented INTOSAI and EUROSAI standards. In addition, the periods before and after the implementation of Law No. 6085 will be comparatively analyzed through quantitative indicators.

Keywords: *Court of Accounts, Audit, Transparency, Accountability, Judicial Accountability.*

JEL Codes: *H11, H83, M42.*

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1. INTRODUCTION

The role of the democratic legitimacy function of auditing has become even more prominent in the post-welfare state period, while the interaction between the Supreme Audit Institutions (SAIs) and parliaments has been constantly changing. Parliaments have also been involved in the processes of legislative and political control and have played an active part in the rationalization of the bureaucratic mechanisms. SAIs are responsible for giving the public assurance that public resources are being managed well, and also to publicize their audit findings. By doing so, they help to improve public auditing's effectiveness and usability. After the Second World War, the Supreme Audit Institutions of developed nations institutionalized and adopted the new methods of auditing. They also launched an initiative to make other countries' SAs benefit from these developments. At the same time, an international institutional framework was set up to promote coordination and foster institutional connections between the Supreme Audit Institutions of all United Nations member states across the world. The Turkish Court of Accounts model is a Continental European model because of its institutional history and judicial powers, among the audit models applied globally. Law No. 6085 on the Turkish Court of Accounts made the Turkish Court of Accounts more modern and closer to the international auditing standards adopted by the International Organization of Supreme Audit Institutions (INTOSAI), and extended its powers of auditing.

2. SUPREME AUDIT WORLDWIDE

Access to neutral and trustworthy information is vital for improving the efficiency of the bureaucracy, for transparency and for involving the public in decision-making processes. Any policy or programme based on principles of good governance can achieve its desired goals only if it builds trust in the public. Fiscal transparency and accountability is also one of the basic control mechanisms of good governance (Köse, 2007).

The procedures used to consider the reports issued by Supreme Audit Institutions also differ depending on the institutional set up of each country. These reports can be examined at the national level by Audit Committees, Finance Committees, Research Committees or Parliamentary Public Accounts Committees. Thus, the way in which the results of the SAI reports are made public can differ depending on the organizational structure and institutional model of the various Supreme Audit Institutions (Yalçın, 2017).

3. INTERNATIONAL STANDARDS: INTOSAI, THE LIMA DECLARATION, AND THE MEXICO DECLARATION

The International Organization of Supreme Audit Institutions (INTOSAI) was founded in 1953. In 1984, INTOSAI started work on the standards for public-sector auditing through its Auditing Standards Committee. INTOSAI Auditing Standards were first published from 1991 on, which is in line with the latest advances in audit methodology and practice. The International Standards of Supreme

Audit Institutions (ISSAIs) and the INTOSAI Guidelines for Good Governance (INTOSAI GOV) are published today by INTOSAI.

a. The Lima Declaration

The IX Congress of INTOSAI in Lima in 1977 established the Lima Declaration as a fundamental document of public sector auditing which is considered to be the most important document in the INTOSAI hierarchy of standards. The Declaration is not a legally binding document, but it has been a very influential document in the evolution of global auditing standards (INTOSAI, 2018).

SAIs are able to carry out their tasks objectively and effectively only when they are independent from the entities they audit and protected from outside influence. According to Lima Declaration, the purpose of Public-sector auditing is to detect the "deviations from accepted standards, and violations of the principles of legality, efficiency, effectiveness and economy in financial management as early as possible to enable correction in individual cases, hold those responsible to account, recover compensation, or take steps to prevent the violations or make them more difficult" (Al Amini, 2021). In addition, the Declaration is clear on the different kind of audits – legality, regularity and performance – stating that all these audits are equally important. Performance auditing, especially, is seen as part and parcel of the evaluation of the economy, efficiency and effectiveness of public administration.

The Congress has laid down guidelines for effective pre-audit, which is essential for proper management of public money put at the disposal of the state. In the government department and institutions, internal audit units are set up, while external audit bodies are not integrated into the organization of the institutions to be audited. Supreme Audit Institutions are independent audit institutions. The heads of the institutions in which the internal audit units are established are their bosses. However, in their respective constitutions, they should be functionally and organizationally independent as much as possible. One of the key functions of Supreme Audit Institutions (SAI) is to review the legality and regularity of financial management and accounting. Apart from this type of audit, another type of audit is equally important that is performance auditing which is conducted for examining the performance, economy, efficiency and effectiveness of public administration. If SAIs are not independent of the audited entities and free from external influences, they cannot exercise their functions objectively and effectively. While the institutions of the State cannot be truly independent, because they are part of the State as a whole, they must have a sufficient level of independence to carry out their tasks effectively.

The establishment of Supreme Audit Institutions and the degree of their independence should be laid down in the Constitution. Good legal safeguards also ought to be put in place to prevent interference or manipulation in the auditing and independence of the Supreme Audit Institutions. International exchange of ideas and experiences in the context of the International Organization of Supreme Audit Institutions is an effective way to assist SAIs in carrying out their work. It is significant for this reason

that uniform terminology for publicsector auditing based on comparative law is being developed. Supreme Audit Institutions must report to parliament or other appropriate public institutions independently every year. Such reports should also be available to the public. Moreover, with the generous public funding allocated to public institutions for contracts and public works, the need exists to audit their use of these funds (INTOSAI-P, 2019a).

b. The Mexico Declaration

In 2007, the Mexico Declaration on Supreme Audit Institution Independence was adopted, which is one of the most important documents that provide a soft-law framework for improving the autonomy and effectiveness of Supreme Audit Institutions (SAIs) globally. The Mexico Declaration builds on the principles highlighted in the Lima Declaration and presents eight core principles for the independence of SAIs, including having an appropriate and effective constitutional and legal framework. These principles can serve as a guide for countries to adapt and enhance their SAI systems, and ensure alignment with international best practices.

The Declaration states a series of principles agreed to and adopted. An adequate legislative structure for the independent functioning of the SAIs is necessary. Appointments, re-appointment, employment, removal and retirement of the heads of SAIs and members of collegial institutions should be regulated by relevant legislation, which sets out the conditions for such appointments. They should be appointed or removed by processes which guarantee their independence from any administrators of the school. Their appointments should be for sufficiently long and fixed terms, so that they can carry out their duty without having the fear of retaliation. Moreover, they should be shielded from prosecution of any acts committed in connection to the normal performance of their duties in the past or present.

SAIs shall have the power to audit the use of public funds, resources and assets, whether legal or otherwise, the collection of revenues due to the state or public entities, the legality and regularity of the accounts of the state and public entities, the economy, efficiency and effectiveness of the operations of the state and public entities and the quality of financial management and reporting of the state and public entities. Unless otherwise required by law, SAIs should not audit a government's or public entity's policy itself, but should audit the execution of a policy. To be able to effectively undertake their statutory duties, SAIs need adequate access to and use of all documents and information, which is timely, unrestricted, direct and free. The results of the audit activities of SAIs should not be concealed. Legislation should require them to report the results of their audits at least once a year. The content of the SAIs' audit reports, as well as the manner in which their recommendations and observations are presented, should be left at their discretion, subject to the opinion of the audited entities, where appropriate.

SAIs should report to the Legislature, or a committee or the governing body of the entity audited, as appropriate, on their recommendations and follow up on those recommendations. SAIs must be

allocated adequate and adequate means in terms of human, material, and financial resources and executive branch members should not be in control of or directing access to human, material, or financial resources of the SAI. The budget of SAIs should be their responsibility and they should allocate their resources accordingly. In addition, the Supreme Audit Institutions should be able to directly appeal to the legislature (INTOSAI-P, 2019b).

c. United Nations

INTOSAI is a non-governmental organization (NGO) having special consultative status with the United Nations Economic and Social Council (ECOSOC). The United Nations in its Resolution A/RES/69/228 of 28 January 2015, noted the importance of increasing the efficiency, accountability, effectiveness and transparency of public administration; the need for capacity-building for the promotion of development; and the importance of efficient, accountable, effective, and transparent public administration for the realization of the internationally agreed development goals. In this context, the United Nations reconfirmed the cooperation with the International Organization of Supreme Audit Institutions (INTOSAI).

The UN (2015) acknowledges that internal and external independence of SAIs is essential for them to carry out their work objectively and effectively. It also recognizes the crucial contribution of Supreme Audit Institutions to the efficiency, accountability, effectiveness and transparency of public administration, to the realization of national development objectives and priorities, and to the international development goals.

The United Nations also recognizes INTOSAI's efforts to promote greater efficiency, accountability, effectiveness, and transparency, as well as the efficient and effective collection and use of public resources for the benefit of citizens. In addition, it invites Member States to implement the principles established in the 1977 Lima Declaration and in the 2007 Mexico Declaration in a way in keeping with their institutional frameworks. The Resolution also reiterates the need for ongoing international cooperation on capacity-building, knowledge-sharing and best practice on public-sector budgeting and auditing to support developing countries.

4. TRANSFORMATION OF THE TURKISH COURT OF ACCOUNTS AND ALIGNMENT WITH INTERNATIONAL PRINCIPLES

In this regard, the Law No. 5018, which was enacted in 2003, is one of the most important reforms in the public financial management field in the domestic legal framework in line with the norms of the public finance management system of the modern era in Türkiye. The principle of the Law is to make sure that public administrations run in a lawful, efficient, economical and effective way, and to put in place mechanisms of fiscal transparency and accountability. Based on this, the allocation and use of public resources in accordance with the goals set by the sectors and the legal framework have turned into a constitutional requirement (Köse, 2020).

In parallel with this reform, a new Law on the Turkish Court of Accounts was adopted in 2010 (Law No. 6085), which changed the traditional organisation of the supreme auditing in Türkiye. The Law has been developed to make the public resources effective, efficient and economical; to make the work of SAIs transparent and accountable; to harmonize the audit procedures, methods and techniques of the SAIs of INTOSAI member countries. The reform was envisaged as the equal use of regularity and performance audit methods, audit of all public funds, resources and activities, legal obligation of auditing to create a culture of public accountability and transparency, and consequently to prevent corruption, the use of auditing according to the internationally accepted auditing standards and independence in operation and function (TBMM, 2010).

The degree of achievement of activities in performance audits is evaluated based on the criteria and targets set by the public administration being audited. This is very different from the way performance auditing is understood in the international standards covered in the previous section. While performance audits under the Turkish Court of Accounts and internal performance measurements under public administrations have similar overarching aims – such as the enhancement of institutional performance and the facilitation of better management – it is important to highlight their differences in professionals, approaches, institutional tools, legal boundaries and legal effects (Çaylak, 2025).

After the reform in 2010, the scope of the audit mandate of the Turkish Court of Accounts has been extended, the variety of the reports has been widened, the accountability in the audit has been strengthened, and extensive reporting to the Grand National Assembly of Türkiye (TBMM) has been established. The performance measurement framework, however, is much more limited than performance auditing as per international standards, and is defined by the strategic planning, performance programs and annual activity reports of public institutions. While developed countries have gradually broadened the scope of performance auditing and increased the resources allocated to this area, the scope of performance auditing in Türkiye has been narrowed, making it possible to argue that ensuring accountability has consequently become more difficult. Prior to the 2010 reform, the Turkish Court of Accounts (TCA) has often conducted performance audits on issues of public concern and interest; after the reform, however, it has not produced any performance audit reports in accordance with international performance audit standards. The Turkish Court of Accounts is a Supreme Audit Institution with a proactive approach in terms of its international relations and global institutional cooperation.

The Turkish Court of Accounts is a member of INTOSAI since 1965 and it is also a member of JURISAI, a group of Supreme Audit Institutions with jurisdictions. It is also active at the regional level in EUROSAI (European Organization of Supreme Audit Institutions) and ASOSAI (Asian Organization of Supreme Audit Institutions). It is also a founding Member State of the Economic Cooperation Organization Supreme Audit Institutions (ECOSAI) and the Organization of Supreme Audit Institutions of Turkic States (TURKSAI). In the past, the Turkish Court of Accounts has assumed considerable

duties in these bodies, such as being a member of ASOSAI's Audit Committee and EUROSAI's Governing Board. It has also been a member of the Governing Board of ECOSAI since 2016.

5. CONCLUSION

Supreme audit is the ultimate institution for accountability and transparency in public finance and is essential to a democratic government under the rule of law. As examined in the frame of this study, the Turkish Court of Accounts, has been involved in ensuring protection over public resources and monitoring the legality of their use in Türkiye since its establishment in 1862 onwards, which is a long track of its institutional history. The institutional change brought about by Law No. 6085, in particular, has helped the Turkish Court of Accounts to ensure significant compliance with the independence and impartiality principles in line with internationally recognized documents and declarations such as the Lima and Mexico Declarations.

The integration of the Turkish public audit system with the international standards is enhanced by the country's active involvement on international forums, including JURISAI, under the leadership of the Turkish Court of Accounts. The Turkish Court of Accounts' audit activities on behalf of the Grand National Assembly of Türkiye in line with institutional independence strengthen the oversight of the executive branch of government by the legislature. Effective monitoring and follow-up of the activities of the reports prepared by the Turkish Court of Accounts, both by Parliament and the public, are key to closing the circle of democratic accountability. In addition to serving as a reporting body, the Turkish Court of Accounts also acts as a “Court of Accounts”, with the authority to establish financial responsibility and to demand the recovery of public losses, making the implementation of audit results easier. It not only ensures the independence of the auditors and other professional members of the institution, but also helps increase the public officials' awareness of their financial obligations. Apart from the compliance audit, the advent of performance audit has reframed the scope of public sector audit to look for whether the public sector uses resources to achieve the desired public benefit and also to check whether it meets the legal requirements for making expenditure. However, further development of this kind of auditing, based on full objective indicators but not taking into consideration administrative expediency, is crucially important in guaranteeing the correct functioning of the audit process.

REFERENCES

Al Amimi, H. S. (2021). Yüksek denetim kurumları: Yolsuzlukla mücadelede oyun değiştiriciler. *International Journal of Government Auditing*, 48(1), 21–22.

Eşki Çaylak, Ş. (2025). Emekli Sayıştay uzman denetçisi Levent Karabeyli ile Sayıştay denetimi üzerine söyleşi. *Publicus*, (4), 319–354.

International Organization of Supreme Audit Institutions. (2018). INTOSAI celebrates Lima Declaration 40th anniversary. *International Journal of Government Auditing*, 45(1), 23–24.

International Organization of Supreme Audit Institutions. (2019a). *INTOSAI-P 1: The Lima Declaration.* https://www.intosai.org/fileadmin/downloads/documents/open_access/INT_P_1_u_P_10/INTOSAI_P_1_en_2019.pdf

International Organization of Supreme Audit Institutions. (2019b). *INTOSAI-P 10: Mexico Declaration on SAI independence*. https://www.intosai.org/fileadmin/downloads/documents/open_access/INT_P_1_u_P_10/INTOSAI_P_10_en_2019.pdf

Köse, H. Ö. (2007). *Dünyada ve Türkiye'de yüksek denetim*. T.C. Sayıştay Başkanlığı.

Köse, H. Ö. (2020). Yüksek denetim kurumlarının yargısal işlevleri ve INTOSAI standartlarında yargının temel ilkeleri. *Sayıştay Dergisi*, (117), 9–38.

TBMM (2010). *Sayıştay Kanunu Teklifi ve Avrupa Birliği Uyum ile Plan ve Bütçe Komisyonu Raporları (2/594.*

United Nations General Assembly. (2014). *Promoting and fostering the efficiency, accountability, effectiveness and transparency of public administration by strengthening supreme audit institutions (A/RES/69/228).* United Nations. http://digitallibrary.un.org/record/787478

Yalçın, S. (2017). *Yüksek denetim kurumlarının kurumsal yapısı ve mali performans*. T.C. Sayıştay Başkanlığı.

THE IMPACT OF HUMAN CAPITAL ON ECONOMIC GROWTH IN ASIAN COUNTRIES: A CURRENT PANEL DATA ANALYSIS

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ABSTRACT

Human capital remains significant in the economics literature as one of the key determinants of sustainable economic growth. This study examines the effects of public education and health expenditures, life expectancy at birth, and secondary school enrolment rates on economic growth for the period 2014-2021 in 48 Asian countries. In the changing economic conjuncture, while Asian countries recorded an average growth of 4.8%, human capital investments showed regional differences. According to the Fixed Effects Model (FEM) results, gross fixed capital formation, public health expenditures, life expectancy at birth, and secondary school enrolment rates positively and significantly affect economic growth. It has been determined that a 1% increase in health expenditures raises growth by 0.14%. In contrast, public education expenditures and population growth negatively affect growth. The fact that the public share allocated to education in Southeast Asia remains at only 3% of GDP indicates structural issues in resource distribution. The findings indicate that the quality of human capital investments is more important than their quantity and highlight the necessity for policies aligned with demographic dynamics.

Keywords: Human Capital, Economic Growth, Health Expenditures, Education Expenditures, Panel Data Analysis, Asian Economies

JEL Codes: C33, E24, H51, H52.

1. INTRODUCTION

The view that a country's economic growth capacity is solely derived from the accumulation of physical capital has been replaced in the second half by a much broader and more inclusive framework. Especially with the establishment of endogenous growth theory by Lucas (1988) and Romer (1986) in the late 1980s, human capital has been defined as a variable within the production function that constitutes the fundamental source of productivity increases. Following this theoretical transformation,

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empirical research has systematically documented the relationships between education level, health status, and the quality of the workforce with economic output.

The Asian continent holds a special place at the centre of this research agenda. Covering a geography that is extremely heterogeneous in terms of both income level and institutional structure, Asia offers a unique field of analysis to observe the impact of human capital investments on growth under different conditions. In this geography, which simultaneously hosts high-income economies like Japan and South Korea as well as underdeveloped countries like Nepal, Afghanistan, and Timor-Leste, it is clear that a single policy prescription cannot be applicable. However, some structural patterns are repeating themselves across the continent: rapid population growth, insufficient public resources, a focus on quantity over quality in education funding, and regional inequalities in healthcare infrastructure are among the foremost.

There is a specific reason for this study to define the review period as 2015–2025. The year 2015 is the year when the United Nations announced the Sustainable Development Goals (SDGs) and brought quality education and universal health coverage to the forefront of global policy priorities thru these goals. The COVID-19 pandemic that occurred during the 2020–2021 period has reexamined the relationship between health expenditures and growth from both theoretical and empirical perspectives. By the end of this period, the share of both health and education expenditures in GDP had changed in most parts of the continent; however, the impact of this change on growth has not yet been systematically examined. Therefore, this study also serves a gap-filling function in terms of time.

It can be said that the study seeks to answer three fundamental questions. Firstly, do public health expenditures and life expectancy at birth have a significant impact on economic growth? Secondly, do public education expenditures and secondary school enrollment rates significantly contribute to growth? Thirdly, how do population growth and gross fixed capital formation shape this relationship? The article consists of six sections: methodology, findings, discussion, and conclusion.

2. LITERATURE REVIEW

The foundations of modern growth theory were laid by Harrod (1939) and Domar (1946); subsequently, Solow (1957) and Swan (1956) expanded this model into a more general framework where capital accumulation, population growth, and external technological progress are jointly determining factors. The main contribution of the Solow model is that it demonstrates, due to the diminishing marginal productivity of physical capital, that per capita growth in the long run can only be sustained by external technological progress. This framework has been subject to serious criticism since the mid-1980s because it leaves the question of where technology comes from unanswered.

Lucas (1988) and Romer (1986, 1990) aimed to fill this gap with the endogenous growth theory. Lucas included the accumulation of human capital as an internal input in the production function and argued that the average level of human capital in an economy creates externalities on individual

productivity. Romer, on the other hand, has shown that the knowledge created by R&D activities can foster long-term growth due to its non-rival and partially non-excludable nature. When these two models are considered together, it is clear that investments in education and health have become the primary source of productivity growth. Schultz (1961) was among the first economists to systematically analyse how investments in knowledge and health for individuals increase productivity by distinguishing human capital from the traditional concept of capital. Becker (1962), on the other hand, based this view on micro foundations and created the first comprehensive frameworks measuring the return rates on investments in education and health. It is now an accepted fact: the transformation of human capital accumulation into a healthy and qualified workforce creates significant economic externalities at both the individual and societal levels.

2.1. Capital Accumulation, Population Growth, and Economic Growth

The positive impact of physical capital accumulation on economic growth is supported by a wide empirical literature covering different country groups and periods. Boamah et al. (2018) examined 18 Asian economies during the period 1990–2017 and revealed that gross fixed capital investments had a strong and significant positive impact on growth. Kesar et al. (2022) documented in their study covering BRICS countries that the relationship between capital accumulation, governance quality, and growth exhibits a mutually reinforcing cyclical structure.

The relationship between population growth and economic growth, on the other hand, is much more contentious. Neoclassical growth models predict that population growth dilutes the capital stock per capita and thus suppresses GDP per capita. This theoretical expectation also finds empirical support in the Asian context. Zahan (2016) showed that in the long term, population growth has a negative impact on GDP per capita in Bangladesh; Yoga et al. (2024) reached a similar conclusion for Indonesia. Both studies explain their results with the structural vulnerabilities to which the low-income population is condemned, leading to a widespread cycle of poverty.

2.2. Education and Economic Growth

The literature examining the impact of education on growth does not present a homogeneous picture in terms of the direction and magnitude of the effect. Blankenau et al. (2007) found a significant positive relationship between education expenditures and growth in the long term in their analysis of 23 industrialised countries. Kiran (2014) revealed a cointegration relationship between education investments and growth in his study examining 18 Latin American countries; Dahal (2016) documented that higher education made significant contributions to both growth and employment in the context of Nepal. However, studies that find a negative or insignificant relationship between public education expenditures and growth are also not negligible. Benhabib and Spiegel (1994) reported a near-zero or slightly negative relationship between education expenditures and growth in a multi-country panel analysis; Devarajan et al. (1996) confirmed this finding. The inconsistency between the findings of these

two groups is largely due to sample differences, model specification preferences, and whether or not the quality of spending is taken into account: controlling only for the amount of spending may mean ignoring the impact of learning outcomes and institutional quality.

2.3. Health and Economic Growth

Studies examining the contribution of health expenditures and health outcomes to economic growth generally indicate a positive relationship. Wang (2011) demonstrated in a panel analysis covering 31 countries that the increase in healthcare expenditures significantly accelerated growth. Piabuo and Tieguhong (2017) found similar results for Central African countries, and Yuksel and Dincer (2018) for E-7 economies. Life expectancy at birth is frequently used in the growth literature as an indicator summarising the quality of health infrastructure. Akinwale (2021) has shown that life expectancy positively affects growth in both the short and long term in the examples of Saudi Arabia and Nigeria. He and Li (2020) found that the correlation between life expectancy and GDP per capita was consistently strong in long-term multi-country data. Sethi et al. (2024), on the other hand, found a bidirectional causality relationship for South Asian countries, demonstrating that the relationship between healthcare expenditures and growth is mutually reinforcing.

3. METHOD AND DATA

This study is based on the endogenous growth model by Lucas (1988) and Romer (1986), using the framework employed by Hanif and Arshed (2016), Pokhrel and Khadka (2019), and Ndaombwa (2023), and updates it with variables specific to the 2015–2025 period. The basic production function is structured as follows:

$$Q=f(L,K,H) \quad (1)$$

Here, L represents labour, K represents physical capital, and H represents human capital stock; it is assumed that the production function has increasing returns to scale. This function operationalises the nonlinear growth relationship with the following econometric model:

$$GSYHit=f\,(GSSSit, Nüf\_Art\_it, KEHit, DYBit, KEEit, OKOit) \quad (2)$$

The model, in its econometric form, is suitable for panel data estimation:

$$lnGSYHit=\beta0+\beta1lnGSSSit+\beta2Nu¨f\_Artit+\beta3KEHit+\beta4DYBit+\beta5KEEit+\beta6OKOit+\mu i+\varepsilon it \quad (3)$$

In the equation, i represents the country index, t the time index; μ_i denotes the country-specific unobserved fixed effect, and ε_{it} the error term. All the data used in the study were compiled from the World Bank World Development Indicators (WDI, 2024) database. The definitions of the variables are presented in Table 1.

Table 1. Definition and Sources of Variables

Variable	Description	Source
lnGDP	GDP at constant 2015 USD prices, natural logarithm	WDI (2024)
lnGFCF	Gross Fixed Capital Formation at constant 2015 USD prices, natural logarithm	WDI (2024)
Pop_Growth	Population growth rate (ages 15–64, %)	WDI (2024)
PHE	Public health expenditure as a percentage of GDP	WDI (2024)
LEB	Life expectancy at birth (years)	WDI (2024)
PEE	Public education expenditure as a percentage of GDP	WDI (2024)
GERSE	Gross enrolment ratio in secondary education (%)	WDI (2024)

Note: Natural logarithmic transformation or standardisation in the form of ratios to GDP was applied to all continuous variables.

The sample consists of 48 Asian countries, namely Afghanistan, Armenia, Azerbaijan, Bahrain, Bangladesh, Bhutan, Brunei, Cambodia, China, Cyprus, Georgia, Hong Kong, India, Indonesia, Iran, Iraq, Israel, Japan, Jordan, Kazakhstan, Kuwait, Kyrgyzstan, Laos, Lebanon, Macao, Malaysia, Maldives, Mongolia, Myanmar, Nepal, Oman, Pakistan, the Philippines, Qatar, Saudi Arabia, Singapore, South Korea, Sri Lanka, Syria, Tajikistan, Thailand, Timor-Leste, Türkiye, Turkmenistan, the United Arab Emirates, Uzbekistan, Vietnam, and Yemen, and is compiled from annual data covering the period 2015–2025.

4. FINDINGS

Table 2 below summarises the main distributional characteristics of all variables for the 11-year analysis period.

Table 2. Descriptive Statistics

Variable	Mean	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Observations
lnGDP	25.71	29.48	21,03	2,04	−0.48	2,41	207,00
lnGFCF	24.41	27.94	19.24	2,01	−0.41	2,28	207,00
Pop_Growth	1,08	3,91	−0.62	0.78	0.42	4,74	207,00
PHE	2,84	9,47	0.41	1,88	2,11	8,14	207,00
LEB	75.21	85.14	64.88	5,41	0.31	1,94	207,00
PEE	3,88	7,84	1,52	1,31	0.74	2,91	207,00
GERSE	91.34	136.84	31.48	18.87	−0.94	4,61	207,00

The lnGDP variable exhibits a slightly left-skewed distribution, reflecting that the large economies in

the sample are pulling the average upwards. Health expenditures (HE) stand out with a high kurtosis value; this is due to the distribution tail caused by high-income countries such as Japan, Israel, and Cyprus. During the period of the intense COVID-19 pandemic in 2020–2021, the share of health expenditures in GDP significantly increased in many countries; this expanded the periodic variation of the variable.

4.1. Panel Unit Root Tests

In the panel unit root analysis, the Levin, Lin, and Chu (LLC) test, which tests for a common unit root process, and the Im, Pesaran, and Shin (IPS) test, which tests for an individual unit root process, along with Fisher-type ADF and PP tests, were applied together. Table 3 shows that all variables are stationary at level — that is, I(0) — confirming that a dynamic panel model is not needed.

Table 3. Panel Unit Root Test Results

Variable	LLC t*	IPS W-stat.	ADF-Fisher χ^2	PP-Fisher χ^2	Decision
lnGDP	—	—	131.48**	214.62***	I(0)
lnGFCF	—	—	162.34***	84.17*	I(0)
Pop_Growth	−10.24***	3,14	171.88***	228.94***	I(0)
PHE	—	—	461.27***	188.44***	I(0)
LEB	−7.28***	0.71**	122.17*	122.17*	I(0)
PEE	—	—	167.48***	111.34***	I(0)
GERSE	—	—	153.61***	94.28	I(0)

Note: *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. The values in parentheses are probability values.

4.2. Correlation Analysis

Table 4. Correlation Matrix

Variables	lnGDP	lnGSSS	Pop_Growth	HE	FR	EEE	SER
lnGDP	1.000						
lnGSSS	0.993	1.000					
Pop_Growth	−0.134	−0.121	1.000				
HE	0.244	0.241	−0.214	1.000			
FR	0.418	0.401	−0.238	0.631	1.000		
EEE	−0.261	−0.239	0.181	0.328	0.118	1.000	
SER	0.182	0.194	−0.224	0.421	0.658	0.204	1.000

The high positive correlation (0.993) between lnGDP and lnGSSS is consistent with expectations; these two variables are theoretically mutually reinforcing. The strong positive correlation (0.658) between DYB and OKO requires caution regarding the potential issue of multicollinearity; therefore, the variance inflation factor test has also been applied.

4.3. Diagnostic Tests Normality

The application of the Jarque-Bera normality test on the residuals shows that as the number of observations increases, the residuals converge to a normal distribution according to the central limit theorem. The test statistic is 5.72, and the p-value is 0.058, which is above the 5% significance threshold. This result indicates that the null hypothesis of the residuals being normally distributed cannot be rejected.

Multicollinearity. Variance inflation factor (VIF) values are presented in Table 5. The fact that VIF < 3.0 for all variables indicates that there is no serious multicollinearity problem.

Table 5. Variance Inflation Factor Results

Variables	VIF	1/VIF
FR	2,74	0.365
HE	1,97	0.508
SER	1,89	0.529
EEE	1,42	0.704
lnGSSS	1,34	0.746
Pop_Growth	1,18	0.847
Mean VIF	1,76	—

The application of the White test produced the result $\chi^2(27) = 118.64$, $p = 0.0000$. The null hypothesis of homoscedasticity is rejected; the presence of heteroscedasticity in the data set is confirmed. Therefore, all regression estimates have been conducted using robust standard errors.

4.4. Hausman Test and Model Selection

The preference between the fixed effects and random effects models has been determined through the Hausman (1978) test. The test result was obtained as $\chi^2(6) = 63.84$ and $p = 0.0000$. This finding reveals that country-specific unobservable effects are correlated with the independent variables and statistically necessitate the use of a fixed effects model. Indeed, in a large country sample like 48, it is theoretically expected that many characteristics that remain constant over time, such as geographical location, institutional legacy, development level, and political economy, are related to the regressor variables.

Table 6. Hausman Test Result

Variables	Fixed Effects Coefficient	Random Effects Coefficient	Difference	S.E.
lnGSSS	0.241	0.778	−0.537	0.011
Pop_Growth	−0.046	−0.049	0.003	—
HE	0.058	0.041	0.017	—
FR	0.051	0.019	0.032	—

EEE	−0.041	−0.084	0.043	—
SER	0.005	0.001	0.004	—

No. $\chi^2(6) = 63.84$; $p = 0.0000$. b = Consistent under H_0 and H_a; B = Inconsistent under H_a, effective under H_0.

4.5. Regression Results

Table 7. Fixed Effects and Robust Fixed Effects Model Results (Dependent Variable: lnGDP)

Variables	Fixed Effects Coefficient	Std. Error	p-value	Robust Fixed Effects Coefficient	Robust Std. Error	p-value
lnGSSS	0.241	0.038	0.000	0.241	0.091	0.009
Pop_Growth	−0.046	0.016	0.004	−0.046	0.021	0.031
HE	0.058	0.013	0.000	0.058	0.031	0.068
FR	0.051	0.011	0.000	0.051	0.014	0.001
EEE	−0.041	0.013	0.001	−0.041	0.019	0.034
SER	0.005	0.001	0.001	0.005	0.002	0.041
Constant	15.914	0.944	0.000	15.914	1.441	0.000

Model Statistics

R^2 (within)	0.6148
R^2 (between)	0.7714
R^2 (overall)	0.7521
Prob> F	0.0000

In the robust fixed effects model, the White correction for inter-group heteroskedasticity has been applied. The p-value of the KEH is interpreted at the 10% significance level.

5. DISCUSSION

The lnGSSS variable has a positive and statistically significant coefficient in both model specifications. In the fixed effects model, the estimated coefficient is 0.241. This figure indicates that a one percent increase in lnGSSS, holding other variables constant, would increase GDP by approximately 0.241 percent. This finding aligns with the neoclassical framework of Solow (1957) and Swan (1956), as well as the recent empirical findings specific to Asian economies by Boamah et al. (2018) and Kesar et al. (2022). The acceleration of infrastructure investments in countries like China, Vietnam, and Bangladesh during the 2015–2025 period partially explains the structural dynamics underlying this coefficient. On the other hand, the fact that a large portion of investments in some countries occurs thru foreign direct investments rather than public institutions indicates that the coefficient should not be interpreted homogeneously across countries.

The negative and significant relationship between the population growth rate and growth (β = −0.046) aligns with the neoclassical growth model's prediction of diminishing capital intensity. This result can be explained by the fact that in a large portion of the low- and middle-income countries in the sample, population growth erodes per capita capital accumulation. Zahan (2016)'s findings for Bangladesh, Thornton (2001)'s findings for Latin America, and Yoga et al. (2024)'s findings for Indonesia support this interpretation. During the 2020–2022 period, the temporary slowdown in population growth due to COVID-19-related deaths in some Southeast Asian and South Asian countries created a period-specific breakpoint in the analysis. The reflection of this structural break in the coefficient estimates may have slightly altered the long-term impact of population growth on economic growth.

Public health expenditures (PHE) have a positive coefficient (β = 0.058) at the ten percent significance level in the robust model specification. Life expectancy (LE) is significant at the one percent level (β = 0.051) and consistently significant in both specifications. This finding aligns with the results of Wang (2011), Piabuo and Tieguhong (2017), and Akinwale (2021), which emphasise the contribution of health outcomes to labour productivity and consequently to growth.

The failure of the increased public health expenditures related to COVID-19 during the 2020–2021 period to fully create the expected positive impact on GDP in the short term once again highlights the importance of intermediate variables such as health system capacity and institutional quality. The bidirectional causality relationship identified by Sethi et al. (2024) for South Asia indicates that growth can also lead to an increase in health expenditures, and it emphasises that the positive coefficient obtained in this study should be interpreted cautiously regarding its causal direction.

The most striking and controversial finding is the negative and significant effect of public education expenditures (PEE) on growth (β = −0.041). This result, at first glance, seems to contradict the established view that education investments support growth, but the findings of Benhabib and Spiegel (1994), Devarajan et al. (1996), and Colombier (2009) detail the theoretically explainable conditions of this negative relationship.
The negative relationship is open to multiple interpretations. Firstly, a significant portion of public education spending in low-income countries in Asia can be allocated to administrative and bureaucratic costs that are not directly linked to learning outcomes; this weakens the channel between spending and efficiency. Secondly, the process of translating increased education spending into labor productivity is a time-consuming one; an eleven-year analysis window may not be sufficient to capture this lagged effect. Thirdly, looking solely at the amount of spending without holding the quality of education systems constant makes it difficult to distinguish between well-designed and poorly designed education policies.

In contrast, the secondary school enrollment rate (OKO) has a positive and significant coefficient ($\beta = 0.005$). Although the absolute magnitude of the coefficient is relatively small, its statistical significance is strong. This finding indicates that, unlike education measured by the amount of spending, the flow indicator reflecting the actual educational participation of the workforce is a more reliable signal of growth. The mechanism emphasised by Weiss (1995) and Dahal (2016) is also valid here: the increase in skilled labour accelerates the accumulation of knowledge and innovation, thereby fostering growth.

6. CONCLUSION AND POLICY RECOMMENDATIONS

This study examined the impact of human capital components on economic growth using an unbalanced panel dataset of 48 Asian countries covering the period from 2015 to 2025. The fixed effects model determined by the Hausman test was re-estimated with robust standard errors due to the issue of heteroskedasticity in the residuals. The findings consistently reveal that gross fixed capital formation, public health expenditures, life expectancy at birth, and secondary school enrollment rates significantly boost growth; however, public education expenditures and population growth have negative effects on growth. These findings offer several important policy implications.

Firstly, if population growth is eroding per capita capital accumulation, Asian governments need to focus on policies that will increase productive investments and manage the balance between the physical capital stock and the population. For countries with a large working-age population, this situation also means active employment policies that will qualify the existing workforce.

Secondly, the negative impact of public education spending on growth shows that simply expanding the sector linearly is not sufficient; it is critically important to direct spending toward the right stage and quality. Focusing not only on increasing the budget but also on improving learning outcomes at the primary and secondary education levels finds stronger support in both the literature and the current findings.

Thirdly, the strong positive impact of life expectancy on growth strengthens the justification for positioning health policy not only from a welfare perspective but also from a productivity perspective. The system shock caused by the COVID-19 pandemic in the middle of the period has concretely demonstrated the importance of investments in healthcare infrastructure on long-term growth capacity.

Some limitations of the study should also be clearly stated. Firstly, the structural break caused by COVID-19 on some variables during the 2020–2021 period may have affected the coefficient estimates; future research focusing on this issue could benefit from the application of structural break tests. Secondly, the lag structure between education expenditure and growth cannot be fully captured by a linear model; dynamic panel estimators will address this relationship in more detail. Thirdly, the heterogeneity between geographical sub-regions — such as the differing dynamics of East Asia and South Asia — can be illuminated through sub-sample analyses.

REFERENCES

Akinwale, Y. O. (2021). Health expenditure, economic growth and life expectancy at birth in resource-rich developing countries: A case of Saudi Arabia and Nigeria. *Journal of Economic Cooperation and Development*, *42*(2), 13–36.

Becker, G. S. (1962). Investment in human capital: A theoretical analysis. *Journal of Political Economy*, *70*(5), 9–49. https://doi.org/10.1086/258724

Benhabib, J., & Spiegel, M. M. (1994). The role of human capital in economic development: Evidence from aggregate cross-country data. *Journal of Monetary Economics*, *34*(2), 143–173. https://doi.org/10.1016/0304-3932(94)90047-7

Blankenau, W. F., Simpson, N. B., & Tomljanovich, M. (2007). Public education expenditures, taxation, and growth: Linking data to theory. *American Economic Review*, *97*(2), 393–397. https://doi.org/10.1257/aer.97.2.393

Boamah, J., Adongo, A., Essieku, R., & Lewis, A. (2018). Financial depth, gross fixed capital formation and economic growth: Empirical analysis of 18 Asian economies. *International Journal of Scientific and Education Research*, *2*(4), 120–130.

Colombier, C. (2009). Growth effects of fiscal policies: An application of robust modified M-estimator. *Applied Economics*, *41*(7), 899–912. https://doi.org/10.1080/00036840601007272

Dahal, G. (2016). The contribution of education to economic growth: Evidence from Nepal. *Journal of Applied Economic Sciences*, *11*(2), 22–41.

Devarajan, S., Swaroop, V., & Zou, H. F. (1996). The composition of public expenditure and economic growth. *Journal of Monetary Economics*, *37*(2), 313–344. https://doi.org/10.1016/S0304-3932(96)90039-2

Domar, E. D. (1946). Capital expansion, rate of growth, and employment. *Econometrica*, *14*(2), 137–147. https://doi.org/10.2307/1905364

Hanif, N., & Arshed, N. (2016). Relationship between school education and economic growth: SAARC countries. *International Journal of Economics and Financial Issues*, *6*(1), 294–300.

Harrod, R. F. (1939). An essay in dynamic theory. *Economic Journal*, *49*(193), 14–33. https://doi.org/10.2307/2225181

Hausman, J. A. (1978). Specification tests in econometrics. *Econometrica*, *46*(6), 1251–1271. https://doi.org/10.2307/1913827

He, L., & Li, N. (2020). The linkages between life expectancy and economic growth: Some new evidence. *Empirical Economics*, *58*(5), 2381–2402. https://doi.org/10.1007/s00181-018-1612-7

Kesar, A., Bandi, K., Jena, P. K., & Yadav, M. P. (2022). Dynamics of governance, gross capital formation, and growth: Evidence from Brazil, Russia, India, China, and South Africa. *Journal of Public Affairs*, *23*(1), e2831. https://doi.org/10.1002/pa.2831

Kiran, B. (2014). Testing the impact of educational expenditures on economic growth: New evidence from Latin American countries. *Quality & Quantity*, *48*(3), 1181–1190. https://doi.org/10.1007/s11135-013-9828-2

Lucas, R. (1988). On the mechanics of economic development. *Journal of Monetary Economics*, *22*(1), 3–42. https://doi.org/10.1016/0304-3932(88)90168-7

Ndaombwa, S. Z. (2023). *Assessing the impact of public expenditure on economic growth of Malawi* [Lisans tezi]. The Catholic University of Malawi. https://doi.org/10.13140/RG.2.2.35503.10405

Piabuo, S. M., & Tieguhong, J. C. (2017). Health expenditure and economic growth: A review of the literature and an analysis between the economic community for central African states (CEMAC) and selected African countries. *Health Economics Review*, *7*(1), 1–13. https://doi.org/10.1186/s13561-017-0159-1

Pokhrel, S., & Khadka, C. B. (2019). Assessment of long and short run relationship amongst macroeconomic variables and economic growth of Nepal. *Economic Journal of Development Issues*, *28*(2), 48–87. https://doi.org/10.3126/ejdi.v28i1-2.33196

Romer, P. M. (1986). Increasing returns and long-run growth. *Journal of Political Economy*, *94*(5), 1002–1037. https://doi.org/10.1086/261420

Romer, P. M. (1990). Endogenous technological change. *Journal of Political Economy*, *98*(5), 71–102. https://doi.org/10.1086/261725

Schultz, T. W. (1961). Investment in human capital. *American Economic Review*, *51*(1), 1–17.

Sethi, N., Mohanty, S., Das, A., & Sahoo, M. (2024). Health expenditure and economic growth nexus: Empirical evidence from South Asian countries. *Global Business Review*, *25*(2), 229–243. https://doi.org/10.1177/0972150920961742

Solow, R. M. (1957). Technical change and the aggregate production function. *Review of Economics and Statistics*, *39*(3), 312–320. https://doi.org/10.2307/1926047

Swan, T. W. (1956). Economic growth and capital accumulation. *Economic Record*, *32*(2), 334–361. https://doi.org/10.1111/j.1475-4932.1956.tb00434.x

Thornton, J. (2001). Population growth and economic growth: Long-run evidence from Latin America. *Southern Economic Journal*, *68*(2), 464–468. https://doi.org/10.2307/1061606

Wang, M. (2011). Investigating the relationship between healthcare expenditure and economic growth in 31 countries. *Journal of Health Economics*, *30*(4), 744–757. https://doi.org/10.1016/j.jhealeco.2011.06.003

Weiss, A. (1995). Human capital vs. signalling explanations of wage. *Journal of Economic Perspectives*, *9*(4), 133–154. https://doi.org/10.1257/jep.9.4.133

World Bank. (2024). *World Development Indicators*. https://databank.worldbank.org/source/world-development-indicators

Yoga, S., Ketut, D., & Lanang, P. T. (2024). The influence of labor and population growth on economic growth in Indonesia: 2017–2022. *Loka Journal of Environmental Sciences*, *1*(3), 81–86.

Yuksel, S., & Dincer, H. (2018). Identifying the causality relationship between health expenditure and economic growth: An application on E7 countries. *Journal of Health Systems and Policies*, *1*(1), 5–22.

Zahan, I. (2016). *The long run relationship between population growth and economic growth: Empirical evidence from Bangladesh* (BIGD Working Paper No. 36). BRAC Institute of Governance and Development.

IS THERE A CAUSAL RELATIONSHIP BETWEEN CDS PREMIUMS, EXCHANGE RATE AND INFLATION IN THE TURKISH ECONOMY?

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ABSTRACT

Credit default swap (CDS) is a key indicator of financial markets. Credit risk premium is defined as a measure of a country or institution's risk of bankruptcy. CDS values, which are of critical importance to both investors and countries, directly affect borrowing costs and economic and financial stability. In this study, the relationship between CDS premium, exchange rate, and inflation in the Turkish economy was analyzed using the Granger causality test. The analysis revealed a bidirectional causal relationship between the exchange rate and inflation. While no statistically significant relationship was found between CDS premium and inflation, a unidirectional causal relationship was found from CDS premium to exchange rate. Overall, the results obtained have shown that exchange rate pass-through is valid in the Turkish economy. The study reveals that CDS premiums play an indirect and limited role through the financial transmission channel, not directly affecting prices but primarily influencing exchange rate.

Keywords: *CDS Premiums, Exchange Rate, Inflation, Granger Causality Test.*

JEL Codes: *C32, E31, F31.*

1. INTRODUCTION

Credit default swaps (CDS) are financial derivative instruments that provide protection against the risk of default by a government or corporate borrower. CDS premiums represent the cost of insuring against credit risk and are widely interpreted as market-based indicators of perceived default risk. CDS protects the creditor against the risk of default by the debtor. Thus, it undertakes to make a specific payment if the debtor is unable to pay the debt. A decrease in CDS premiums means that the borrower's credit risk has decreased, thus strengthening the borrower's ability to repay the debt. An increase in CDS premiums indicates a higher risk of bankruptcy for the borrower, a decrease in debt repayments, and increased credit risk. In financial markets, CDS prices reflect investors' perception of risk vis-a-vis borrowers. A country's CDS premium is affected by changes occurring both domestically and internationally. While changes abroad include interest rate policies set by major central banks like the FED, geopolitical tensions, and wars, changes domestically include the state of inflation, central bank

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reserves, the consistency of economic policies, and political stability. CDS premiums are generally measured on 5 and 10-year bonds. A CDS premium between 0 and 100 basis points indicates low risk, meaning a reliable economy or company. A risk perception between 100-200 basis points indicates a moderate level, between 250-500 basis points indicates a high level, and above 500 basis points indicates a very high level.

CDS premiums, a crucial financial indicator for both investors and countries, directly affect borrowing costs, economic stability, and financial market fragility. If the CDS premium is high, the country's borrowing costs increase. These situation forces governments to accept higher interest rates to secure external financing, increasing public costs. High CDS premiums reduce investor confidence and hinder the inflow of foreign capital into the country. Therefore, it leads to a decrease in investments in the economy and negatively affects economic growth. Conversely, this increases investor confidence in the economy. This, in turn, stimulates economic growth by increasing capital inflows and the number of existing investments. High CDS premiums cause the Turkish Lira to depreciate and the exchange rate to rise. This, in turn, increases the general price level through the cost channel. High CDS premiums can reduce confidence in the financial system, leading to a credit crunch and consequently an economic slowdown.

The CDS premium began to be measured when Turkey first started issuing international bonds in global markets in the early 2000s. While Turkey's CDS premium was at low levels until 2013, it began to rise in 2018 due to geopolitical developments, currency and debt crises. Turkey's 5-year CDS premium reached its highest level in 2022, at 908.4 basis points. As a result of the tight monetary policy implemented after this year and some economic decisions taken, the CDS premium fell to 278 basis points by the end of 2023. In 2026, it stabilized in the range of 220-250 basis points.

This study was conducted to gain a better understanding of the relationship between both financial indicators and macroeconomic performance. Therefore, the relationship between CDS premium, exchange rate, and inflation has been examined. Thus, an attempt has been made to clearly demonstrate how financial risk affects macroeconomic stability. The findings are also expected to provide important information to policymakers.

The remainder of this study is structured as follows: The second section contains a literature review summarizing studies examining the relationship between CDS premiums, inflation, and exchange rates; the third section presents data and methodology; the fourth section provides the discussion, and the fifth section conclusion.

2. LITERATURE REVIEW

Table 1 summarizes empirical studies examining the relationships between CDS, exchange rates and inflation in Türkiye and other national economies. Studies in the literature reveal strong

relationships between these variables. The direction and impact of these relationships vary depending on the country sample, time period, and econometric methods used.

Table 1. Empirical Studies on CDS Premiums, Exchange Rates and Inflation (Evidence from Türkiye and Other Countries)

Authors (Year)	Country / Period	Variables	Methodology	Main Findings
Kebłowski (2011)	EU members (2001M1-2011M4)	CDS, ER	Panel	CDS→ER
Korkmaz and Bayır (2015)	Türkiye (2008M1-2014M11)	ER, INF	Granger causality	CPI → ER, ER → PPI
Karamelikli and Korkmaz (2016)	Türkiye (2003:1-2015:11)	ER, INF	NARDL	ER ↑- INF↑
Rashid, Ahmad and Yasmin(2017)	Pakistan (2001M1-2015M2)	CDS, ER, INF	ARDL	ER, INF→CDS (+, SR), INF→CDS (+, LR)
Açcı, Kayhan and Bayat (2018)	Fragile Five (2009M9-2017M1)	CDS, ER	Granger causality	CDS→ER
Işıklı and Akin (2018)	Türkiye (2007M4-2017M1)	CDS, ER, INF	VAR	ER→ CDS, INF
Kahyaoğlu (2019)	Türkiye (January 2, 2013- October 4, 2018)	CDS, ER	Partial co-integration (PCI)	ER↑→ CDS↑
Münyas (2020)	Türkiye (2005M1-2019M12)	CDS, ER	Granger causality	CDS ↔ ER
Gürel (2021)	Türkiye (2011M1-2020M9)	CDS, ER	SVAR	ER↑→CDS↑
Turna and Özcan (2021)	Türkiye (2005Q1–2019Q2)	ER, INF	ARDL	Türkiye: ER → INF (SR & LR)
Aytekin and Abdioglu (2021)	BRICS-T &Fragile Five (2013Q4-2019Q3)	CDS, ER, INF	Panel	ER, INF→CDS(+)
Emikönel and Orhan (2023)	Fragile Five (1990:M1-2020:M12)	ER, INF	ARDL	Indonesia, South Africa: ER impact on INF (LR)
Valogo, Duodu, Yusif and Baidoo (2023)	Ghana (2002:M1-2018:12)	ER, INF	TAR	ER depreciation → INF(+)

Su, Ren and Al-Qasos (2024)	G7 and BRICS-5 (2017-2023)	CDS, ER	ARMA-cDCC-FIGARCH	CDS→ER
Akbaş, Dönmez and Can (2024)	BRIC-T (1995Q1-2022Q4)	ER, INF	Panel	ER→INF(-) (Except China)
Yerlikaya (2024)	Türkiye (2010M1-2022M3)	CDS, ER	ARDL	ER→CDS↑
İltaş and Güzel (2024)	BRICS-T (2020:1-2024:6 daily)	CDS, ER	Hacker and Hatemi-J bootstrap causality	ER, CDS +(LR), CDS→ER (SR/Türkiye)
Muñoz, Gálvez-Gamboa and Dávila (2025)	Latin America (2009M1-2024M6)	CDS, ER	TVP-VAR	CDS↔ER
Anachedo, Nwanna and Jeff-Anyeneh (2025)	Nigeria (1986-2023)	ER, INF	RLS	ER→INF(+)
Kasap (2025)	Türkiye (2020M1-2024M12)	CDS, ER	LCM, TRM	ER→CDS↑
Simanjuntak and Fauzie (2026)	Indonesia (every month 2015-2023)	CDS, ER	VECM	CDS→ER(+)(LR)

Note: ER: Exchange rate, CDS: CDS premiums, INF: Inflation, PPI: Producer price index, CPI: Consumer price index,→: Unidirectional causality, ↔: Bidirectional causality, LR: Long run, SR: Short run, (+): Positive relationship, (−): Negative relationship, ↓: decrease, ↑: increase.

3. DATA AND METHODOLOGY

This study analyzes the relationship between CDS premiums, exchange rate, and inflation using the Granger causality test. Monthly data for the period 2020M1-2026M4 has been collected. CDS premiums have been on an upward trend since 2018 due to increasing financial volatility and changing macroeconomic policies. Therefore, the sampling period was started in 2020. During this period, disruptions in supply chains and sudden changes in capital mobility were observed. Economic shocks and exchange rate fluctuations, exacerbated by the COVID-19 pandemic, have negatively impacted the Turkish economy. During this period, CDS premiums became one of the leading indicators revealing financial stress. Furthermore, the high inflation rates, exchange rate volatility, and frequently changing monetary policies that emerged in the Turkish economy after 2020 are important indicators of macroeconomic instability. Descriptions of the variables used in the analysis and their data sources are presented in Table 2.

Table 2. Variables

Code	Variable	Description
CDS	CDS: 5-Year USD-Denominated CDS Premium (TRGV5YUSAC=R)	Data obtained from Investing.com.
CPI	Consumer Price Index (2003=100)	Data was obtained from the Central Bank of the Republic of Türkiye (CBRT).
ER	Exchange Rate Data (USD/TRY)	Data was obtained from the CBRT.

Logarithmic transformation was not applied to the CDS series because it is already expressed in basis points. In contrast, the logarithms of the CPI and ER series were taken to balance for variance and allow for elasticity-based interpretations.

Before passing on to the VAR estimation, in order to determine whether the variables are stationary or not, unit root tests have been carried out. The purpose of carrying out the unit root tests is that misleading regression results do not emerge and that reliable statistical results are obtained. The stationarity results of the series, according to the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests, are given in Table 3.

Table 3. ADF and PP Unit Root Test Results

Variables			ADF		PP	
			t-statistic	p-value	t-statistic	p-value
CDS	Constant	Level	-1.658	0.448	-1.843	0.357
	Trend-Constant	Level	-2.841	0.187	-3.005	0.137
ΔCDS	Constant	First difference	-5.797	0.000*	-19.822	0.000*
	Trend-Constant	First difference	-5.747	0.000*	-21.271	0.000*
LER	Constant	Level	-1.204	0.668	-1.242	0.652
	Trend-Constant	Level	-1.756	0.715	-0.794	0.961
ΔLER	Constant	First difference	-7.605	0.000*	-23.935	0.000*
	Trend-Constant	First difference	-7.552	0.000*	-23.757	0.000*
LCPI	Constant	Level	-0.252	0.925	0.188	0.970
	Trend-Constant	Level	-2.109	0.531	-2.259	0.450
ΔLCPI	Constant	First difference	-8.770	0.000*	-16.142	0.000*
	Trend-Constant	First difference	-8.750	0.000*	-18.697	0.000*

Notes: *indicates significance at 1% level. ADF lag length is selected based on SC. PP bandwidth is determined using Bartlett kernel.

According to the results of the unit root tests presented in Table 3, the CDS, ER, and CPI variables are found to be non-stationary at their levels, while they become stationary after first differencing. Since all variables are integrated of order one, I(1), they are deemed appropriate for VAR estimation in their differenced forms.

The optimal lag length in the study is selected using several information criteria, including the Likelihood Ratio (LR), Final Prediction Error (FPE) and Akaike Information Criterion (AIC), with the

results indicating a lag order of 2. In addition, since the dataset is composed of monthly observations, the VAR specification is also considered with a lag length of six in the constructed model. Test results showing the VAR lag length are given in Table 4.

Table 4. Lag Length Test Results

Lag	LR	FPE	AIC	SC	HQ
0	NA	0.002	2.575	2.672	2.613
1	86.552	0.000	1.504	1.893*	1.658*
2	22.047*	0.000*	1.409*	2.089	1.679
3	14.093	0.000	1.431	2.403	1.817
4	5.538	0.001	1.593	2.856	2.094
5	8.358	0.001	1.697	3.251	2.313
6	11.461	0.001	1.728	3.574	2.460

According to the heteroscedasticity test, the chi-square (Chi-sq) statistic was found to be 90.032, and the p-value was found to be 0.073. The results of the ARCH-LM test show that the null hypothesis of constant variance cannot be rejected at the 5% significance level (p = 0.073). This result proves that the residuals of the model do not show a significant heteroscedasticity.

Since all the variables in the model are stationary at the same level, the Granger causality test can be carried out. The Granger causality test formulations are given below (Granger, 1969).

$$\Delta CDS_t = \alpha_0 + \sum_{i=1}^{p} \alpha_{1i}\, \Delta CDS_{t-i} + \sum_{i=1}^{p} \beta_{1i}\, \Delta LER_{t-i} + \sum_{i=1}^{p} \gamma_{1i}\, \Delta LCPI_{t-i} + \varepsilon_{1t} \quad (1)$$

$$\Delta LER_t = \alpha_2 + \sum_{i=1}^{p} \alpha_{2i}\, \Delta LER_{t-i} + \sum_{i=1}^{p} \beta_{2i}\, \Delta CDS_{t-i} + \sum_{i=1}^{p} \gamma_{2i}\, \Delta LCPI_{t-i} + \varepsilon_{2t} \quad (2)$$

$$\Delta LCPI_t = \alpha_3 + \sum_{i=1}^{p} \alpha_{3i}\, \Delta LCPI_{t-i} + \sum_{i=1}^{p} \beta_{3i}\, \Delta CDS_{t-i} + \sum_{i=1}^{p} \gamma_{3i}\, \Delta LER_{t-i} + \varepsilon_{3t} \quad (3)$$

Hypotheses:

H_0: $\beta_1 = \beta_2 = \ldots = \beta_p = 0$

H_1: $\beta_1 \neq \beta_2 \neq \ldots \neq \beta_p \neq 0$

In Table 5, the Granger causality test results that show the relationship between CDS, ER and CPI are given.

Table 5. Granger Causality Test Results

Direction of Causality	F-Statistic	Probability(p)	Decision
ΔLER does not Granger cause ΔCDS	1.082	0.344	No
ΔCDS does not Granger cause ΔLER	3.499	0.035**	Yes
ΔLCPI does not Granger cause ΔCDS	1.145	0.324	No
ΔCDS does not Granger cause ΔLCPI	0.154	0.856	No
ΔLCPI does not Granger cause ΔLER	4.833	0.011**	Yes
ΔLER does not Granger cause ΔLCPI	18.367	0.000*	Yes

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

According to the causality results in Table 5, firstly a unidirectional relationship from CDS to exchange rate has been found. The null hypothesis that CDS is not the cause of exchange rate has been rejected at the 5% significance level. Secondly, a bidirectional causal relationship was found between the USD/TRY exchange rate and inflation. The null hypothesis that inflation is not the cause of the exchange rate was rejected at the 5% significance level. The null hypothesis that the exchange rate is not the cause of inflation was rejected at the 1% significance level.

4. DISCUSSION

The Granger causality test results indicate that exchange rate pass-through is valid in the Turkish economy. A bidirectional causal relationship has been found between exchange rate and inflation. The exchange rate has a direct impact on inflation. For the Turkish economy, which imports energy, raw materials, and intermediate goods in particular, the exchange rate is a decisive factor. When the exchange rate increases, it is reflected in the production process in terms of costs. As costs increase, companies pass on these increased costs to the prices of the goods they produce and sell. Thus, cost-push inflation emerges in the economy. However, no direct relationship has been found between CDS premiums and inflation. The test results indicate a relationship between CDS premiums and exchange rate. Exchange rate also affect inflation. Therefore, in the Turkish economy, CDS premiums indirectly affect inflation through financial channels.

The results differ from the studies carried out by Rashid, Ahmad and Yasmin (2017), Işıklı and Akin (2018), Münyas (2020), Aytekin and Abdioglu (2021), Gürel (2021), Akbaş, Dönmez and Can (2024), Yerlikaya (2024), Muñoz, Gálvez-Gamboa and Dávila (2025), and Kasap (2025), while coming out similar to the studies carried out by Kebłowski (2011), Korkmaz and Bayır (2015), Karamelikli and Korkmaz (2016), Açcı, Kayhan and Bayat (2018), Turna and Özcan (2021), Emikönel and Orhan (2023), Valogo, Duodu, Yusif and Baidoo (2023), İltaş and Güzel (2024), Su, Ren and Al-Qasos (2024), Anachedo, Nwanna and Jeff-Anyeneh (2025), and Simanjuntak and Fauzie (2026).

5. CONCLUSION

This study analyzes the relationship between CDS premium, an indicator of financial risk for the Turkish economy, exchange rate, and inflation using the Granger causality test. Monthly data for the period 2020M1-2026M4 were used. The Granger causality test revealed a bidirectional relationship between the exchange rate and inflation. A unidirectional causal relationship has been identified from CDS premiums to exchange rates. There is no relationship between CDS premiums and inflation. These results demonstrate that exchange rate pass-through is valid in the Turkish economy. CDS premiums do not have a direct impact on inflation. CDS premiums affect the exchange rate and, indirectly, inflation. CDS premiums influence exchange rates and, through an indirect financial transmission mechanism, affect inflation.

Reducing or keeping CDS premiums low is very important for every country. To have a low risk premium, it is primarily necessary to keep inflation under control. Price stability must be ensured in the economy. In order to achieve price stability in the Turkish economy, it is essential that the monetary policies implemented are effective. To reduce inflation, the central bank is implementing a tight monetary policy. In line with these policies, interest rates and reserve requirements have been increased recently. The aim is to reduce CDS premiums by ensuring price stability. Structural reforms in agriculture, industry, and technology are needed to protect the country's economy from external shocks. Food prices play a significant role in inflation. A serious and systemic agricultural policy can reduce food imports from abroad, thereby decreasing foreign exchange expenditures. At the same time, the impact of food prices on the domestic market can be prevented. Fiscal discipline must be maintained consistently. Budget deficits must be brought under control and government spending must be reduced. Economic policies must be transparent and these decisions must inspire confidence in economic units.

Other researchers working on this topic may use different methods. By performing the Breitung-Candelon frequency domain causality test, they can examine the short, medium, and long run separately. They can use machine learning methods.

REFERENCES

Açcı, Y., Kayhan, S., & Bayat, T. (2018). The effect of credit default swap premiums on developing markets' economies: The case of exchange rates. *Theoretical and Applied Economics, 25*(4[617]), 235–252. https://store.ectap.ro/articole/1370.pdf

Akbaş, Y. E., Dönmez, Z., & Can, E. (2024). The effect of output level, exchange rate and interest rate on inflation in BRIC-T countries. *Review of Economics and Political Science, 9*(5), 472–489. https://doi.org/10.1108/REPS-08-2023-0091

Anachedo, C. K., Nwanna, I. O., & Jeff-Anyeneh, S. E. (2025). Dynamics of exchange rate on inflation and interest rate in Nigeria: A robust least square (RLS) approach. *African Banking and Finance Review Journal, 20*(4), 66–81.

Aytekin, S., & Abdioglu, N. (2021). Do CDS spreads and inflation move together? The experience of the Fragile Five countries and the BRICS-T. *Scientific Annals of Economics and Business, 68*(2), 163–175. https://doi.org/10.47743/saeb-2021-0009

Emikönel, M., & Orhan, A. (2023). An empiric analysis on the relationship between exchange rates and inflation in Fragile Five countries. *Journal of Yasar University, 18*(70), 237–251. https://izlik.org/JA57UA37LY

Granger, C. W. J. (1969). Investigating causal relations by econometric models and cross-spectral methods. *Econometrica, 37*(3), 424–438. https://doi.org/10.2307/1912791

Gürel, S. P. (2021). Makrekonomik koşullar ve küresel risk faktörü ülke risk primlerini nasıl etkiler? Türkiye'den yeni kanıtlar. *Business & Management Studies: An International Journal, 9*(2), 547–560. https://doi.org/10.15295/bmij.v9i2.1800

Işıklı, E., & Akin, T. (2018). The relationship between energy prices, CDS, USD currency and inflation rate in Turkey. *CEA Journal of Economics, 13*(2), 21–34.

İltaş, Y., & Güzel, F. (2024). The nexus between CDS premiums and exchange rates: Evidence from BRICS countries and Türkiye. *Ekonomi, Politika & Finans Araştırmaları Dergisi, 9*(4), 796–811. https://izlik.org/JA69ZW74CT

Kahyaoğlu, S. B. (2019). Long term relationship between CDS and currency exchange rates: The Turkish case. *Balıkesir University The Journal of Social Sciences Institute, 22*(41), 219–235. https://doi.org/10.31795/baunsobed.580572

Karamelikli, H., & Korkmaz, S. (2016). The dynamics of exchange rate pass-through to domestic prices in Turkey. *Journal of Business, Economics and Finance, 5*(1), 39–48. https://doi.org/10.17261/Pressacademia.2016116552

Kasap, A. (2025). The relationship between CDS spreads and macroeconomic variables: An analysis of Türkiye using nonlinear models. *Malatya Turgut Özal University Journal of Business and Management Sciences, 6*(1), 19–36. https://izlik.org/JA94ZJ99SC

Kebłowski, P. (2011). The behaviour of exchange rates in the Central European countries and credit default risk premiums. *Central European Journal of Economic Modelling and Econometrics, 4*, 221–237. https://doi.org/10.24425/cejeme.2011.119313

Korkmaz, S., & Bayır, M. (2015). Döviz kuru dalgalanmalarının yurtiçi fiyatlara etkisi. *Niğde Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi, 8*(4), 69–85. https://izlik.org/JA63MA57JW

Muñoz, E., Gálvez-Gamboa, F., & Dávila, E. S. (2025). Spillovers between sovereign CDS, exchange rate and market fear: Evidence from Latin America. *The Journal of Globalization, Competitiveness, and Governability, 19*(3), 20–34. https://doi.org/10.58416/GCG.2025.V19.N3.01

Münyas, T. (2020). Kredi temerrüt swapları ile euro ve dolar kurları arasındaki ilişkinin değerlendirilmesi: Türkiye örneği. *Business & Management Studies: An International Journal, 8*(2), 1113–1130. https://doi.org/10.15295/bmij.v8i2.1439

Rashid, A., Ahmad, F., & Yasmin, A. (2017). Exploring the relationship between macroeconomic indicators and sovereign credit default swap in Pakistan. *Journal of Risk Finance, 18*(4), 368–380. https://doi.org/10.1108/JRF-03-2017-0049

Simanjuntak, A. D., & Fauzie, S. (2026). The effect of foreign exchange reserves and credit default swap on exchange rate in Indonesia. *Talenta Conference Series: Local Wisdom, Social, and Arts, 9*(1), 262–270. https://doi.org/10.32734/lwsa.v9i1.2745

Su, M., Ren, Y., & Al-Qasos, A. (2024). What drives the dynamic relationship between sovereign credit default swaps and exchange rates? *Applied Economics Letters, 31*, 1–7. https://doi.org/10.1080/13504851.2024.2428430

Turna, Y., & Özcan, A. (2021). The relationship between foreign exchange rate, interest rate and inflation in Turkey: ARDL approach. *Journal of Ekonomi, 3*(1), 19–23. https://izlik.org/JA98EX78HF

Valogo, M. K., Duodu, E., Yusif, H., & Baidoo, S. T. (2023). Effect of exchange rate on inflation in the inflation targeting framework: Is the threshold level relevant? *Research in Globalization, 6*, 1–10. https://doi.org/10.1016/j.resglo.2023.100119

Yerlikaya, B. (2024). Time series analysis on credit default swap (CDS) and market indicators: The case of Türkiye. *Yıldız Social Science Review, 10*(2), 136–147. https://doi.org/10.51803/yssr.1588759

DO INSTITUTIONS UNLOCK GREEN ECONOMIC GROWTH? EVIDENCE FROM GREEN INNOVATION, TRADE, AND ENERGY

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ABSTRACT

Green growth is becoming a strategic development direction in Vietnam's economic transformation process, especially in the context of the government increasingly emphasizing the role of technological innovation, sustainable trade, and energy transition to harmonize economic growth and environmental protection. Stemming from this practical need, this study empirically investigates the impact of green innovation, green trade, and clean energy production on Vietnam's green economic growth, while clarifying the role of institutional quality in shaping the effectiveness of these green drivers. Utilizing annual data over the period 2002–2021 from different reliable sources, this study employs the fully modified ordinary least squares (FMOLS) to estimate the relationship between the research variables and handle common problems in time-series data.

Empirical results indicate that green innovation, green trade, and cleaner energy production all contribute positively to Vietnam's green economic growth. This finding implies that promoting environmentally friendly technological innovation, expanding green trade flows, and increasing capacity for cleaner energy production can lay a crucial foundation for the transition to a more sustainable growth model. However, when institutional quality is incorporated into the model as a conditional factor, the results show that the impacts of green drivers are not entirely uniform. Specifically, green innovation and cleaner energy production continue to have a significant positive impact on green economic growth, while green trade exhibits a significant negative impact. The robustness test, conducted by replacing cleaner energy production with cleaner energy consumption, also shows a similar trend, thus reinforcing the reliability of the empirical findings.

This study contributes to the literature on green growth by providing specific empirical evidence for Vietnam, a developing economy with an urgent need for green transition. Our findings suggest that Vietnam needs to continue encouraging green innovation and expanding cleaner energy while improving institutional quality to enhance the effectiveness of green policy implementation. In particular, green trade needs more prudent governance through clear environmental standards, better monitoring capacity, and mechanisms for screening imported goods and technologies, ensuring that

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trade truly becomes a driver of green economic growth rather than creating additional environmental pressure or undermining the effectiveness of the green transition.

Keywords: *Green Innovation, Green Trade, Cleaner Energy Production, Cleaner Energy Consumption, Green Economic Growth, Institutional Quality.*

JEL Codes: *O4, Q5, F18.*

1. INTRODUCTION

As countries try to deal with climate change, resource loss, energy insecurity, and the environmental effects of traditional manufacturing, green economic growth has become one of the most important parts of their development plans (OECD, 2011; World Bank, 2012). Green growth aims to improve economic well-being while lowering emissions, protecting natural capital, and making better use of resources (Stern, 2008). This is different from traditional development models, which encourage more production. This problem is especially important for Vietnam because its economy has grown thanks to fast development and greater integration into global markets. But these changes have also made people use more energy and put more stress on the environment (Government of Vietnam, 2021; World Bank, 2025). So, Vietnam's green shift needs a united effort to improve technology, encourage businesses that are good for the environment, make clean energy, and ensure that institutions are better run (OECD, 2017).

Green innovation, green trade, and green energy are three interrelated channels through which this shift might occur (Porter & Linde, 1995; Wei et al., 2023). Green trade spreads better technologies and more resource-efficient ways of making things by offering environmental goods, professional support, and long-lasting production networks (Rennings, 2000; Copeland & Taylor, 2004). Green energy makes these systems stronger by reducing our reliance on fossil fuels and giving the economy a better base (Apergis & Payne, 2010). These benefits, however, are unlikely to occur automatically. Because the quality of regulations, the efficiency of the government, the openness of policies, and the trustworthiness of those policies all affect how well green resources are used and how regularly environmental standards are met (North, 1990; Kaufmann et al., 2011).

Despite growing scholarly interest, three gaps remain evident in the literature. First, previous studies frequently examine innovation, energy, trade, and institutions separately, providing limited understanding of their joint contribution to green economic growth (Wei et al., 2023). Second, Vietnam-specific research remains limited and generally focuses on emissions, conventional growth, or individual green determinants rather than an integrated model of green economic performance. A recent Vietnamese study investigated green innovation, renewable energy, industrialization, and institutional quality, but did not incorporate green trade into the same empirical framework (Phuc, 2025). Third, institutional quality is commonly included as a direct determinant or control variable rather than a

conditioning factor capable of altering the effects of several green drivers (Acemoglu et al., 2005; Kaufmann et al., 2011).

To address these gaps, this study examines the effects of green innovation, green trade, and clean energy production on Vietnam's green economic growth and evaluates how the estimated relationships change when institutional quality is considered. Annual data for 2002–2021 are obtained from OECD Statistics, the U.S. Energy Information Administration, and the World Development Indicators database. We use Fully Modified Ordinary Least Squares to estimate coefficients in cointegrated time-series models while correcting for endogeneity and serial correlation. The baseline results show that green economic growth is helped by green innovation, green trade, and clean energy production. On the other hand, the institution-augmented model shows positive benefits for innovation and clean energy but a substantial negative effect for green trade. The main findings are supported by the robustness results that similar effects are seen when clean energy consumption is used instead of production. The study adds value because it combines three green drivers into a framework that works for Vietnam, explains the structural conditions that make these drivers create green growth, and gives a deeper knowledge of green trade.

The study is outlined as follows: Section 2 presents the literature review. Section 3 delineates the methodology for the study and the data. Section 4 delineates the empirical findings. Section 5 ultimately addresses the conclusions and policy implications.

2. LITERATURE REVIEW

Green economic growth is best viewed as the result of a systemic shift in which technology advancement, trade integration, energy transition, and institutional governance reinforce or restrain one another (OECD, 2011). Ecological modernization theory holds that economic growth and environmental protection can go hand in hand if technological and structural changes make resources more productive while reducing the environmental impact of production (Jännicke, 2008). Endogenous growth theory posits that new ideas and greater knowledge can lead to long-term gains in productivity. But institutional economics explains why these gains are not the same in countries with similar technology possibilities (Romer, 1990; North, 1990). All of these points of view show that green development isn't caused by a single green input, but by economies' ability to originate, disperse, power, and manage cleaner productive activity (Popp, 2002; Acemoglu et al., 2005).

This integrated mechanism starts with green innovation, which creates better technologies, makes energy use more efficient, and cuts down on trash during production (Rennings, 2000; Popp, 2002). According to the Porter hypothesis, credible environmental rules might encourage enterprises to rethink goods and manufacturing processes, allowing innovation advantages to cover some of the cost of environmental compliance (Porter and Linde, 1995; Jaffe et al., 2005). The benefits of innovation, however, are restricted when innovations cannot extend beyond their initial producers or markets

(Grossman & Krueger, 1995; Copeland & Taylor, 2004). Green trade overcomes this barrier by exchanging environmental commodities, information, manufacturing equipment, and cleaner technologies across borders, broadening the economic reach of green innovation (Antweiler et al., 2001).

However, the environmental value of innovation and trade is dependent on the energy system that drives production and consumption (Apergis & Payne, 2010). Cleaner equipment may provide only a few environmental advantages if power generation is still dominated by carbon-intensive fuels. But renewable energy can multiply technical efficiency improvements by reducing the carbon content of economic activity (Sadorsky, 2009; Zhao & Shah, 2024). Innovation may also lower the cost of renewable technologies, while trade allows countries to acquire the equipment and expertise required to increase clean energy capacity (Popp, 2002). So, green trade, energy, and innovation all work together as part of a single structural shift, rather than being separate forces that drive green growth (Wei et al., 2023).

But research on trade and the environment shows that this balance can have different outcomes depending on the size, make-up, and method used (Antweiler et al., 2001; Copeland & Taylor, 2004). Trade may be good for the environment because it can lead to cleaner technologies and more specialized industries. But if economic growth is faster than efficiency gains, it can also have a big effect on resource use and emissions (Managi et al., 2009). Because of this, green trade is more likely to help green growth when it supports low-carbon value chains and local technological progress rather than just selling more goods (Copeland & Taylor, 2004). Wei et al. (2023) look at evidence from leading green economies that green innovation, green trade, and renewable energy may all help improve the quality of the environment, but the amount of each contribution varies from country to country.

If these complementarities are turned into green economic results, institutions play a role (North, 1990; Kaufmann et al., 2011). Strong institutions protect intellectual property, lower the risk of investments, make sure environmental rules are followed, and run the infrastructure needed for green business and clean energy (Acemoglu et al., 2005; Rodrik, 2007). They also make it less likely that green trade will be used to sell old technology, fake environmental certifications, or businesses that pollute a lot (Copeland & Taylor, 2004). Because of this, institutional quality should not be seen as a separate indicator of green growth but rather as a factor that makes green growth possible and affects it.

There is evidence to support the integrated viewpoint, but the results depend on the level of growth, the time frame, and the estimation method used (Teklie & Yağmur, 2024; Gan, 2025). Teklie and Yağmur (2024) discovered that green innovation, clean energy, and good institutions are all good for African countries in the long run. Short-term effects, on the other hand, are not as strong. Research in developing countries shows that estimates for innovation, renewable energy, and institutions are different for FMOLS, DOLS, and OLS specifications. This shows that the methods used are sensitive to the context (Gan, 2021). In Vietnam, studies show that green innovation, renewable energy, and good

institutions have positive long-term effects. However, green trade has not been properly included in the same analysis framework (Phuc, 2025).

The remaining gap is how the three green drivers affect Vietnam's green economic growth and whether institutional quality affects their efficacy. We forecast that green energy and green innovations will help the green economy grow. However, green trade could have either good technological effects or negative effects on scale and adjustment, based on the institutional conditions. The quality of institutions is thus thought to affect both the number and direction of these relationships by impacting the efficacy of regulation, technology absorption, and green resource allocation.

3. DATA AND METHODOLOGY

This section covers the methodological framework used to investigate the data set in this study.

3.1. Data Sources

The specific goal of this study is to explain how green innovation, green trade, and green energy contribute to green economic growth in the institutional context of Vietnam. We use Vietnamese data from 2002 to 2021 for its empirical investigation. We collect data from different sources such as the Organization for Economic Co-operation and Development (OECD) statistics, the U.S. Energy Information Administration (EIA), the International Monetary Fund (IMF) statistics, and the World Development Indicators (WDI). Table 1 presents the brief description of the variables.

Table 1. Description of Variables

Variable	Notation	Measurement	Data Source	References
Dependent Variable				
Green economic growth	GEG	Green economic growth = GDP + EE – NRP – NFD – CO_2 Where: "GDP is Gross domestic product growth (Annual %); EE is education expenditure (% of GDP); NRP is fossil fuel consumption (% of total); NFD is net forest depletion (% of GNI); CO_2 is carbon emissions (% of fuel)"	WDI	Sohag et al. (2019)
Independent Variables				
Green Innovation	GI	"Environmental-related technologies"	OECD	Wang et al. (2019)
Green Trade	GT	"Share of export of environmental goods to total export"	IMF	Ahmed et al. (2022)
Cleaner Energy Production	CEP	"Share of electricity generated by renewable power plants in total electricity generated by all types of plants"	U.S. Energy Information Administration	Sohag et al. (2019)

Cleaner Energy Consumption	CEC	"Share of renewable energy in total final energy consumption"	U.S. Energy Information Administration	Sohag et al. (2019)
Institutional quality index	IQI	"Average estimate of six dimensions of governance measures: voice and accountability, political stability and absence of violence/terrorism, government effectiveness, regulatory quality, rule of law, and control of corruption"	WDI	Cao et al. (2022)
Control variables				
Industrialization	IND	"The percentage of industrial added value to GDP (% of GDP)"	WDI	Nan et al. (2022)
Foreign direct investment	FDI	"Foreign direct investment, net inflows (% of GDP)"	WDI	Ofori et al. (2023)

Source: Elaborated by the authors.

3.2. Model Specification

The main objective of this study is to determine the impact of green innovation, green trade, and green energy, as influenced by institutional quality, on Vietnam's green economic growth during the period from 2002 to 2021. Based on the research of Sohag et al. (2019), Wang et al. (2019), Ahmed et al. (2022), & Cao et al. (2022), the study expresses the functional forms of Equation (M1) and Equation (M2):

$$GEG = f(GI, GT, CEP, IQI, IND, FDI) \quad (M1)$$

$$GEG = f(GI, GT, CEC, IQI, IND, FDI) \quad (M2)$$

where GEG, GI, GT, CEP, CEC, IQI, IND, and FDI denote green economic growth, green innovation, green trade, cleaner energy production, cleaner energy consumption, institutional quality index, industrialization, and foreign direct investment.

The study transforms Equations (M1) and (M2) into their panel estimable form as specified in the equations below. In addition, we use interaction variables between institutional quality and the variables: green innovation, green trade, cleaner energy production, and cleaner energy consumption to build research models.

$$GEG_t = \beta_0 + \beta_1 GI_t + \beta_2 GT_t + \beta_3 CEP_t + \beta_4 IQI_t + \beta_5 IND_t + \beta_6 FDI_t + \varepsilon_t \quad (1)$$

$$GEG_t = \beta_0 + \beta_1 GI_t + \beta_2 (GI*IQI)_t + \beta_3 GT_t + \beta_4 CEP_t + \beta_5 IQI_t + \beta_6 IND_t + \beta_7 FDI_t + \varepsilon_t \quad (2)$$

$$GEG_t = \beta_0 + \beta_1 GI_t + \beta_2 GT_t + \beta_3 (GT*IQI)_t + \beta_4 CEP_t + \beta_5 IQI_t + \beta_6 IND_t + \beta_7 FDI_t + \varepsilon_t \quad (3)$$

$$GEG_t = \beta_0 + \beta_1 GI_t + \beta_2 GT_t + \beta_3 CEP_t + \beta_4 (CEP*IQI)_t + \beta_5 IQI_t + \beta_6 IND_t + \beta_7 FDI_t + \varepsilon_t \quad (4)$$

$$GEG_t = \beta_0 + \beta_1 GI_t + \beta_2 (GI*IQI)_t + \beta_3 GT_t + \beta_4 (GT*IQI)_t + \beta_5 CEP_t + \beta_6 (CEP*IQI)_t + \beta_7 IQI_t + \beta_8 IND_t + \beta_9 FDI_t + \varepsilon_t \quad (5)$$

$$GEG_t = \beta_0 + \beta_1 GI_t + \beta_2 GT_t + \beta_3 CEC_t + \beta_4 IQI_t + \beta_5 IND_t + \beta_6 FDI_t + \varepsilon_t \quad (6)$$

$$GEG_t = \beta_0 + \beta_1 GI_t + \beta_2 (GI*IQI)_t + \beta_3 GT_t + \beta_4 CEC_t + \beta_5 IQI_t + \beta_6 IND_t + \beta_7 FDI_t + \varepsilon_t \quad (7)$$

$$GEG_t = \beta_0 + \beta_1 GI_t + \beta_2 GT_t + \beta_3 (GT*IQI)_t + \beta_4 CEC_t + \beta_5 IQI_t + \beta_6 IND_t + \beta_7 FDI_t + \varepsilon_t \quad (8)$$

$$GEG_t = \beta_0 + \beta_1 GI_t + \beta_2 GT_t + \beta_3 CEC_t + \beta_4 (CEC*IQI)_t + \beta_5 IQI_t + \beta_6 IND_t + \beta_7 FDI_t + \varepsilon_t \quad (9)$$

$$GEG_t = \beta_0 + \beta_1 GI_t + \beta_2 (GI*IQI)_t + \beta_3 GT_t + \beta_4 (GT*IQI)_t + \beta_5 CEC_t + \beta_6 (CEC*IQI)_t + \beta_7 IQI_t + \beta_8 IND_t + \beta_9 FDI_t + \varepsilon_t \quad (10)$$

It must be noted that β's(1, 2, … 9) and $\beta 0$ represent unknown parameters to be estimated and the constant term. t represents the time trend. Also, the disturbance error term (ε) is assumed to follow a normal distribution with zero mean and constant variance.

3.3. Methods

First, in this study, we utilize the unit root test and the cointegration test for panels to investigate data stationarity and long-run variable relationships in the research model. Next, we use the Fully Modified Ordinary Least Squares (FMOLS) estimation technique. FMOLS is a regression technique for estimating parameters in linear regression models, especially when dealing with non-stationary data, serial correlation, and potential endogeneity. It overcomes the limitations of Ordinary Least Squares (OLS) in some circumstances, resulting in more accurate forecasts, especially for small sample sizes. Finally, we use the robustness test to confirm the research models' robustness.

4. EMPIRICAL RESULTS

This section shows and analyzes the descriptive statistics, panel unit root, panel cointegration, baseline testing, and robustness testing.

4.1. Descriptive Statistics

The descriptive statistics for the variables used in the sample are reported first (as shown in Table 2).

Table 2. Descriptive Statistics

Variables	Obs	Mean	Std. dev.	Min	Max
GEG	20	-1.6111	0.0580	-1.7041	-1.5123
GI	20	0.1379	0.0572	0.0356	0.2524
GT	20	0.0281	0.0145	0.0074	0.0514
CEP	20	0.3862	0.0576	0.2947	0.5000
CEC	20	0.0835	0.0180	0.0545	0.1220
IQI	20	-0.4814	0.0898	-0.5974	-0.3371

IND	20	0.3667	0.0191	0.3302	0.4020
FDI	20	0.0496	0.0166	0.0339	0.0966

Source: Elaborated by the authors.

Table 2 reveals green economic growth (GG)'s mean value is -1.6111, ranging from -1.7041 to -1.5123. Green innovation (GI)'s mean value is 0.1379, with the minimum and maximum values of 0.0356 and 0.2524, respectively. Green trade (GT)'s mean value is 0.0281, ranging from 0.0074 to 0.0514. Cleaner energy production (CEP) has a mean value of 0.3862 with a minimum value of 0.2947 and a maximum value of 0.5000. Cleaner energy consumption (CEC)'s mean value is 0.0835, ranging from 0.0545 to 0.1220. Institutional quality index (IQI) has a mean value of -0.4814 with a minimum value of -0.5974 and a maximum value of -0.3371. Industrialization (IND)'s mean value is 0.3667 with the minimum and maximum values of 0.3302 and 0.4020, respectively. Foreign direct investment (FDI)'s mean value is 0.0496, ranging from 0.0339 to 0.0966.

4.2. Panel Unit Root

Table 3 displays the results of the Levin-Lin-Chu unit-root test, which is used to confirm data stationarity. The null hypothesis of this test is "nonstationary series". Results show that GEG, CEP, and FDI are stationary at the level of zero in both cases with and without trend. At the first difference, GI, GT, CEC, IQI, and IND become stationary, as the null hypothesis of "non-stationary series" is rejected at a 5% level (p-value < 0.05). This means that GI, GT, CEC, IQI, and IND are integrated into order 1.

Table 3. Levin–Lin–Chu Unit-Root Test

Variables	Level		First-Difference		Order of integration
	Without trend	With trend	Without trend	With trend	
GEG	0.0070	0.0278	0.0019	0.0200	I(0)
GI	0.0585	0.1388	0.0012	0.0142	I(1)
GT	0.1429	0.0070	0.0159	0.0435	I(1)
CEP	0.0037	0.0076	0.0006	0.0050	I(0)
CEC	0.4134	0.0001	0.0000	0.0001	I(1)
IQI	0.5826	0.3369	0.0328	0.1233	I(1)
IND	0.2532	0.6424	0.0201	0.0062	I(1)
FDI	0.0075	0.0165	0.0030	0.0123	I(0)

Source: Elaborated by the authors.

4.3. Panel Cointegration

Table 4 displays the results of the Pedroni cointegration test, which determines if variables have a long-term relationship. The probability values of the Phillips–Perron test and the Augmented Dickey–Fuller test are less than 0.05. In contrast, the probability values of the Modified Phillips–Perron test are more than 0.05. Based on the majority of the results, the result shows that the null hypothesis of "no

cointegration" is rejected at the level of 5%, showing the presence of a long-term link between variables in all of the research models.

Table 4. Pedroni Panel Cointegration Test

Models		Modified Phillips–Perron test	Phillips–Perron test	Augmented Dickey–Fuller test
Model 1	Statistic	1.3640	-5.7152	-2.6137
	p-value	0.0863	0.0000	0.0045
Model 2	Statistic	1.1675	-1.5335	-1.5243
	p-value	0.1215	0.0626	0.0637
Model 3	Statistic	1.2903	-10.0818	-3.9047
	p-value	0.0985	0.0000	0.0000
Model 4	Statistic	1.0685	-5.7838	-3.5055
	p-value	0.1427	0.0000	0.0002
Model 5	Statistic	0.7588	-3.4849	-2.9585
	p-value	0.2240	0.0002	0.0015
Model 6	Statistic	1.2073	-4.0658	-2.7320
	p-value	0.1137	0.0000	0.0031
Model 7	Statistic	1.1517	-2.0886	-2.0463
	p-value	0.1247	0.0184	0.0204
Model 8	Statistic	1.3142	-8.6735	-3.1428
	p-value	0.0944	0.0000	0.0008
Model 9	Statistic	1.4578	-3.7388	-2.4308
	p-value	0.0724	0.0001	0.0075
Model 10	Statistic	0.9057	-2.5042	-2.1328
	p-value	0.1825	0.0061	0.0165

Source: Elaborated by the authors.

4.4. Baseline Test

The study uses FMOLS to investigate the impact of green innovation, green trade, and cleaner energy production, as influenced by institutional quality, on Vietnam's green economic growth. The FMOLS results are reported in Table 5.

Table 5. Baseline Test

Variables	(1)	(2)	(3)	(4)	(5)
GI	0.0246 (0.612)	2.3778*** (0.000)	-0.1052** (0.045)	0.0667 (0.222)	1.6257*** (0.000)
GI x IQI		4.6656*** (0.000)			3.3674*** (0.000)
GT	3.3238*** (0.000)	4.0550*** (0.000)	-13.2872*** (0.000)	3.2321*** (0.000)	-13.5681*** (0.000)
GT x IQI			-38.5914*** (0.000)		-40.3814*** (0.000)
CEP	0.3413*** (0.000)	0.2825*** (0.001)	0.4382*** (0.000)	2.4790*** (0.000)	2.0654*** (0.000)
CEP x IQI				4.5065*** (0.000)	3.5251*** (0.000)
IQI	-0.4665*** (0.000)	-1.1475*** (0.000)	0.6725*** (0.000)	-2.1862*** (0.000)	-1.1191*** (0.000)
IND	-0.5199*** (0.001)	0.0229 (0.928)	0.8664*** (0.000)	-0.2513 (0.145)	1.5091*** (0.000)
FDI	1.0781*** (0.000)	0.9914*** (0.000)	0.8987*** (0.000)	0.7415*** (0.000)	0.5964*** (0.000)
Constant	-1.9258*** (0.000)	-2.4639*** (0.000)	-1.9130*** (0.000)	-2.8258*** (0.000)	-3.0019*** (0.000)
N	19	19	19	19	19
R^2	0.4572	0.4786	0.6370	0.6040	0.7828

Source: Elaborated by the authors.

The FMOLS estimates identify a stable relationship between the selected green drivers and Vietnam's green economic growth during 2002–2021. In the baseline model, green innovation has a positive and significant effect, indicating that cleaner technologies and environmental knowledge improve resource productivity and reduce the ecological costs associated with economic expansion (Porter & Linde, 1995; Popp, 2002). Green trade also has a positive coefficient, which supports the argument that getting access to environmentally friendly goods, better inputs, and foreign technological knowledge may help raise productivity in the home country (Antweiler et al., 2001). By reducing the use of fossil fuels and making the output base lower in carbon, clean energy production also supports green economic growth (Apergis & Payne, 2010).

Green innovation and clean energy production continue to have good and statistically significant benefits when institutional quality is taken into account. Based on these results, it looks like technological progress and the change to clean energy are two of the main factors behind Vietnam's green growth. Existing study from Vietnam finds positive effects from green innovation, renewable

energy, and governmental quality, even though the models used and the time period of the samples are different (Phuc, 2025).

When institutional factors are considered, green trade, on the other hand, turns negative and statistically significant. This means that its effect depends on the quality of government rather than trade growth alone (North, 1990; Copeland and Taylor, 2004). This switch can happen when foreign technologies are not good for local production, when green certification is not enough, or institutional restrictions prevent trade-related resources from promoting local technical skills (Managi et al. 2009). The finding should therefore be interpreted as evidence of an institutionally conditional trade effect rather than a general rejection of environmentally oriented trade (Rodrik, 2008; Kaufmann et al., 2011).

4.5. Robustness Test

To test the robustness of the research models, we use cleaner energy consumption instead of cleaner energy production to represent green energy. Results of the robustness test are presented in Table 6.

Table 6. Robustness Test

Variables	(6)	(7)	(8)	(9)	(10)
GI	0.0128 (0.844)	1.9368*** (0.001)	-0.0672** (0.039)	0.0043 (0.941)	1.9614*** (0.000)
GI x IQI		3.8081*** (0.001)			4.0016*** (0.000)
GT	2.3942*** (0.000)	3.2158*** (0.000)	-12.1710*** (0.000)	2.2399*** (0.000)	-16.4500*** (0.000)
GT x IQI			-34.1859*** (0.000)		-45.9951*** (0.000)
CEC	1.8048*** (0.000)	1.4884*** (0.000)	1.8075*** (0.000)	1.9562* (0.073)	5.2552*** (0.000)
CEC x IQI				0.0806 (0.973)	8.3515*** (0.000)
IQI	-0.5701*** (0.000)	-1.1160*** (0.000)	0.4203*** (0.000)	-0.5672*** (0.008)	-0.5188*** (0.000)
IND	-0.2626 (0.202)	0.1548 (0.483)	0.9962*** (0.000)	-0.2422 (0.215)	1.6236*** (0.000)
FDI	0.9519*** (0.000)	0.9070*** (0.000)	0.7080*** (0.000)	0.9579*** (0.000)	0.5594*** (0.000)
Constant	-2.0553*** (0.000)	-2.4813*** (0.000)	-2.0365*** (0.000)	-2.0646*** (0.000)	-2.7171*** (0.000)
N	19	19	19	19	19
R^2	0.4931	0.5474	0.6382	0.5874	0.7243

Source: Elaborated by the authors.

The robustness specification replaces clean energy production with clean energy consumption and yields a substantively similar pattern. Green innovation and clean energy remain positive, whereas green trade retains its negative effect after institutional factors are considered. These results identify innovation and clean energy as robust drivers while highlighting institutional quality as a critical condition for converting green trade into sustainable economic gains (North, 1990; Teklie & Yağmur, 2024).

5. CONCLUSIONS

This study examined the effects of green innovation, green trade, and green energy on Vietnam's green economic growth while treating institutional quality as a condition shaping the effectiveness of these drivers. The baseline results show that green innovation, green trade, and clean energy production all help green economic growth. This means that technological progress, environmentally friendly trade, and the energy change may all work together to speed up development. Green innovation and clean energy are still good and important when you look at the quality of the institutions that support them. The green trade, on the other hand, has a lot of bad effects. The robustness study that uses clean energy usage comes to the same findings, showing that the main conclusions are not affected by a particular energy metric.

These findings have several policy implications for Vietnam. Green innovation policy should put an emphasis on environmental research and development, the creation of green patents, collaboration between universities and businesses, and the use of cleaner production methods by businesses. Energy strategy should update transmission facilities, make it easier for investors to get energy, and encourage businesses and families to use low-carbon energy. It should also increase the capacity of renewable energy sources. Green trade strategy shouldn't focus on increasing the amount of trade. Instead, it should focus on environmental standards, screening technologies, accurate certification, and getting people in the country involved in sustainable value chains. These attempts should be paired with changes to institutions. Because clear rules, consistent policies, good management, and stopping corruption all play a part in whether green resources are good in the long run.

The negative coefficient of green trade should not be interpreted as a recommendation for restricting trade. Instead, it should be seen as proof that environmentally friendly trade needs better regulation and more local ability to absorb it. Vietnam should thus tie trade deals and tax breaks for investors to clear environmental standards, learn new technologies, and programs that help local businesses grow their supply chains. With this kind of cooperation, green technology that is brought in from other countries could help with national clean energy and innovation goals without causing technical reliance or adding to the cost of adjusting to it.

REFERENCES

Acemoglu, D., Johnson, S., & Robinson, J. A. (2005). Institutions as a fundamental cause of long-run growth. In P. Aghion & S. N. Durlauf (Eds.), *Handbook of economic growth* (Vol. 1A, pp. 385–472). Elsevier. https://doi.org/10.1016/S1574-0684(05)01006-3

Ahmed, F., Kousar, S., Pervaiz, A., Trinidad-Segovia, J. E., del Pilar Casado-Belmonte, M., & Ahmed, W. (2022). Role of green innovation, trade and energy to promote green economic growth: A case of South Asian nations. *Environmental Science and Pollution Research, 29*(5), 6871–6885. https://doi.org/10.1007/s11356-021-15881-4

Antweiler, W., Copeland, B. R., & Taylor, M. S. (2001). Is free trade good for the environment? *American Economic Review, 91*(4), 877–908. https://doi.org/10.1257/aer.91.4.877

Apergis, N., & Payne, J. E. (2010). Renewable energy consumption and economic growth: Evidence from a panel of OECD countries. *Energy Policy, 38*(1), 656–660. https://doi.org/10.1016/j.enpol.2009.09.002

Cao, H., Khan, M. K., Rehman, A., Dagar, V., Oryani, B., & Tanveer, A. (2022). Impact of globalization, institutional quality, economic growth, electricity and renewable energy consumption on carbon dioxide emission in OECD countries. *Environmental Science and Pollution Research, 29*(16), 24191–24202. https://doi.org/10.1007/s11356-021-17076-3

Copeland, B. R., & Taylor, M. S. (2004). Trade, growth, and the environment. *Journal of Economic Literature, 42*(1), 7–71. https://doi.org/10.1257/002205104773558047

Gan, J. (2025). New insights into how green innovation, renewable energy, and institutional quality shape environmental sustainability in emerging economies. *Frontiers in Environmental Science, 13*, Article 1525281. https://doi.org/10.3389/fenvs.2025.1525281

Government of Vietnam. (2021). *Decision No. 1658/QD-TTg approving the National Green Growth Strategy for 2021–2030, vision towards 2050*. https://en.baochinhphu.vn/national-green-growth-strategy-for-2021-2030-vision-towards-2050-11142515.htm

Grossman, G. M., & Krueger, A. B. (1995). Economic growth and the environment. *The Quarterly Journal of Economics, 110*(2), 353–377. https://doi.org/10.2307/2118443

Jaffe, A. B., Newell, R. G., & Stavins, R. N. (2005). A tale of two market failures: Technology and environmental policy. *Ecological Economics, 54*(2–3), 164–174. https://doi.org/10.1016/j.ecolecon.2004.12.027

Jänicke, M. (2008). Ecological modernisation: New perspectives. *Journal of Cleaner Production, 16*(5), 557–565. https://doi.org/10.1016/j.jclepro.2007.02.011

Kaufmann, D., Kraay, A., & Mastruzzi, M. (2011). The worldwide governance indicators: Methodology and analytical issues. *Hague Journal on the Rule of Law, 3*(2), 220–246. https://doi.org/10.1017/S1876404511200046

Managi, S., Hibiki, A., & Tsurumi, T. (2009). Does trade openness improve environmental quality? *Journal of Environmental Economics and Management, 58*(3), 346–363. https://doi.org/10.1016/j.jeem.2009.04.008

Nan, S., Wang, Z., Wang, J., & Wu, J. (2022). Investigating the role of green innovation in economic growth and carbon emissions nexus for China: New evidence based on the PSTR model. *Sustainability, 14*(24), Article 16369. https://doi.org/10.3390/su142416369

North, D. C. (1990). *Institutions, institutional change and economic performance*. Cambridge University Press. https://doi.org/10.1017/CBO9780511808678

OECD. (2011). *Towards green growth*. https://doi.org/10.1787/9789264111318-en

OECD. (2017). *Green growth indicators 2017*. https://doi.org/10.1787/9789264268586-en

Ofori, E. K., Onifade, S. T., Ali, E. B., Alola, A. A., & Zhang, J. (2023). Achieving carbon neutrality in post COP26 in BRICS, MINT, and G7 economies: The role of financial development and governance indicators. *Journal of Cleaner Production, 387*, Article 135853. https://doi.org/10.1016/j.jclepro.2023.135853

Phuc, D. N. (2025). The impact of green innovation, renewable energy, industrialization and institutional quality on green growth in Vietnam. *International Journal of Innovative Research and Scientific Studies, 8*(2), 4511–4519. https://doi.org/10.53894/ijirss.v8i2.6386

Popp, D. (2002). Induced innovation and energy prices. *American Economic Review, 92*(1), 160–180. https://doi.org/10.1257/000282802760015658

Porter, M. E., & van der Linde, C. (1995). Toward a new conception of the environment-competitiveness relationship. *Journal of Economic Perspectives, 9*(4), 97–118. https://doi.org/10.1257/jep.9.4.97

Rennings, K. (2000). Redefining innovation—Eco-innovation research and the contribution from ecological economics. *Ecological Economics, 32*(2), 319–332. https://doi.org/10.1016/S0921-8009(99)00112-3

Rodrik, D. (2007). *One economics, many recipes: Globalization, institutions, and economic growth*. Princeton University Press. https://doi.org/10.1515/9781400829354

Romer, P. M. (1990). Endogenous technological change. *Journal of Political Economy, 98*(5, Part 2), S71–S102. https://doi.org/10.1086/261725

Sadorsky, P. (2009). Renewable energy consumption and income in emerging economies. *Energy Policy, 37*(10), 4021–4028. https://doi.org/10.1016/j.enpol.2009.05.003

Sohag, K., Taşkın, F. D., & Malik, M. N. (2019). Green economic growth, cleaner energy and militarization: Evidence from Turkey. *Resources Policy, 63*, Article 101407. https://doi.org/10.1016/j.resourpol.2019.101407

Stern, N. (2008). The economics of climate change. *American Economic Review, 98*(2), 1–37. https://doi.org/10.1257/aer.98.2.1

Teklie, D. K., & Yağmur, M. H. (2024). The role of green innovation, renewable energy, and institutional quality in promoting green growth: Evidence from African countries. *Sustainability, 16*(14), Article 6166. https://doi.org/10.3390/su16146166

Wang, Q., Qu, J., Wang, B., Wang, P., & Yang, T. (2019). Green technology innovation development in China in 1990–2015. *Science of the Total Environment, 696*, Article 134008. https://doi.org/10.1016/j.scitotenv.2019.134008

Wei, S., Jiandong, W., & Saleem, H. (2023). The impact of renewable energy transition, green growth, green trade and green innovation on environmental quality: Evidence from top 10 green future countries. *Frontiers in Environmental Science, 10*, Article 1076859. https://doi.org/10.3389/fenvs.2022.1076859

World Bank. (2012). *Inclusive green growth: The pathway to sustainable development*. https://hdl.handle.net/10986/6058

World Bank. (2025). *Viet Nam 2045: Growing greener—Pathways to a resilient and sustainable future*. https://doi.org/10.1596/43308

Zhao, T., & Shah, S. A. A. (2024). Green energy, economic growth, and innovation for sustainable development in OECD countries. *Sustainability, 16*(22), Article 10113. https://doi.org/10.3390/su162210113

ECONOMIC IMPACT OF AGRICULTURAL AND RURAL POLICIES: LUSHNJË CASE STUDY

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ABSTRACT

This paper aims to assess the impact of policies on rural and agricultural data, such as yield, area used for agricultural purposes, and production between 1998 and 2024 in Albania. The analysis is focused on three agricultural production categories: perennial fruit crops, vegetable crops and arable crops. Pearson's r coefficient, Kendall's tau-b, Spearman's rho, chi test, Phi coefficient were used to analyse the factor relationships. A quantitative analysis was carried out in the form of a survey on 200 farmers in the Lushnjë municipality and used for regression analysis, comparative and descriptive statistics. The qualitative analysis was centred around the literature that has been published on the topic of public, agricultural and rural policies. Conclusions derived from qualitative data were used to interpret policy effectiveness.

Keywords: *Agricultural Policies, Rural Development, Climate Change, Subsidies, Gender Equality in Agriculture, Land Fragmentation.*

JEL Codes: *Q18, Q12, Q15, O18.*

1.INTRODUCTION

Albania's agricultural transition reveals fundamental tensions between policy ambition and rural development realities. While agriculture contributes approximately 15.5% of GDP (INSTAT, 2025), more than double the regional average and comparable to developing economies (World Bank, 2025), the elevated share signals structural inefficiency rather than sectoral vitality.

Industries that add a higher value added to the economy of a country typically emerge as the country develops, but this is something we have yet to see in the Albanian economy, given that agriculture remains a large contributor to the GDP. The rural economy shows patterns of slow development, despite being compared to countries in the region that share similar characteristics. From a historical perspective, reforms in 1945 redistributed 50% of the arable land surface, then a centrally planned economy, followed by a transition to a market economy in the 1990s (Barolli, 2005). Each

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period was characterized by rapid transfers of assets on a large scale, shaping contemporary institutional and policy frameworks.

The total size of agricultural land was 699 thousand hectares in 1998, making up 24.3% of the national landmass of Albania (INSTAT, 2025). In 2024, production of fruit trees grew by 262.3%, production of arable land grew by 74.2%, and production of vegetables grew by 54.2% since 1998 (INSTAT, 2025). In the meantime, the total agricultural land available decreased by 0.7%, as an absolute value from 1998 and 2024.

Agricultural exports grew by 27% since 2020 (53,287 million ALL in 2024), yet the agricultural sector still performs worse than regional peers, facing issues like fragmented ownership, limited technological adoption, weak supply chain integration, and food safety regulations and compliance limitations (INSTAT, 2025). These challenges intensify as climate change alters production patterns and global market volatility creates new risks for Albanian farmers.

The National Strategy for Agriculture, Rural Development and Fisheries 2021-2027 (NSARDF) represents the government's most ambitious response, allocating approximately 850 million euros over seven years for income support, technological adoption, and value chain strengthening (Council of Ministers, 2022). The strategy explicitly targeted EU integration through alignment with the National Plan for European Integration (NPIE 2021-2023), particularly Chapters 11 (agriculture and rural development), 12 (food safety, veterinary and plant health), and 13 (fisheries), incorporating Common Agricultural Policy (CAP) and Common Fisheries Policy (CFP) frameworks post-2020. Recognizing that 40% of Albania's population depends on agriculture, rural development, or fisheries, the strategy embeds institutional monitoring through Integrated Policy Management Groups (IPMGs) coordinated by the Prime Minister's Office, compliance with the EU Gender Action Plan (2021-2025) and Equal Treatment Directive (2006/54/EC), with affirmative measures including prioritized pre-accession assistance (IPA), which includes support for IPA rural development programmers (IPARD III) grant selection for women, equal access to direct payments, and guaranteed information access regardless of gender or ethnic origin.

Public investment has not transformed the sector, which is a concerning factor when it comes to rural development, institutional capacity, and policy design. In this paper, we analyse agricultural policy instruments, outcomes, institutions, and implementation. This analysis contributes to literature regarding agricultural policy effectiveness in transition economies and rural development, and it is carried out through analytical frameworks; countries with similar characteristics, policy documents, statistical evaluation, and survey methodology. Our research question aims to assess whether Albania's policy framework prepares rural communities for CAP integration and sustainable development.

2.LITERATURE REVIEW

The evolution of Albania's agricultural regulatory framework reflects a gradual alignment with EU standards, yet questions remain about its implications for rural communities' adaptive capacity. The 2002 plant variety protection law, while establishing intellectual property frameworks, granting breeders patent rights within 30 days through MARD, with appeal mechanisms and penalty structures (50,000-150,000 ALL in fines, doubling upon repetition, with 60% to state budget and 40% to patent holders), primarily addresses commercial breeding interests (Assembly of Albania, 2002).

An agriculture and rural development law came into effect in 2007, which established an inter-ministerial committee among CAP fund absorption institutions, introduced electronic databases on farms, producers, land use, livestock, less developed areas (Parliament of Albania, 2007). This marked the first shift toward CAP compliance.

An effort to be compatible with EU phytosanitary regulations was made starting with the 2011 law on plant propagation material (Assembly of Albania, 2011). A traceability law came into effect in 2016, mandating comprehensive databases and their maintenance across plant protection product chains, with penalties ranging from 10,000-500,000 ALL, license invalidation, and product seizure (Assembly of Albania, 2016). These requirements may disproportionally affect smallholder farmers who lack digital literacy, similar to challenges faced in Bulgaria by farmers during its pre-accession period (Georgiev, Stoeva, Dirimanova, 2025). In the case of Bulgaria, compliance costs accelerated rural depopulation.

Unresolved land disputes and tenures complicate rural development even further in the Albanian economy. A legislation entered into force in 2023 aims to address incomplete privatization of former agricultural enterprise facilities (Assembly of Albania, 2023). This legislation targets beneficiaries, legal claimants, and entitled parties, who may have missing documentation, unpaid contracts, absent notarization. The institutional lag in a modern, formal, and efficient property rights legal system, even three decades post the transition to a market economy, places unnecessary constraints on farmers and investment capacity in rural development and the economy overall.

Recent policy signals suggest awareness of these structural constraints. The 2024 guideline introduces agricultural support through direct subsidies calibrated to livestock units, cultivated area, and production typology, with progressively reduced marginal benefits for large-scale producers except within collective structures such as farmer groups or Agricultural Cooperative Societies (ACS), explicitly promoting inclusive rural development within sustainable and organic transition paradigms (MARD, 2024). Differentiated support mechanisms are a part of CAP Pillar II principals, among its rural development approaches. In spite of this, a 2024 study identified significant disparity in implementation, among which were included insufficiency in monitoring and related infrastructure, overall institutional capacity, and climate action measures (Stojcheska et al., 2024). An initiative

supported by FAO was established in 2024, with the objective of amending agricultural cooperative and related legislation and addressing institutional inefficiency. This project titled "Support for the amendment of the existing law on organizations of agricultural cooperation" reviews outdated legal and institutional frameworks (FAO, 2024). It directly affects tax obligations, legal status clarification, financial regulations, land use rights, subsidies, and trade. This institutional strengthening parallels Romania's pre-accession experience, where cooperative sector modernization proved critical for effective CAP fund absorption and rural development outcomes (Tudor, Rosu, 2022).

3. DATA SET

This analysis examines internal and external factors influencing agricultural and rural development policies in Albania during 2014-2024, with comparative reference to the base period 2000-2013. The assessment draws on data from INSTAT, MARD, the European Commission's progress reports on Albania's EU membership application, and World Bank agricultural sector analyses. The SARDF 2021-2027 represents a strategic shift towards EU policy integration, emphasizing institutional capacity building through initiatives such as the establishment of an agency for IPARD.

Albania's agricultural mechanization trends reveal the sector's structural characteristics and alignment challenges with EU standards. Agricultural machinery data from 1998-2024 (INSTAT, 2025) shows that following Albania's 2014 EU candidate status, mechanization growth averaged 2.8% annually (2014-2024) compared to 6.6% in the pre-candidacy period (1998-2014). However, absolute machinery numbers increased from 238,998 (1998-2013) to 340,014 (2014-2024), reflecting persistent small-scale operations rather than the consolidation expected through cooperatives. The prevalence of auto combines, minitractors, and small cultivators contrasts sharply with EU trends towards precision farming technologies, GPS systems, and autonomous equipment (CEMA, 2024; EU CAP Network, n.d.), highlighting infrastructure gaps that affect rural competitiveness. Land fragmentation remains a structural constraint on rural development. Irrigated areas stabilized post-2014, with factual irrigated area growing 1.53% annually and actual irrigated area growing 2.48% (2014-2024), demonstrating improved water management compared to the volatile pre-candidacy period. The 177.32% increase in factual irrigated area between 2000 and 2024 represents significant infrastructure investment, though agricultural land in 2024 (677.3 thousand ha) supported only 627.6 ha of organic production-0.09% of total agricultural area (INSTAT, 2025).

Financial interventions, including 3.8 billion ALL in agricultural investments and the tax-free oil scheme for farmers (20,000 beneficiaries in 2021), have supported rural livelihoods (Council of Ministers, 2022). The average amount of employees in rural regions increased by 49% from 2010 to 2023, with women's employment rising by 38% in this period. In the category of food, beverages, and tobacco processing, employment grew by 54% (INSTAT, 2024). While this may suggest there are opportunities for women in rural regions, a study found they face exclusion and insufficient support that

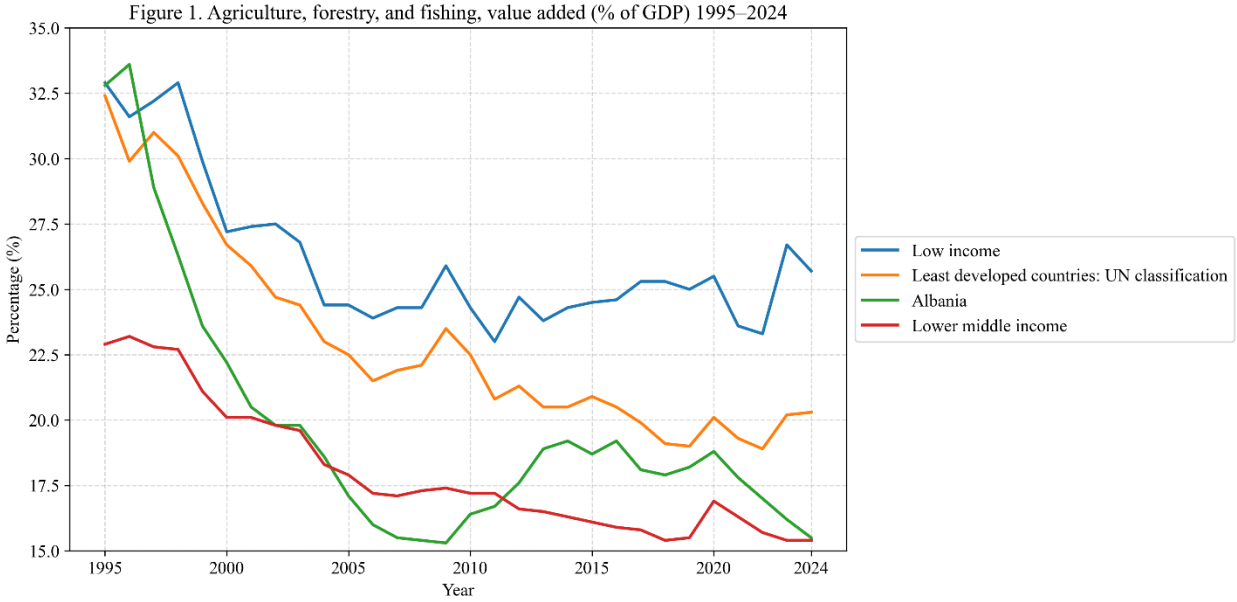
only perpetuate inequalities, preventing women from achieving full participation in rural development (Sulaj, Themelko, 2024). Export dynamics reflect rural producers' market positioning challenges. While exports increased 37% from 2020 to peak at 486,784 million ALL in 2022, they subsequently declined 23% by 2024 to 372,600 million ALL (INSTAT, 2025). In Albania, production values have been consistently increasing, even as the size of agricultural land fluctuated or showed gradual decline. 2014 and 2024 area decreases did not compromise production or yield; 2024 achieved the highest yield figure, nearly double the 1998 value, despite 5.8% less cultivated area. This decoupling of production from land expansion represents a critical shift towards intensification, though yield volatility (lowest in 2003, with production nadir in 1998) underscores vulnerability to external shocks affecting rural income stability.

Organic agriculture expansion, driven primarily by export demand for medicinal and aromatic plants and olives rather than domestic markets, demonstrates rural producers' dependence on international buyers. Financial constraints, inadequate marketing channels, and collection infrastructure create market access barriers throughout the Western Balkans, whilst low domestic consumer awareness further discourages organic farming (Stojcheska et al., 2024).

Although Albanian legal framework has improved, rural infrastructure and environmental reforms lag behind requirements (Canfora, 2025). The agricultural sector made up 15.5% of the Albanian GDP in 2024, the regional average was an average of 5.1% during that same year (World Bank, 2025)cr. In 1995, 32.8% of the GDP was contributed from agriculture in Albania, but Bosnia and Hercegovina faced a similar challenge in diversifying their economy, and they overcame it much faster, which positions Albania uniquely in the Western Balkans. High rural unemployment often masks underemployment, particularly in women and youth in unpaid agricultural work, which creates challenges for rural development and designing appropriate strategies (Meçe & Ribaj, 2019).

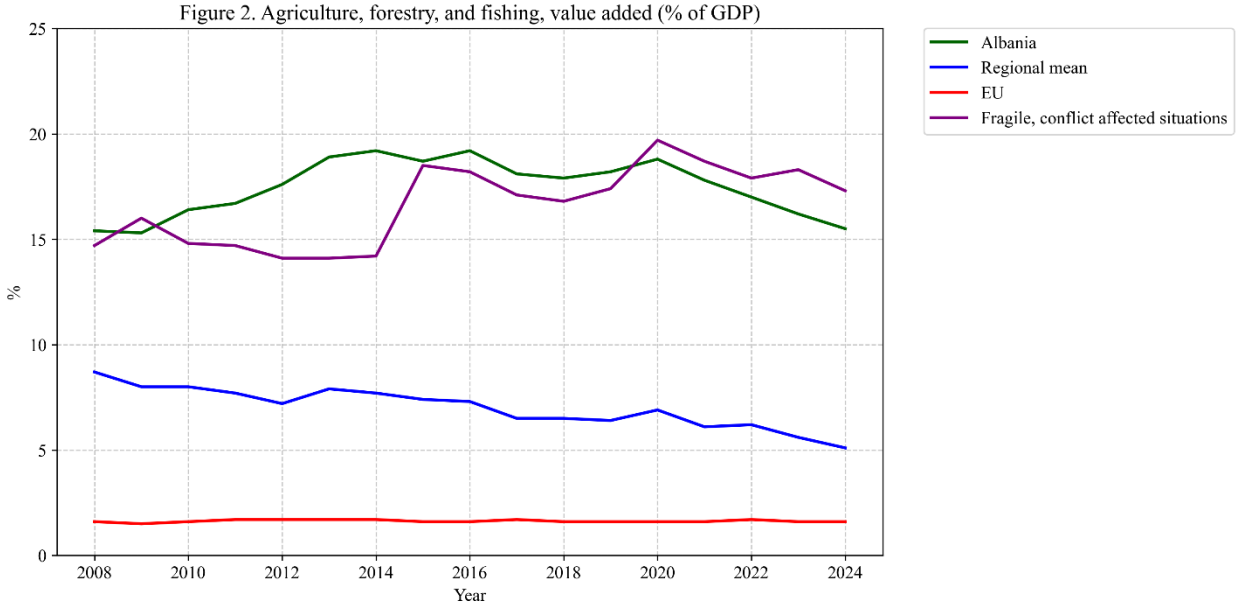
According to World Bank data, fragile and conflict-affected situations alongside low and lower-middle income countries exhibit similar agricultural GDP shares. The Western Balkans regional average (excluding Albania) demonstrates progressive economic transformation. Bosnia and Herzegovina reduced agriculture's GDP contribution from 35.9% in 1994 to 4.3% by 2024, falling below the threshold typical of low-income countries by 2000 (World Bank, 2025). Structural transformation in industry contribution to GDP involve gradual sectoral shifts as a country develops, with patterns showing agricultural share declining and manufacturing and services increasing (Byerlee et al., 2008).

Figure 1. Agriculture, forestry, and fishing, value added (% of GDP) 1995–2024



Source: Developed by the authors based on World Bank (2025).

Figure 2. Agriculture, forestry, and fishing, value added (% of GDP)



Source: Developed by the authors based on World Bank (2025)

Total calculated agricultural production for 2024 reached 11,495,313 tons across fruit trees, field crops, and vegetables. Field crop yields exceeded fruit tree yields ninefold in 2024 compared to 1998, highlighting differential productivity trajectories across commodities that shape rural economic opportunities.

To understand relationships between agricultural area, production, and yield, as these variables are central to rural development policy evaluation, Pearson correlation coefficients were calculated using annual changes rather than absolute values to capture temporal dynamics. With our approach, we seek to evaluate policies based on their impact, which includes understanding whether annual recorded changes in production are correlated to annual changes in yield, because this can help us gauge how

successful agricultural modernization has been. If the correlation is stronger to changes in crop sizes or agricultural land available, corresponding with that category of agricultural product or overall, it might help us see if development has been extensive or intensive. A strong positive correlation between yield and production can mean inputs, irrigation, the help of extension services, or better agricultural practices led to higher production, while low or negative correlation, in this case, would show stagnant yields alongside increases in production, which can indicate marginal land use or climate impacts.

4. METHODOLOGY

This study employs a mixed methods approach to assess how agricultural and rural development policies affect farming communities in Albania, with particular attention to farmers' preparedness for EU CAP alignment. Our research combines primary and secondary data analysis and collection to conclude an evaluation on rural development outcomes and policy effectiveness in these regions.

Our study site for the survey is the municipality of Lushnja, located in the county of Fier, which was chosen due to being the main producer of vegetables in Albania. Fier alone contributed 39.3% of domestic vegetable production in 2024, and 28.1% of agricultural production overall. The municipality of Lushnja has a concentrated farming population, allowing us a sufficient sample size for statistical analysis.

The primary data collection method used a survey as an instrument for collecting data, in the form of a structured questionnaire about demographic data, policy awareness, perceived impacts on rural livelihoods, and future expectations. Data collection was carried out through four weeks. The secondary data used was obtained from official sources at the national and international level, and later used for comparative analysis, trends and statistical indicators.

A quantitative analysis performed on the data we collected, using Excel, R, and Python. The Pearson correlation coefficient is used to show relationships between variables such as annual production changes, annual area changes, annual productivity changes, across various categories of agricultural production. Our approach sought to differentiate between improvements in yield and effects of land expansion, as correlations between production and area changes reveal land use scaling patterns. Correlation between yield and production changes indicate whether intensification or land enlargement contributes to productivity changes. A Pearson chi-square test of independence, Cramer's V, and various tests were used to assess the relationships between variables from our survey.

5. CONCLUSION

This study examined Albanian farmers' readiness for EU Common Agricultural Policy integration through analysis of policy frameworks, production trends, and primary survey data from 200 farmers in Lushnja municipality. Albania's policy frameworks reflect EU and CAP standards, implementation remains disproportionately focused on structural competitiveness measures with

minimal emphasis on direct income support, climate action, social equity, and rural development funding, which are the dimensions CAP prioritizes. This misalignment between normative and operational priorities, combined with favouring production investment over inclusive rural transformation, positions Albania poorly for integration that requires environmental and administrative compliance. Policies can address misalignment from three broad categories, which are land structure, cooperative infrastructure, and institutional or administrative exclusion in rural areas. These issues can turn CAP integration from a rural development opportunity into a mechanism that exaggerates current inequalities.

The fundamental question of our analysis is about whether CAP integration would modernize rural development in Albania or further agricultural marginalization. We believe the answer depends on current policy interventions that must address documented capacity gaps prior to accession. Essential services must be accessible to all rural residents, otherwise CAP benefits will concentrate among a few individuals which already have an economy of scale. The agri-food sector's role accounting for approximately half of rural employment (Council of Ministers, 2022).

The implication of agricultural sector work in rural areas is that agricultural policy failure translates directly into broader rural development crisis. The policy implications indicate Albanian agricultural policy must shift from assuming readiness based on harmonizing legal frameworks, and measure the implementation while actively building functional capacity across interdependent facets of rural development. Isolated technical fixes are likely to fail, hence why a coordinated systems have to be built, as they are the only viable pathway to rural development.

The survey findings demonstrate that farmers clearly identify infrastructure, bureaucratic simplification, and cooperative support as priorities. Farmers cannot benefit from infrastructure investments if they lack cooperative structures to share costs. Cooperatives cannot form successfully if farmers lack administrative capacity to navigate legal requirements. Farmers will not be able to easily transport their produce if public infrastructure is neglected or not maintained. Neither administrative nor organizational capacity will drive participation if the underlying physical infrastructure makes agricultural production inherently inefficient. The dimensions of all the problems surrounding the agricultural sector, rural development, rural livelihoods and regions, are mutually reinforcing. The most significant characteristic is the compounding effect these variables impose on one another, hence the difficulty in identifying independent and dependent factors, especially when the effect studied is on a small scale, and in cases where it is not feasible to solve the core problems due to costs and time limitations.

Based on our survey findings rural development policies may be constrained by farmer age and other factors such as receptiveness to innovation, which suggests that older farmers, who dominate Albanian agriculture, may be systematically disadvantaged in competing with the EU. When we

combine these variables with our analysis outcome that income did not increase with experience, we can conclude the sector fails to retain experienced farmers (due to income stagnation) and fails to attract young people (due to lack of prospects). This does not have to be an inevitable outcome of economic growth and EU integration. These issues can be actively fixed through coordinated investment in physical infrastructure and institutions in rural regions. The window for this intervention category is closing and the opportunity for preparatory capacity building is declining, which increases the risk of exclusionary patterns (i.e., subsidy access reinforcing rural inequality despite its intention in policymaking to reduce income disparities). For Albanian rural communities, policymakers, and farmers, the options are plain and obvious; investment in all dimensions that impact rural livelihoods directly or acceptance that the CAP will deepen divides between smallholders and agribusiness corporations.

7. RECOMMENDATIONS

We propose a three-phase readiness framework, categorized into three phases based on short-term and long-term needs regarding EU alignment. Within two years, administrative capacity building can be resolved, through extension service expansion and farmer training in documentation, legal compliance, and digital systems. Within four years, cooperative infrastructure development can be implemented with the objective of being fully aligned with the CAP and ready for their competitiveness at the end of the four-year program. We found that farmers who plan to keep working in the agricultural sector are more likely to join a cooperative in the future, which should encourage policymakers to create the appropriate structures that make this kind of economy of scale the easiest path for a rural resident to take if they want to work in agriculture.

Long-term interventions include physical infrastructure investment in storage, processing, irrigation systems, and climate monitoring infrastructure that directly help Albanian agriculture to meet CAP's environmental and productivity standards. The analysis showing that increases in land used lead to yield increases underlines how infrastructure is central to increase yield through optimized practices and technological integration.

The surveyed farmer education pattern limits capacity for complex farm management, including CAP compliance requirements. In order to benefit from programs, farmers need to be educated on relevant subjects, that they will directly benefit from. Agricultural income and dependence distribution highlight a vulnerability in rural households to agriculture, which means rural development and related policies must support diversification of income, in order to promote stability, in accordance with CAP objectives.

Our recommendation that improving rural infrastructure and public services must be the first step taken by local government in order to stop the perpetual cycle and compounding effect of a neglected region. Backed even by our survey findings, agricultural policy alone cannot reverse rural decline. CAP

integration without parallel investment in rural amenities, services, and economic diversification risks accelerating rural exodus by making agricultural income disparities more visible while offering no pathway for non-competitive farmers.

REFERENCES

Assembly of the Republic of Albania. (2007). *Law No. 9817 of 22 October 2007 on agriculture and rural development*. Official Gazette of the Republic of Albania. https://faolex.fao.org/docs/pdf/alb83478.pdf

Bachev, H. (2008). *Post-communist transformation in Bulgaria: Implications for development of agricultural specialization and farming structures* (MPRA Paper No. 7771). University Library of Munich. https://EconPapers.repec.org/RePEc:pra:mprapa:7771

Barolli, B. (2005). An overview of the Albanian history: With main emphasis on economy. *Journal of Contemporary Society and Culture, 34*, 241–266.

Byerlee, D. R., de Janvry, A. F., Sadoulet, E. M. L., Townsend, R., & Klytchnikova, I. I. (2008). *World development report 2008: Agriculture for development* (Report No. 41455). World Bank. https://doi.org/10.1596/978-0-8213-7235-7

Canfora, I. (2025). The implementation of instruments of pre-accession assistance for rural development (IPARD) face to the challenges of Albanian agricultural sector. *Euro-Balkan Law and Economics Review, 1*. https://doi.org/10.15162/2612-6583/2106

Council of Ministers. (2022, June 29). *Decision No. 460 of 29 June 2022 on the approval of the Strategy for Agriculture, Rural Development, and Fisheries, 2021–2027*.

Csáki, C., & Jámbor, A. (2013). The impact of EU accession: Lessons from the agriculture of the new member states. *Post-Communist Economies, 25*(3), 325–342. https://doi.org/10.1080/14631377.2013.813139

Duka, B., Dervishi, A., Grosha, E., Ivziku, D., Rocco, G., Stievano, A., & Notarnicola, I. (2025). Inequalities in the distribution of the nursing workforce in Albania: A regional analysis using the Gini coefficient. *Nursing Reports, 15*(2), Article 30. https://doi.org/10.3390/nursrep15020030

Georgiev, M., Stoeva, T., & Dirimanova, V. (2025). Legal and economic challenges before agricultural integration: From cooperatives to associations. *Bulgarian Journal of Agricultural Science, 31*(3), 455–463. https://doi.org/10.2139/ssrn.5377495

Gjokutaj, E. (2021). Albania: The impact of economic and fiscal policy in the agricultural sector. *Economicus, 1*, 7–27. https://www.ceeol.com/search/article-detail?id=1238317

Jámbor, A., & Gorton, M. (2025). Twenty years of EU accession: Learning lessons from Central and Eastern European agriculture and rural areas. *Agricultural and Food Economics, 13*, Article 1. https://doi.org/10.1186/s40100-025-00346-w

Marku, D., Minga, A., & Theodhori, O. (2024, October 12–13). *Trajectories of rural youth and the future role of rural communities in Albania* [Conference presentation]. XXII IBANESS Congress on Economics, Business, and Management, Ohrid, North Macedonia.

Meçe, M., & Ribaj, A. (2019). The rural development and employment in Albania. *European Journal of Economics and Business Studies, 5*(1).

Ministry of Agriculture and Rural Development. (2024). *Directive No. 6 of 7 March 2024 on the criteria, procedures, and administration of the program fund for agriculture and rural development*. Official Gazette of the Republic of Albania. https://faolex.fao.org/docs/pdf/alb230040.pdf

Osmani, M., Kolaj, R., Borisov, P., & Arabska, E. (2022). Why agricultural policies fail and two cases of policy failures in Albania. *Agricultural and Resource Economics: International Scientific E-Journal, 8*(2).

Rogelj, M. J., Šiftar, H., Poljak, T. T., & Mikuš, O. (2024). Challenges and opportunities for young farmers in the implementation of the Rural Development Program 2014–2020 of the Republic of Croatia. *Open Agriculture, 9*(1), Article 20220374. https://doi.org/10.1515/opag-2022-0374

Sabeva, M. (2020). Effect of policy measures supporting the agricultural sector in Bulgaria after EU membership. *Economic Alternatives, 1*, 91–104. https://EconPapers.repec.org/RePEc:nwe:eajour:y:2020:i:1:p:91-104

Shahini, E. (2024). Economic assessment of the impact of climate change on agriculture in Albania and Ukraine. *Ukrainian Black Sea Region Agrarian Science, 28*(3), 55–66. https://doi.org/10.56407/bs.agrarian/3.2024.55

Sosoli, I. (2024, October 12–13). *The impact of the debt crisis on interest rates: A comparative analysis of Albania and the Eurozone (2008–2022)* [Conference presentation]. XXII IBANESS Congress on Economics, Business, and Management, Ohrid, North Macedonia.

Stojcheska, A. M., Zhllima, E., Kotevska, A., & Imami, D. (2024a). Western Balkans agriculture and rural development policy in the context of EU integration—The case of Albania and North Macedonia. *Regional Science Policy & Practice, 16*(8), Article 100049. https://doi.org/10.1016/j.rspp.2024.100049

Stojcheska, A. M., Zhllima, E., Miftari, I., Kotevska, A., & Imami, D. (2024b). Agri-food trends and policy: Green Deal challenges and opportunities in EU pre-accession countries (Albania, Kosovo, North Macedonia). *New Medit, 23*(3). https://doi.org/10.30682/nm2403e

Sulaj, A., & Themelko, H. (2024). Agritourism as a pathway to women's empowerment: Insights from rural Albania. *European Countryside, 16*(4), 628–646. https://doi.org/10.2478/euco-2024-0032

Taka, A., Doko, A., Malltezi, J., Musabelliu, B., Sulçe, S., & Veselaj, E. (2017). Agricultural land valuation in Albania. *Asian Journal of Agricultural Extension, Economics & Sociology, 15*(2), 1–15. https://doi.org/10.9734/AJAEES/2017/37275

Tudor, M., & Roșu, E. (2022). Agricultural cooperatives in Romania—Evolution and structure. In *The crisis after the crisis: When and how the new normal will be* (pp. 706–720). https://doi.org/10.2478/9788366675889-099

GERMAN INDUSTRIAL POLICY UNDER SYSTEMIC COMPETITION: THE RETURN OF THE STRATEGIC STATE

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ABSTRACT

Recent years have witnessed a marked reorientation in German industrial policy, driven by successive shocks and broader global shifts, particularly geoeconomic fragmentation and intensifying international competition. These developments have exposed vulnerabilities in the German productive base and intensified concerns about its erosion and the potential relocation of industrial activity, reflected in persistently high energy costs, structural pressures on production and growing divergences in sectoral performance. Against this backdrop, the paper examines the mechanisms that have weakened Germany's industrial position and discusses the resilience of key segments alongside the vulnerability of energy-intensive industries and small and medium-sized enterprises, drawing on a comparison with other European economies. Methodologically, the analysis combines a sector-sensitive assessment of industrial pressures with a structured review of recent policy shifts, focusing on energy intensity, production constraints and the evolving role of supply-chain and dependency risks in industrial performance. The federal government's response to these pressures signals a shift in the rationale for public intervention from a predominantly rules-based framework focused on market coordination and competitive neutrality to an economic security rationale that legitimises more active strategic state instruments. This orientation is reflected in measures aimed at diversifying energy supplies, critical input sources and export markets, accelerating the energy transition, modernising infrastructure, supporting innovation in transformative technologies and reducing critical dependencies. The paper also situates these responses within the broader framework of European industrial policy, which shapes both feasibility and the available policy space. The analysis concludes that this reconfiguration of German industrial policy should be understood not merely as a reaction to crises, but as a strategic adaptation to an era of systemic competition, with implications for the future of the German industrial model and for the European Union's economic resilience.

Keywords: *German Industrial Policy, Systemic Competition, Economic Security, Industrial Competitiveness, Strategic State.*

JEL Codes: *L52, O25, F52.*

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1. INTRODUCTION

For decades, the strength of the German economy has been associated with the existence of an extensive, diversified, and deeply integrated industrial base, in which large, internationally active corporations have coexisted with a dense network of small and medium-sized enterprises (*Mittelstand*). Many of the latter hold world-leading positions in specialised technological niches or operate as specialised suppliers within the value chains of flagship industries, such as the automotive sector (Altenburg, 2024). Added to this configuration were a high capacity for innovation, complex domestic value chains, and a pronounced export orientation, factors that gave manufacturing a far more prominent role in the national economy than in most other European states. The development paradigm that took shape after the turn of the millennium simultaneously relied on a particularly favourable external environment: relatively low-cost natural gas from the Russian Federation and competitively sourced inputs, primarily from China and Central and Eastern Europe, which sustained high-tech industrial production destined for global markets, particularly the Chinese market. Yet, it was precisely this deep integration into the global economy, long one of the primary sources of German competitive advantage, that generated dependencies whose strategic nature became increasingly evident with the recent shift in the international geopolitical and geoeconomic landscape.

In recent years, this configuration has been subjected to an unusually dense succession of shocks and structural transformations. Disruptions to global supply chains triggered by the COVID-19 pandemic, the Russian Federation's aggression against Ukraine and the subsequent energy shock, intensifying technological rivalry among major economies, the acceleration of the green and digital transitions, and China's move towards high-value-added industrial segments have progressively altered the operating conditions of the German model. From this perspective, the geopolitical rupture of 2022 served as a powerful catalyst. The industrial recovery following the pandemic shock proved short-lived, while energy market disruptions precipitated a severe contraction in output, concentrated particularly in industries dependent on access to competitively priced energy (Boston Consulting Group [BCG], The German Economic Institute [IW[1]] and The Federation of German Industries [BDI[2]], 2024). In the case of Germany, the effects of the crisis were amplified by its prior dependence on Russian natural gas, as well as by delays in expanding renewable energy capacity at a sufficiently rapid pace (Von Der Burchard, 2022; Federal Ministry for Economic Affairs and Climate Action, 2023).

However, interpreting the difficulties of German industry exclusively through the lens of the energy shock would lead to an incomplete diagnosis. Recent developments point to deeper vulnerabilities linked to deteriorating competitiveness, insufficient infrastructure investment, the slow pace of administrative digitalisation, regulatory rigidities, skill shortages, and the transformation of trade

[1] The acronym stands for Institut der deutschen Wirtschaft (often designated as IW Köln).
[2] The acronym stands for its original German title Bundesverband der Deutschen Industrie, the umbrella organisation representing federal industry and industry-related service providers.

relations with China. Excessively complex administrative procedures continue to pose a barrier to investment and structural economic transformation (Bundesverband der Deutschen Industrie e.V. [BDI], 2024), while public investment remains below the European Union average, and accumulated investment backlogs in municipal infrastructure have reached considerable proportions (KfW Research, 2025). Concurrently, the economic relationship with China has fundamentally changed. While for several decades China functioned as a commercial and investment partner complementary to the German export model, its technological ascent and the transformation of Chinese companies into direct competitors of Western producers have prompted German industry to reassess the nature of bilateral relations and the necessity of a strategy capable of balancing open markets with the protection of domestic industrial capabilities (BDI, 2019).

These pressures are not evenly distributed across Germany's productive industrial base, and this differentiation constitutes a key factor in interpreting the current transformation. Energy-intensive industries, including the chemicals and metals sectors, occupy a distinct position within the German industrial architecture, as they sit upstream in numerous value chains and supply indispensable intermediate goods to other productive activities. After 2022, these very branches recorded the most persistent contractions, whereas segments characterised by lower energy intensity demonstrated greater adaptive capacity. Empirical evidence confirms both the differentiated nature of sectoral developments and the more pronounced decline in energy-intensive German segments compared to the aggregate dynamics of European industry. These pressures are compounded by specific vulnerabilities of the *Mittelstand*, for which the costs of technological transformation and administrative compliance, as well as constraints regarding financing, skills, and innovation capacity, are more difficult to accommodate. Consequently, the debate over the future of German industry cannot be reduced to a simplistic opposition between continuity and deindustrialisation. More relevant is the question of the extent to which the economy is undergoing a differentiated process of erosion, restructuring and adaptation of productive capabilities, with effects that vary considerably across sectors and categories of firms.

The changing operating conditions of the German industrial model have occurred alongside a broader shift in the logic of industrial policy. The postwar era of selective interventions was followed by a long period dominated by horizontal policies. Even during this horizontal-policy phase, elements of enabling and sector-specific support – such as public research institutions, vocational training systems, development finance etc. – persisted beneath the surface of formal market neutrality. In recent years, however, technological transformations, the greening of production, geoeconomic fragmentation, and vulnerabilities revealed by supply chain disruptions have brought industrial policy back to the centre of economic strategies. In this sense, the "return" of the strategic state refers not to the reappearance of state involvement as such, but to the renewed explicitness and strategic orientation of intervention. Recent literature interprets this evolution not as a mere restoration of traditional interventionism, but as the emergence of a form of industrial policy in which economic objectives intersect with climate,

technological, and geopolitical imperatives (Tagliapietra and Veugelers, 2023; Altenburg, 2024). In Germany's case, this shift is visible in the transition from a predominance of instruments aimed at improving the general framework conditions towards a more selective mix of tools targeted at diversifying supply sources and export markets, securing critical inputs, accelerating the energy transition, modernising infrastructure, and fostering technologies deemed strategic. Industrial policy is thus becoming increasingly and more explicitly tied to objectives of economic security, resilience, and technological autonomy, without this shift implying the abandonment of the competitive order or the substitution of market mechanisms with a dirigiste model.

In this context, the present paper examines the relationship between the erosion of the conditions that had traditionally underpinned Germany's industrial competitiveness and the recent reconfiguration of federal industrial policy. The analysis first examines the mechanisms that have weakened the position of German industry, focusing on energy costs, structural constraints, changes in international trade and technological relations, strategic dependencies, and performance divergences across major sectors and categories of firms. It then investigates the shift in the rationale, objectives and instruments of public intervention to determine the extent to which the federal response indicates the emergence of a "strategic state", in which the preservation and transformation of productive capabilities are increasingly integrated into the logic of economic security. Methodologically, the study combines a descriptive-comparative analysis of industrial trends with a sector-sensitive approach and a structured examination of the main industrial policy documents, strategies and instruments adopted in recent years. The European dimension is treated as a cross-cutting element throughout the analysis, as Germany's policy space is shaped simultaneously by national priorities and by the EU framework governing competition, decarbonisation, strategic autonomy and industrial resilience. The hypothesis advanced is that this reorientation extends beyond a short-term response to the recent sequence of crises and reflects a deeper strategic adaptation of the German state to an international economic environment in which competition between productive, technological and institutional models is increasingly taking on a systemic character.

2. LITERATURE REVIEW

The revival of industrial policy has become one of the most significant shifts in contemporary economic governance. After several decades in which selective intervention was frequently viewed with scepticism and horizontal policies aimed at improving general framework conditions were largely favoured, successive crises and structural transformations have altered both the scope and the justification of state involvement. Earlier criticism centred on information asymmetries, government failure and the risks associated with "picking winners", whereas more recent approaches increasingly conceptualise industrial policy as a process of coordinating investment, learning and structural transformation (Rodrik, 2004; Juhász, Lane and Rodrik, 2024). The shift has been reinforced by objectives that conventional efficiency-based frameworks address only incompletely, including

decarbonisation, technological upgrading, resilient supply chains and the preservation of strategic productive capabilities. In Europe, these concerns have increasingly converged in a new green and strategic industrial-policy agenda combining horizontal improvements in framework conditions with targeted support for technologies and capacities regarded as critical for net-zero transformation and resilience (Tagliapietra and Veugelers, 2023). Altenburg (2024) similarly argues that the contemporary debate has moved beyond the conventional opposition between unfettered markets and top-down state allocation towards more pragmatic forms of public-private coordination around technological and productive transformation.

Germany represents a particularly revealing case because the contemporary shift cannot be interpreted as a transition from a historically non-interventionist model towards state intervention. The German political economy has long combined competition-oriented institutions and rule-based coordination with enabling and, at times, sector-specific forms of support, including public research institutions, vocational training systems, development finance and close forms of public-private cooperation. Industrial policy therefore persisted even during periods in which its explicit legitimacy remained contested (Altenburg, 2024). The more recent transformation concerns the rationale, intensity and selectivity of intervention. Schneider (2023) interprets *Germany's Industrial Strategy 2030* as evidence of a contested paradigm shift in a country traditionally associated with ordoliberal restraint, while the *Federal Government's 2023 industrial strategy* explicitly linked the preservation of the industrial base with prosperity and economic security (Federal Ministry for Economic Affairs and Climate Action, 2023). More recently, Duso, Gornig and Schiersch (2025) argue that horizontal measures aimed at improving general production conditions, while necessary, are insufficient to overcome Germany's investment and innovation backlog, and advocate a strategic, European and competition-oriented industrial policy combining targeted support with mechanisms designed to preserve competitive discipline. The emerging pattern is therefore better understood as a recalibration of the state-market relationship: horizontal framework policies remain important but are increasingly complemented by selective measures directed towards industrial transformation, critical technologies and strategic productive capabilities.

A related strand of literature concerns the changing meaning of economic interdependence. Germany's export-oriented model benefited extensively from open markets, internationally fragmented value chains and strong external demand, yet geopolitical rivalry has made the concentration, substitutability and strategic relevance of external dependencies increasingly salient. The BDI's characterisation of China as both "partner" and "systemic competitor" already captured this tension in 2019, reflecting growing concern that a relationship previously driven largely by economic complementarity was evolving towards direct technological and industrial competition (BDI, 2019). The energy rupture following the Russian Federation's aggression against Ukraine further reinforced concerns over concentrated dependencies and accelerated efforts to diversify energy supplies and reduce

exposure to strategically sensitive inputs (Von Der Burchard, 2022; Federal Ministry for Economic Affairs and Climate Action, 2023). Industrial policy has consequently become increasingly intertwined with economic-security considerations, without this implying autarky or indiscriminate protectionism. Rather, the emerging approach extends the criteria by which productive capacities are evaluated, incorporating resilience, security of supply and technological autonomy alongside conventional considerations of efficiency and competitiveness.

This transformation is simultaneously embedded in a broader European industrial-policy architecture. National policy space is both constrained and enabled by EU competition rules, state-aid provisions, trade policy, common funding instruments and increasingly ambitious initiatives in strategic technologies and decarbonisation. Di Carlo and Schmitz (2023) show how EU industrial policy has expanded beyond its traditional regulatory foundations towards a framework that increasingly combines the promotion of strategic production with the protection of the Single Market. Tagliapietra and Veugelers (2023) similarly emphasise the need to combine horizontal measures strengthening the attractiveness and functioning of the Single Market with targeted support for clean technologies and productive capabilities. Germany's industrial-policy reorientation must therefore be understood within a multilevel governance structure in which national intervention is neither autonomous from European constraints nor merely restricted by them but shaped through an evolving interaction between domestic priorities and common European strategic objectives.

Taken together, these strands suggest that the contemporary German shift is better conceptualised not as a return to traditional interventionism, but as the emergence of a more explicitly strategic rationale for industrial policy. The notion of the "strategic state" employed in this paper does not denote a dirigiste state or the displacement of competitive markets. It refers instead to a configuration in which the preservation and transformation of productive capabilities are increasingly assessed through the combined lenses of competitiveness, resilience, technological autonomy and economic security. Existing research has examined on the one hand, the revival of industrial policy and the evolution of its instruments and, on the other, the deterioration of Germany's industrial competitiveness associated with energy costs, investment weaknesses, technological pressures and external dependencies. The connection between these two processes remains less systematically articulated. The present article addresses this gap by examining whether sectorally differentiated pressures on German industry have contributed to a durable reconfiguration of the rationale, objectives and selectivity of state intervention, rather than merely generating temporary crisis-management measures.

3. METHODOLOGY

The analysis combines a structured documentary examination of industrial policy with a descriptive-comparative assessment of secondary statistical indicators, within a predominantly qualitative research design. The methodological framework addresses two complementary dimensions: first, the nature and intensity of the pressures affecting Germany's industrial base and second, the extent

to which these pressures have been accompanied by changes in the rationale, objectives and selectivity of public intervention. The statistical component therefore serves a diagnostic and contextual function and does not seek to identify causal relationships through econometric techniques.

The documentary component is based on a structured review of the main federal and European strategies and policy documents adopted in recent years, including those concerning industrial policy, economic security, energy diversification, decarbonisation, administrative simplification, innovation and the strengthening of strategic technological capabilities. These sources are complemented by the positions formulated by representative German industry organisations, particularly the Federation of German Industries, as well as by assessments produced by leading national economic research institutes and the Deutsche Bundesbank. To distinguish short-term crisis responses from a more structural reorientation of industrial policy, the identified instruments are examined according to their objectives, degree of selectivity, intervention mechanisms and level of governance. A measure is considered relevant to the emergence of a strategic policy logic when it explicitly targets the preservation or transformation of critical productive capabilities, the reduction of external dependencies, the strengthening of resilience, the support of targeted technological transformation or the public assumption of part of the investment risk.

The quantitative component draws on official statistical sources selected on the basis of comparability, temporal continuity and relevance to the industrial diagnosis. The core indicators include industrial production and manufacturing gross value added (GVA), the performance of energy-intensive and selected manufacturing sectors, energy-cost pressures, investment dynamics, as well as developments in external trade and competitiveness. The main statistical sources are the German Federal Statistical Office (Destatis), through the GENESIS-Online database and Eurostat. These are complemented, where relevant, by indicators published by KfW Research on investment and the *Mittelstand,* by assessments of national competitiveness and infrastructure produced by the International Institute for Management Development (IMD), and by evidence on skilled-labour shortages provided by the German Competence Centre for Skilled Labour (KOFA). This combination of sources allows the industrial diagnosis to be triangulated without reducing the analysis to a purely econometric exercise or attributing the deterioration in industrial performance to a single explanatory factor.

The main time horizon covers the 2016–2025 period, with particular attention to developments before and after the geopolitical rupture of 2022. This periodisation is not intended to isolate the causal effect of the energy shock, but rather to assess the extent to which the post-2022 deterioration represents an acceleration of structural vulnerabilities already visible beforehand. For the analysis of industrial policy, particular attention is given to the period beginning in 2019, thereby capturing the initial reorientation associated with *Germany's Industrial Strategy 2030*, followed by the subsequent reinforcement of resilience and economic-security considerations after the pandemic and the geopolitical rupture of 2022.

The sectoral analysis is conducted at two levels. At the aggregate level, developments in manufacturing are compared with those of energy-intensive industries to capture differences in exposure and performance associated with energy-related pressures. At a more disaggregated level, selected sectors that are particularly relevant to Germany's productive structure are examined, including chemicals and basic metals, alongside industries such as automotive and machinery and equipment manufacturing, where available data allow divergent trajectories to be identified. Firm-size heterogeneity is considered where comparable evidence is available, with particular attention to the *Mittelstand* through data published by KfW Research and evidence from business surveys. The comparative dimension is introduced by benchmarking German developments against aggregate trends in EU-27 industry and, selectively, against the trajectories of other relevant European economies.

By combining these two methodological components, the research design seeks not merely to describe the simultaneous deterioration of industrial performance and expansion of public intervention, but to examine the relationship between them. The analysis therefore assesses whether recent changes in German industrial policy primarily represent temporary crisis-management measures or point to a more persistent reconfiguration of the rationale of intervention, in which competitiveness, technological transformation, resilience and economic security are increasingly integrated into a broader strategic logic.

4. RESULTS AND DISCUSSION

The evidence points to a differentiated weakening of Germany's industrial position rather than to a uniform process of deindustrialisation. While the post-2022 energy shock intensified pressures on energy-intensive industries, the observed deterioration also reflects broader structural constraints, including investment weaknesses, administrative burdens, skills shortages and intensifying geoeconomic and technological competition. The analysis therefore distinguishes between short-term, sector-specific vulnerabilities and more structural, economy-wide competitiveness pressures, before examining how these developments relate to the changing orientation of German industrial policy.

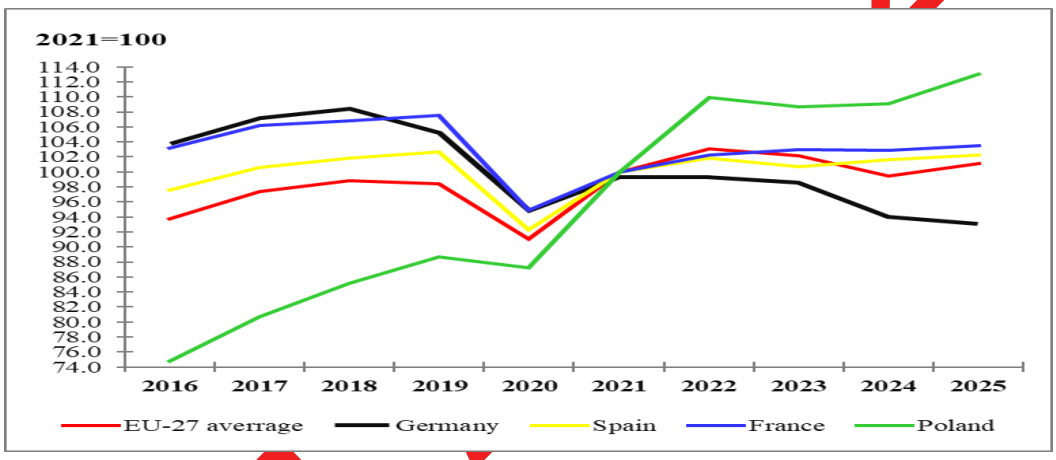
Against this background, the following discussion assesses whether recent policy measures should be understood primarily as temporary responses to successive crises or as part of a more durable reconfiguration of public intervention, increasingly shaped by resilience, technological capabilities, strategic dependencies and economic security considerations.

4.1. Structural and Geoeconomic Pressures on German Industry

The deterioration of Germany's industrial performance predates the most acute phase of the recent energy crisis, but the succession of shocks since the beginning of the decade has markedly intensified this process. The recovery in industrial activity following the COVID-19 pandemic proved short-lived, as the Russian Federation's aggression against Ukraine and the ensuing disruption of European energy markets generated a new set of pressures. The resulting contraction was particularly pronounced in

industries whose production processes depend heavily on access to competitively priced energy (BCG, IW & BDI, 2024). This development did not, however, affect the entire manufacturing base uniformly. Rather, it reinforced an already visible divergence between more exposed industrial segments and activities with a greater capacity to absorb or adjust to the changing cost and competitive environment. As Figure 1 shows, Germany's relative industrial weakening was already discernible before 2022 and became considerably more pronounced thereafter. While manufacturing production in the EU-27 and several comparator economies recovered or broadly stabilised above their 2021 levels, German output followed a persistent downward trajectory. The post-2022 downturn therefore cannot be interpreted solely as part of a general European industrial slowdown, but points to a distinctly more pronounced deterioration in Germany's manufacturing performance.

Figure 1. Manufacturing Production Index in Germany and in Selected EU Economies, 2016–2025 (2021=100)



Source: Author's calculations based on Eurostat (2026), *Production in industry* (online code: sts_inpr_m);
Note: Annual averages calculated from monthly seasonally and calendar-adjusted data.

The comparative trajectories reinforce the specificity of the German deterioration. By 2025, manufacturing production in Germany stood 6.2% below its 2021 level, whereas output was above that benchmark in the EU-27 as a whole and in all selected comparator economies. The divergence was particularly pronounced vis-à-vis Poland, where manufacturing production exceeded its 2021 level by 13.0%, but was also visible relative to France and Spain, whose output stood 3.5% and 2.2% above the baseline, respectively. Moreover, Germany's relative weakening cannot be dated exclusively to the post-2022 energy shock, as its manufacturing trajectory had already begun to diverge from several European peers before the geopolitical rupture.

The aggregate deterioration conceals increasingly divergent trajectories across the main components of German manufacturing. As Figure 2 (Box 1) shows, the weakening has been particularly pronounced in chemicals and other energy-intensive activities, while the machinery and equipment sector has also followed a persistent downward trajectory. The automotive industry displays a different pattern, combining strong pre-pandemic expansion with an exceptional contraction in 2020 and only partial subsequent recovery. The trajectory of basic metals further highlights the concentration of

persistent production losses among industries characterised by structurally high energy requirements. These differences confirm that Germany's industrial adjustment cannot be interpreted as a uniform contraction of manufacturing. Rather, it reflects a sectorally differentiated process in which exposure to energy costs interacts with technological, demand-side and broader competitiveness pressures.

Box 1. Sectoral Divergence and the Changing Weight of German Manufacturing, 2016–2025

Figure 2. Manufacturing production in selected sectors (2021=100)*

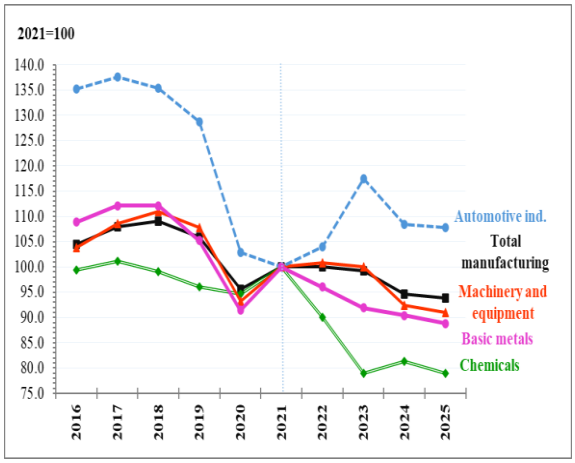
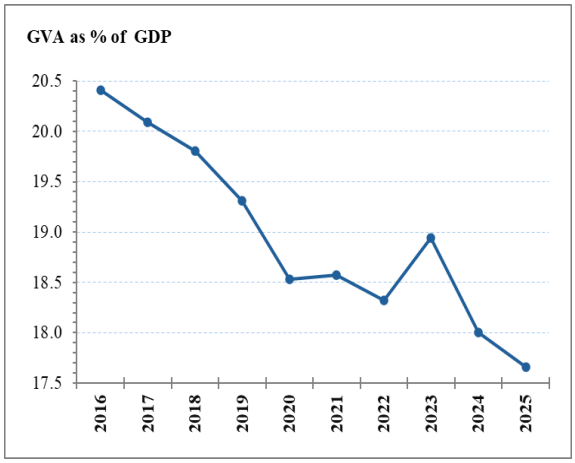


Figure 3. Manufacturing gross value added as share of GDP (%)**



Source: Author's calculations based on data from the Federal Statistical Office of Germany (Destatis, 2026a,b), Index of production in manufacturing, months (code: 42153-0002), and National accounts – Gross value added, gross domestic product, years (code: 81000-0001);
Notes: *Annual production indices are calculated as averages of the monthly series and subsequently rebased to 2021=100; **Manufacturing GVA as a share of GDP is calculated at current prices.

Energy-intensive industries are especially relevant because they occupy upstream positions in German and European value chains, supplying intermediate inputs to a broad range of downstream activities. The interruption of Russian gas supplies therefore affected not only their direct production costs but also the cost structure of the wider industrial system. Following a prolonged period of relative stability, natural gas and electricity prices for German non-household consumers increased sharply from 2021 onwards, initially as post-pandemic global demand recovered and subsequently under the impact of the war in Ukraine and the interruption of Russian gas deliveries. Although prices eased from their 2022–2023 peaks, they remained above pre-crisis levels in 2024–2025 (AG Energiebilanzen e.V., 2026). At the same time, the transition towards climate-neutral production requires substantial additional investment in precisely those activities most exposed to elevated energy costs. Energy exposure should therefore be regarded as an important amplifier of sectoral divergence rather than as a sufficient explanation for Germany's overall industrial weakening.

The sectoral evidence is accompanied by a longer-term decline in the relative weight of manufacturing in the German economy. Manufacturing gross value added accounted for slightly above one fifth of GDP in the middle of the previous decade, but its share subsequently followed a

predominantly downward trajectory, despite a temporary rebound in 2023 (Figure 3, Box 1). This evolution reinforces the diagnosis of structural industrial weakening, although the indicator requires cautious interpretation because it is expressed in current prices and therefore captures changes in relative prices and sectoral composition alongside developments in real productive activity. Read together with the production indices, however, the decline in manufacturing's economic weight provides further evidence that the challenges confronting German industry extend beyond the immediate consequences of the post-2022 energy shock.

The downward trajectory cannot be separated from the structural profile of German industrial specialisation. The federal industrial model has historically concentrated productive resources and research and development capacity in medium-high-technology sectors, notably automotive, chemicals and machinery, generating substantial productivity gains and durable competitive advantages (German Council of Economic Experts, 2025). Yet the same specialisation has also produced a degree of technological path dependence. Innovation has remained strongly oriented towards the incremental refinement of mature technologies, while frontier domains such as information and communication technologies, biotechnology and artificial intelligence have expanded at a considerably faster pace globally (Acemoglu, 2023). This suggests that Germany's current industrial weakness reflects not only adverse cost conditions but also increasing difficulties in translating long-established technological strengths into leadership in emerging technological domains.

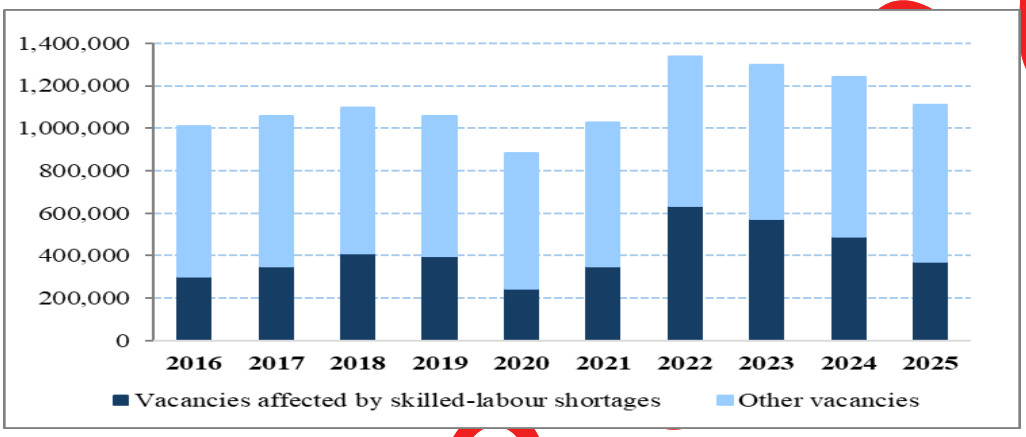
Beyond the sectoral patterns captured by the production indicators, Germany's industrial adjustment is also constrained by a deterioration in several key location conditions. Investment and infrastructure deficiencies, administrative complexity and slower implementation capacity increasingly affect firms' ability to modernise productive assets and undertake technological transformation. Administrative procedures remain particularly burdensome in investment-intensive areas, where lengthy planning and approval processes can delay the expansion of infrastructure and productive capacity (BDI, 2024).

The quality of transport infrastructure, digital connectivity, security of energy supply and the performance of education-related institutions are also important determinants of industrial competitiveness, while accumulated investment shortfalls in these areas constrain Germany's capacity for economic modernisation. The infrastructure component of the IMD World Competitiveness Ranking illustrates this deterioration: Germany fell from 9th place in 2022 to 20th in 2024, before recovering partially to 13th place in 2025 (International Institute for Management Development, 2026). This trajectory suggests that Germany retains a comparatively strong infrastructure base, although its international position coexists with significant domestic investment deficiencies. KfW Research estimates the municipal investment backlog at approximately EUR 216 billion, with particularly

pronounced gaps in transport and educational infrastructure, while public investment remains below the EU average (KfW Research, 2025; Eurostat, 2026[3]).

Skill shortages represent a further structural constraint on Germany's industrial competitiveness. Population ageing, the gradual retirement of the baby-boom generation and the evolving technological profile of production are progressively eroding the country's traditional advantage in vocational and technical expertise (Figure 4).

Figure 4. Job Vacancies and Skilled-Labour Shortages in Germany, 2016–2025



Source: Author's representation based on data published by the German Competence Centre for Skilled Labour (KOFA, 2026);
Note: Total job vacancies are represented by the sum of the two bar segments. The first category refers to vacancies which, according to the KOFA methodology, cannot be filled by unemployed workers with the corresponding qualifications; the second epresents the difference between total vacancies and those affected by skilled-labour shortages, i.e. vacancies that are theoretically fillable.

Rather than reflecting a purely cyclical tension in the labour market, these shortages point to a deeper imbalance between the qualifications required by an industrial economy undergoing decarbonisation, digitalisation and automation and the supply of suitably skilled workers. Data from the German Competence Centre for Skilled Labour (KOFA, 2026) illustrate the persistence of this imbalance.

Although the total number of vacancies declined in 2025 from its 2022 peak, approximately 370,000 positions could not be filled with workers holding the required qualifications, equivalent to roughly one third of all vacancies. This decline in aggregate labour demand therefore did not eliminate the structural mismatch between available skills and firms' requirements. The persistence of recruitment difficulties is also confirmed by a recent survey conducted by the ifo Institute, which found that around 28% of German companies continued to face difficulties in recruiting skilled workers despite the broader economic slowdown (ifo Institute, 2026).

Investment and labour constraints are particularly relevant for the *Mittelstand*, whose capacity to undertake technological transformation depends on both internal resources and access to external finance. KfW Research (2026) points to subdued investment environment across German enterprises,

[3] Eurostat data on Investment share of GDP by institutional sectors (online data code: sdg_08_11).

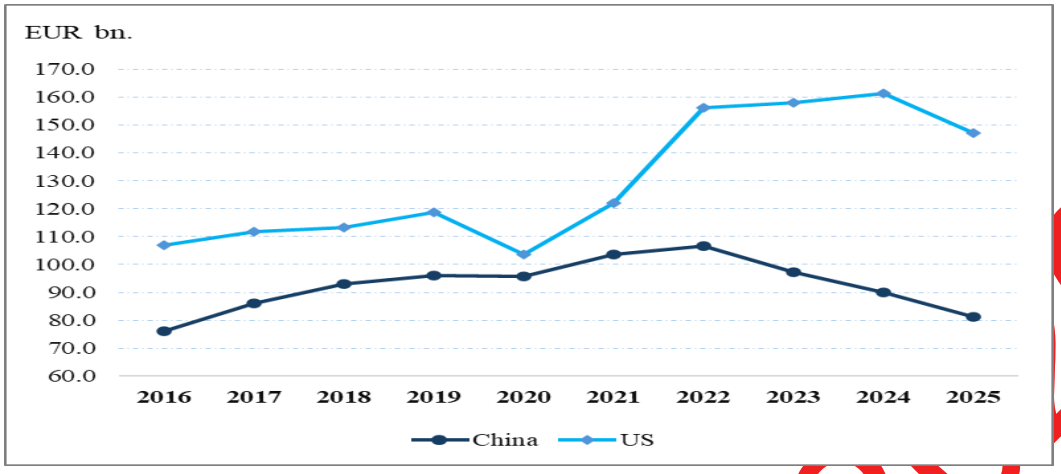
with only 57% of surveyed enterprises having invested during the preceding year despite 92% continuing to report investment needs. Among firms that refrained from investing, the main obstacles included macroeconomic uncertainty, elevated costs, limited internal funds, unfavourable financing conditions and bureaucratic requirements. The resulting vulnerability of smaller and medium-sized firms should therefore be understood less as a uniform consequence of energy intensity than as the cumulative effect of constrained investment capacity, transformation costs, administrative burdens and persistent skill shortages.

Germany's industrial model, traditionally built on open markets, strong export performance and deep integration into global production networks, is particularly exposed to the shift from rules-based globalisation towards a more fragmented economic order in which technology, energy, raw materials and the location of investment have increasingly become instruments of geoeconomic competition (Federal Ministry for Economic Affairs and Climate Action, 2023). China's technological upgrading has progressively intensified competition in advanced industrial segments that are also central to Germany's productive specialisation. This pressure has become visible in trade performance: in 2025, the marked decline in German exports to China was associated with intensifying local industrial competition, particularly in the automotive sector and electromobility (Deutsche Bundesbank, 2026).

The United States represents a different but equally important source of competitive pressure. The *Inflation Reduction Act* (IRA) in 2022 reinforced an interventionist industrial-policy model based on extensive tax incentives and subsidies designed to attract domestic production and investment in clean technologies. For European and German industry, the concern was therefore not confined to stronger competition in final markets but extended to the potential relocation of investment and productive capacity towards the United States (Lynch, Moens and Stolton, 2023). More recently, this investment-related pressure has been compounded by a less favourable trade environment. German exports to the US weakened markedly in 2025 as market-access conditions deteriorated under the new American tariff framework[4](Figure 5).

[4] The new tariff framework resulted from unilateral measures introduced by the US administration in 2025 on several categories of strategic goods, including steel, aluminium, motor vehicles and automotive components. Their impact was only partly mitigated by the EU–US agreement reached in July 2025, which established a tariff ceiling of up to 15% for most European products exported to the US market, while preserving significant asymmetries in bilateral trade relations (European Commission, 2025).

Figure 5. German Goods Exports to the United States and China, 2016–2025 (EUR billion)



Source: Author's representation based on data published by Destatis (2026a), Foreign trade – years, countries (code: 51000-0003);
Note: Values are expressed in current prices.

The contrasting trajectories of the two markets underline the changing external conditions confronting German industry. While the Chinese market has become increasingly shaped by stronger domestic industrial competition, recent developments in the United States combine investment-related incentives with more restrictive trade conditions. The simultaneous intensification of Chinese industrial rivalry, US investment competition and renewed barriers to trade illustrates how Germany's competitiveness increasingly depends not only on firm-level efficiency, but also on the capacity to operate within a more fragmented and strategically contested international economic environment.

Viewed across these dimensions, Germany's industrial weakness emerges as the result of interacting sectoral, structural and geoeconomic pressures rather than from a single adverse shock. Energy-intensive industries have borne a disproportionate share of the post-2022 cost adjustment, but the broader deterioration also reflects investment and infrastructure deficiencies, constraints on technological upgrading, persistent skill mismatches, differences in firms' capacity to absorb transformation costs and a less favourable external competitive environment. The resulting pattern is therefore one of differentiated industrial erosion and restructuring rather than homogeneous deindustrialisation. This heterogeneity is central to the policy question examined in the following section, as the increasing diversity of industrial vulnerabilities has progressively exposed the limitations of responses based exclusively on general framework conditions.

4.2. From Vulnerability to Strategic Policy Intervention

The reorientation did not begin with the post-2022 energy crisis. Germany's Industrial Strategy 2030 had already signalled a greater willingness to deploy selective instruments in strategically relevant sectors, while the subsequent sequence of shocks recast this emerging interventionism more explicitly around resilience and economic security (Schneider, 2023).

The differentiated pressures identified above have been accompanied by a progressive broadening of the German industrial-policy response. The 2023 federal industrial strategy reflects this shift by treating the preservation of a competitive industrial base as essential not only for growth and prosperity, but increasingly for economic security and the capacity to manage structural transition (Federal Ministry for Economic Affairs and Climate Action, 2023). Accordingly, improvements in general framework conditions are now combined with more targeted forms of intervention aimed at stabilising vulnerable productive capacities, accelerating decarbonisation and technological upgrading, modernising infrastructure, and mobilising investment in areas considered critical for future competitiveness. The strategy itself explicitly couples improvements in the domestic business environment with a proactive funding role for the state in clearly defined cases, signalling a move beyond the conventional supply-side logic without abandoning it. The policy response therefore extends beyond short-term crisis mitigation towards an intentional effort to shape the direction and resilience of long-term industrial modernisation.

Economic-security considerations have simultaneously widened the objectives assigned to industrial policy. Diversification of energy and critical raw-material supplies, reduced dependence on single external suppliers, more resilient value chains, and the preservation of strategically relevant manufacturing capabilities have become increasingly intertwined with conventional competitiveness goals. Importantly, this logic is framed not in terms of autarky, but of retaining, rebuilding or attracting capabilities that can be scaled up, when necessary, within European and allied production networks. The same logic applies to technological transformation: public support is directed not only towards correcting market failures, but also towards accelerating investment in low-carbon production, frontier innovation, and strategic technologies where high adjustment costs, systemic uncertainty, or external dependencies might otherwise impede modernisation. In this respect, the emerging policy mix increasingly combines protection against immediate supply disruptions with proactive efforts to reshape the technological and productive foundations of German industry.

This reorientation is inseparable from the European policy architecture within which German intervention operates. While EU competition and state-aid frameworks continue to discipline national measures, European initiatives increasingly enable targeted support for strategic production, net-zero technologies, and resilient supply ecosystems. Germany's policy space is therefore neither purely national nor simply constrained by European rules; it is increasingly shaped through the interaction between domestic industrial priorities and a broader EU agenda centred on competitiveness, decarbonisation, strategic resilience, and economic security. The federal strategy goes further in defining economic security as a European rather than nationally self-sufficient objective: sufficient strategic capacity elsewhere in the Union can reduce the need for duplication at national level, while German productive capabilities are themselves treated as part of Europe's wider industrial resilience. This multilevel dimension is particularly decisive for Germany, whose industrial capabilities are deeply

embedded in European value chains and whose domestic adjustment has implications across the Single Market. The resulting configuration is best understood as an explicitly strategic form of public intervention rather than a regression to conventional dirigisme. Competitive markets and horizontal framework policies remain foundational, yet they are increasingly complemented by selective instruments justified on the grounds of resilience, technological sovereignty, economic security, and the preservation of productive capacities whose loss would be difficult or prohibitively costly to reverse. The state consequently assumes a stronger coordinating and risk-sharing role in the transformation of industry, without displacing private firms as the primary drivers of investment and innovation. At the same time, the strategy places explicit limits on such selectivity: targeted funding requires specific justification, should remain compatible with competitive allocation wherever possible, and should be subject to monitoring and exit mechanisms designed to prevent permanent subsidy dependence. The scope of this strategic turn nevertheless remains bounded by fiscal constraints, European state-aid discipline, and the imperative to maintain competitive market structures, pointing to the emergence of a hybrid strategic state rather than an unconstrained expansion of public intervention.

5. CONCLUSION

The evidence assembled in this paper does not support a narrative of uniform German deindustrialisation, but rather one of differentiated industrial erosion and restructuring. Energy-intensive branches have borne a disproportionate share of the post-2022 cost shock, while machinery and other segments of manufacturing have followed distinct trajectories of weakening or incomplete recovery. These sectoral pressures have interacted with more gradual constraints on the competitiveness of the German industrial model, including investment and infrastructure shortfalls, administrative rigidities, persistent skills mismatches, uneven adjustment capacities across firms and a more contested geoeconomic environment shaped by Chinese industrial upgrading and increasingly interventionist US industrial and trade policies. The post-2022 energy shock therefore acted as an accelerant rather than as the sole cause of a deterioration whose structural origins were already visible beforehand.

This diagnosis is mirrored by a significant shift on the policy side. The federal response, whose reorientation was already visible before 2022 and became more explicit in the 2023 industrial strategy, indicates a movement beyond a predominantly horizontal and rules-based approach towards one in which resilience, technological sovereignty and economic security increasingly inform the rationale and selectivity of public intervention alongside conventional competitiveness objectives. This reconfiguration has not produced a dirigiste model. Horizontal framework policies and competitive markets remain central, while selective instruments are constrained by fiscal limits, European state-aid discipline and the continuing requirement to preserve competitive allocation. The resulting configuration is therefore best understood as a hybrid strategic state, in which government assumes a stronger coordinating and risk-sharing role without displacing firms as the primary agents of investment

and innovation. Its European dimension is equally important: German industrial policy is increasingly embedded in a multilevel framework in which national productive capacities, EU strategic autonomy and the resilience of European value chains are mutually interdependent.

These findings broadly support the paper's initial hypothesis that the reconfiguration of German industrial policy cannot be adequately understood as a succession of ad hoc crisis responses. The shift predates the 2022 energy shock and was subsequently consolidated through strategic policy frameworks centred on competitiveness, transformation and economic security. The qualitative and documentary nature of the analysis nevertheless limits any definitive claim about its permanence. Whether the strategic-state orientation becomes a durable feature of German economic governance, rather than a transitional response to an unusually dense sequence of shocks, will depend on how the emerging policy logic withstands changes in fiscal conditions, energy costs, technological competition and the wider geoeconomic environment.

REFERENCES

Acemoglu, D. (2023). Distorted Innovation: Does the Market Get the Direction of Technology Right? *American Economic Association (AEA) Papers and Proceedings, 113*, 1-28. doi:10.1257/pandp.20231000.

AG Energiebilanzen e. V./AGEB. (2026). *Evaluation Tables on the Energy Balance for the Federal Republic of Germany 1990 to 2024.* Retrieved from AGEB: https://ag-energiebilanzen.de/en/.

Altenburg, T. (2024). *Industrial policy trends in Germany.* Santiago: Economic Commission for Latin America and the Caribbean (ECLAC). Retrieved from https://repositorio.cepal.org/server/api/core/bitstreams/75d226ef-36a3-40fc-8f19-c2f417cbecc5/content.

Boston Consulting Group (BCG), The German Economic Institute (IW) & The Federation of German Industries (BDI). (2024). *Transformation Paths for Germany as an Industrial Nation.* Berlin: Boston Consulting Group. Retrieved from https://bdi.eu/de/publications/publications/transformation-paths-for-germany-as-an-industrial-nation.

Bundesverband der Deutschen Industrie e.V. (BDI)/The Federation of German Industries . (2024, 11 06). *Deutschland-Tempo machen: Schnellere Planungs- und Genehmigungsverfahren für die Industrie.* Retrieved from BDI - Publikationen: https://bdi.eu/en/publications/deutschland-tempo-machen-1.

Bundesverband der Deutschen Industrie e.V. (BDI)/The Federation of German Industries. (2019, 01 10). *China: Partner and Systemic Competitor - How Do We Deal with China's State-Controlled*

Economy? Retrieved October 09, 2024, from BDI - Publikationen: https://english.bdi.eu/publication/news/china-partner-and-systemic-competitor.

Competence Center for Securing a Skilled Workforce/KOFA. (2026). *Überblick Fachkräftemangel (Overview of skilled labour shortages).* Retrieved from KOFA: https://www.kofa.de/daten-und-fakten/ueberblick-fachkraeftemangel/.

Deutsche Bundesbank. (2026, March 26). *German balance of payments in 2025 - Monthly Report, March 2026.* Retrieved from Deutsche Bundesbank Publications - Current Monthly Reports: https://publikationen.bundesbank.de/publikationen-en/reports-studies/monthly-reports/monthly-report-march-2026-991174?article=german-balance-of-payments-in-2025--991186.

Di Carlo, D., & Schmitz, L. (2023). Europe first? The rise of EU industrial policy promoting and protecting the single market. *Journal of European Public Policy, 30*(10), 2063-2096. doi:https://doi.org/10.1080/13501763.2023.2202684.

Duso, T., Gornig, M., & Schiersch, A. (2025). For a Strategic, European and Competition-Oriented Industrial Policy. *Intereconomics, 60*(4), 215-220. doi:10.2478/ie-2025-0042.

European Commission. (2025, August 21). *EU and US publish Joint Statement on transatlantic trade and investment.* Retrieved from European Commission - Press Release: https://ec.europa.eu/commission/presscorner/detail/en/ip_25_1973.

Eurostat. (2026). *Database*. Retrieved from Eurostat - the official website of the European Union: https://ec.europa.eu/eurostat/data/database.

Federal Ministry for Economic Affairs and Climate Action (BMWK). (2023, October 24). *Industrial policy in changed times: Safeguarding our industrial base, renewing our prosperity, boosting our economic security.* Retrieved from BMWK Publications - Industrial Policy: https://www.bundeswirtschaftsministerium.de/Redaktion/EN/Publikationen/Industry/industrial-policy-in-changing-times.html.

Federal Statistical Office of Germany (Destatis). (2026a). *GENESIS-online*. Retrieved from Database of the Federal Statistical Office: https://genesis.destatis.de/datenbank/online/.

Federal Statistical Office of Germany (Destatis). (2026b). *Destatis Publications - National Accounts - Domestic Product - First annual results - Fachserie 18 Reihe 1.2 - First quarter 2026.* Retrieved June 28, 2026, from Destatis: National Accounts - Domestic Product: https://www.destatis.de/EN/Themes/Economy/National-Accounts-Domestic-Product/_node.html#.

German Council of Economic Experts. (2025, May 21). *Structural change in Germany: productivity, regional aspects and the labour market.* Retrieved from German Council of Economic Experts -

Publications: Productivity Reports: https://www.sachverstaendigenrat-wirtschaft.de/en/publications/productivity-reports.html.

Ifo Institute. (2026, February 25). *Economic Slowdown Eases Shortage of Skilled Workers in Germany.* Retrieved from "ifo" Institute: https://www.ifo.de/en/facts/2025-02-17/economic-slowdown-eases-shortage-skilled-workers-germany.

International Institute for Management Development (IMD). (2026). *World Competitiveness Ranking 2026.* Retrieved from IMD- Country Profile: Germany: https://www.imd.org/entity-profile/germany-wcr/.

Juhász, R., Lane, N. J., & Rodrik, D. (2024). The New Economics of Industrial Policy. *Annual Review of Economics, 16*, 213-242. doi:https://doi.org/10.1146/annurev-economics-081023-024638.

KfW Research. (2025, July 01). *Municipalities complain about worsening investment backlog.* Retrieved from KfW, Press Release: https://www.kfw.de/About-KfW/Newsroom/Latest-News/Pressemitteilungen-Details_855680.html.

KfW Research. (2026, July 01). *Financing climate clouded – investment activity subdued.* Retrieved from KfW Business Survey 2026: https://www.kfw.de/About-KfW/Newsroom/Latest-News/News-Details_899584.html.

Lynch, S., Moens, B., & Stolton, S. (2023, February 08). *France and Germany go it alone as EU summit prepares to tackle fightback against US.* Retrieved from Politico: https://www.politico.eu/article/france-and-germany-go-it-alone-as-eu-leaders-meet/.

Rodrik, D. (2004). Industrial Policy for the Twenty-First Century. *KSG Faculty Research Working Paper Series RWP04-047*, 1-58. Retrieved from https://www.hks.harvard.edu/publications/industrial-policy-twenty-first-century.

Schneider, E. (2023). Germany's Industrial strategy 2030, EU competition policy and the Crisis of New Constitutionalism. (Geo-)political economy of a contested paradigm shift. *New Political Economy, 28*(2), 241-258. doi:https://doi.org/10.1080/13563467.2022.2091535.

Tagliapietra, S., & Veugelers, R. (2023). Industrial policy in Europe: past and future. In S. Tagliapietra, & R. Veugelers, *Sparking Europe's new industrial revolution: A policy for net zero, growth and resilience* (pp. 13-28). Brussels: Bruegel. Retrieved from https://www.bruegel.org/blueprint/sparking-europes-new-industrial-revolution-policy-net-zero-growth-and-resilience.

Von Der Burchard, H. (2022, October 19). *'We failed' on Russia: Top German Social Democrat offers mea culpa.* Retrieved from Politico: https://www.politico.eu/article/we-failed-germany-depended-on-russia-social-democrat-said/.

FOREIGN INVESTMENTS IN THE FOOD SECTOR IN TURKEY

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ABSTRACT

The food sector is an industrial branch that processes animal and vegetable raw materials obtained through agriculture in factories, transforming them into packaged, ready-to-consume products with a long shelf life. Human consumption needs and technological advancements have enabled the rapid development of the food sector and the expansion of investment areas.

While the food sector in Turkey developed rapidly following the proclamation of the Republic, regulations enacted over the years have drawn a portion of the increasing volume of foreign investments into the food industry. In this study, while the first section examines the food sector along with its share in Turkey's foreign trade, the second section illustrates examples of corporate acquisitions in the Turkish food sector and identifies the companies that have entered the market through foreign direct investments.

Keywords: *Food Sector, Foreign Direct Investment (FDI), Mergers and Acquisitions (M&A), Foreign Trade, Turkish Economy.*

JEL Codes: *F21, F14, L66, G34.*

1. INTRODUCTION

The industrial branch that transforms plant and animal raw materials obtained from the agricultural sector into long-shelf-life and ready-to-consume products through one or more applied processes is called the food sector. For the food sector, which meets its raw material requirements from agriculture, the agricultural sector and the food industry interact with each other globally and develop in parallel. The usage rate of agricultural products in the production of food items varies across products. For instance, while this rate is low in milk, meat, fruits, and vegetables, it is high in wheat, sugar beet, and oilseeds (İTO, 2006: 19).

Although agricultural production varies depending on seasons and regions, the continuous demand for food and the perishable nature of agricultural products necessitate the application of certain processing and preservation methods. This function is fulfilled by the "Food Industry" (İSO, 2006: 34).

The food industry satisfies the nutritional requirements of consumers by producing foodstuffs. Since they are of agricultural origin, foodstuffs are perishable; however, their shelf life can be extended

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by adding various additives. Along with technological developments, product diversity can be increased. Since it allows for storage, balancing the supply and demand of foodstuffs becomes easier. Due to its importance in nutrition, legal regulations are necessary in marketing services. Furthermore, owing to the presence of numerous manufacturing companies with different capacities, competition will inevitably arise in areas such as price, service quality, and product diversity (Güneş et al., 2002: 18).

According to the international classification system of the food industry, the food sector is categorized into eight sub-sectors: the flour sector, the pulses sector, the meat and meat products sector, the fruit and vegetable sector, the dairy sector, the vegetable oil sector, the feed industry, and sugar and confectionery products. These eight sectors display parallelism with the "manufacture of food products, beverages, and tobacco products sector" in the European Union in terms of products and production methods (Başar et al., 2008: 32).

1.1. The Food Sector in the Turkish Economy

The presence of rich agricultural resources and the prevalence of livestock farming in the Turkish economy have been influential in the establishment and development of the food processing industry (Susmuş and Ozan, 2011: 10).

Since most of the raw materials are obtained from the agricultural sector, products belonging to almost all sub-sectors of the food industry are manufactured in our country. However, the dispersed nature of production and operation across various branches complicate the accuracy of data obtained regarding the sector (Balu et al., 2007: 313).

Major developments in the Turkish food sector following the proclamation of the Republic include:

- Uşak Sugar Factory was established. (1926)
- The first tea factory was established. (1947)
- The number of canning factories increased rapidly. (1948)
- Meat and Fish Institution (*Et Balık Kurumu*) was established (1952), along with meat integrated plants, pioneering developments in the meat processing industry.
- Margarine production commenced. (1953)
- The first dairy factory, Atatürk Forest Farm (*Atatürk Orman Çiftliği*), was established. (1957)
- Dairy Industry Corporation (*Süt Endüstrisi Kurumu - SEK*) was established. (1963)
- In the 1970s, factories for fruit juice and frozen foods were established.
- Snack foods became widespread, and private sector investments increased (post-1980) (DPT, 52-53).

Following 1980, the economy transitioned to an export-led industrialization model, during which significant changes were implemented in the foreign trade regime, including the food sector. Initially, foreign trade in food and agricultural products was liberalized. In 1984, import duties and tariffs applied to the food sector were substantially reduced.

The industrialization process in the Turkish economy after the proclamation of the Republic originated with the food sector, leading to the establishment of modern food processing factories. In the 1950s, characterized by an environment of economic and political liberalization, a noticeable increase occurred in private sector investments within the high-value-added food processing industry. With the transition to the planned economy period, state presence in the food sector expanded, accompanied by significant increases in investments primarily directed toward the dairy, fish, and meat processing industries. The post-1980 period stands out as an era dominated by neoliberal policies aimed at supporting the private sector to the extent possible through export-oriented industrialization programs.

Although the food industry is an agriculture-based industry, it holds an important position in the Turkish economy. Accounting for a 20% share in total manufacturing output and providing employment for approximately 100,000 people, the food sector generates an average of 5% of the total value added. Significant advancements occurred in the food sector during the 1990s, where the sector met domestic demand while utilizing its export potential through expanded production (Yulafçı and Cinemre, 2005: 60-63).

Challenges in the food sector stem from agriculture-related infrastructural problems, informality, a concentration of financially and technically weak small-scale enterprises, and a shortage of technical personnel. These issues have negatively affected the production growth in the food sector in recent years. Furthermore, the shrinking domestic demand caused by post-1999 domestic and global economic crises directed the sector toward exports. Additionally, technical requirements imposed on entry to developed markets and ongoing issues regarding homogeneous product production have acted as restrictive factors for the food sector's expansion into foreign markets (TÜSİAD, 2007: 109).

The food sector emerges as a strong industry owing to the presence and diversity of non-import-dependent agricultural raw materials and fertile irrigable lands. Furthermore, the geopolitical advantages of Turkey and the export opportunities of the sector are regarded as added value. Turkey, with its young and growing population, exhibits growth in terms of both production and consumption.

According to industry leaders, beyond favorable geopolitical conditions, the dynamism in the agriculture and livestock sectors grants significant advantages to the sector:

- Turkey possesses a large domestic market,
- Turkey is surrounded by countries with rising income levels and increasing consumption expenditures.

According to key actors in the sector, the future of the food industry is promising. These developments within the sector can be linked to the country's young population, rising welfare levels, and increased consumer spending. In particular, the rapid growth in demand for branded products in our country has led conscious investors to prioritize branding in the food sector and to undertake new investments.

Despite all this growth in the food sector, several problems remain prominent. These can be listed as follows:

- Global climate change reduces crop yield,
- Yield reductions cause supply contractions, leading to increases in food prices,
- Unregistered / unmapped production,
- Global economic crises constraining consumer spending,
- High production costs,
- Lack of consumer awareness,
- Difficulties encountered in procuring high-quality and homogeneous raw materials.

The main raw material of the food sector is obtained from agriculture; thus, instabilities in the agricultural sector directly impact the food sector. High energy and raw material costs adversely affect the performance of food and beverage manufacturers, thereby impacting the food sector negatively.

Turkey's young population and its openness to new brands and products, alongside the growth of the tourism sector, have led to increased consumption in the food and beverage industry, thereby driving the food sector's expansion. Since the food sector has not yet reached full maturity, the introduction of new products into the Turkish economy presents an ongoing opportunity for the sector (Turan, 2013: 70-72).

1.2. Foreign Trade in the Food Sector within the Turkish Economy

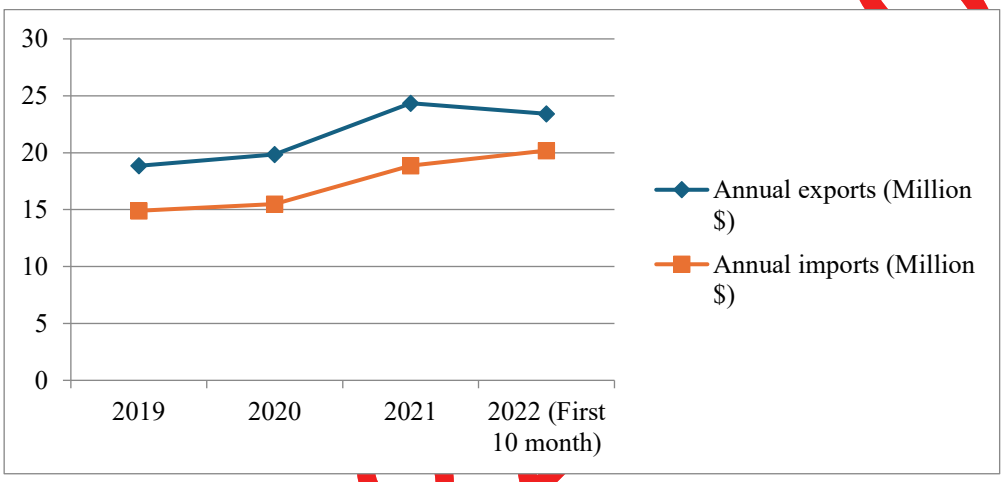
The neoliberal policies implemented after 1980 and the export-oriented growth models served as major drivers for the opening up of the Turkish economy and Turkish firms to foreign markets. With the liberalization of foreign trade, the country's economic capacity expanded significantly in terms of both exports and imports, undergoing substantial development.

Within the scope of predominantly export-led growth policies, major changes occurred in the food sector. In 1984, import duties and fees on food products were significantly reduced, leading to a substantial increase in imports. Examining import figures reveals an increase in animal products within the food sector. Furthermore, as a result of recent advancements in food technology, the sector has established export-driven production, reaching a competitive position in international markets.

In the Turkish economy, modern food industry facilities established specifically to enhance exports after 1980 enabled a notable increase in food exports. However, traditional agricultural products still account for a major share of Turkey's exports (İGEME, 2004).

Currently, traditional food items—primarily pasta, alongside flour and bakery products, frozen fruits and vegetables, canned goods, tomato paste, and hazelnuts—are export products with continuously increasing production levels in the Turkish economy. Consequently, the food sector, whose share in total exports has been growing annually in recent years, contributes significant foreign currency inflow to the Turkish economy (Turan, 2013: 75).

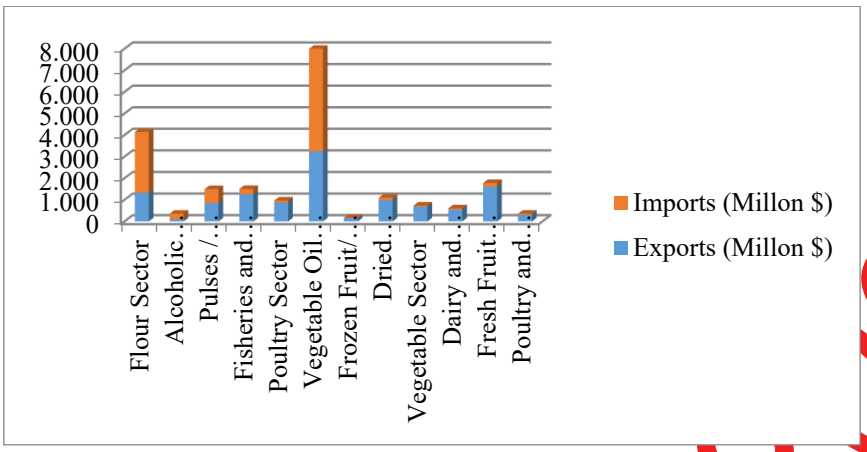
Figure 1. Comparison of Food Sector Export and Import Data by Years



Source: TUIK.

As shown in Table 1, data from 2019 and the first 10 months of 2022 were utilized. It is observed that a surplus exists between the exports and imports of the food sector. Examining the export figures reveals that despite representing only the first 10 months of 2022, the export volume closely approaches that of 2021. With the inclusion of November and December data, it may be observed that food sector exports increased continuously throughout these four years. In addition, imports, similar to exports, demonstrate a steady annual increase. It is further observed that this growth persisted despite the data being denominated in US dollars and the high exchange rate environment.

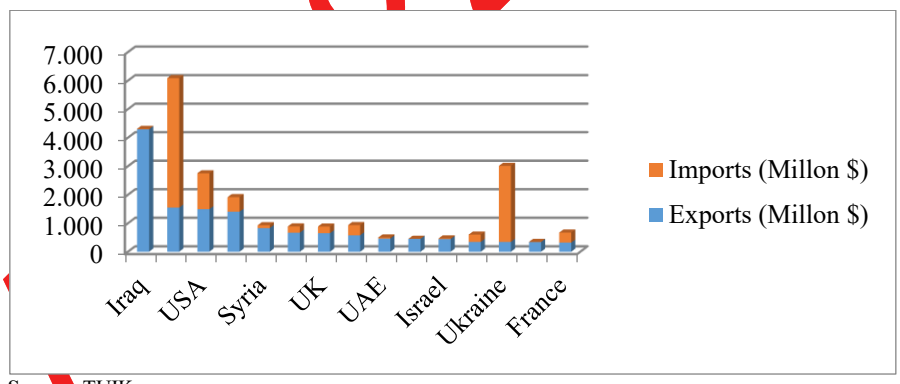
Figure 2. Foreign Trade Data of Selected Food Sector Commodities for the First 10 Months of 2022



Source: TUIK.

As shown in Table 2, the export and import data are analyzed by breaking them down into the sub-sectors of the food industry. Examining both export and import figures reveals that the vegetable oil sector emerged as the sub-sector with the highest foreign trade volume, followed by the flour sector. The most fundamental feature distinguishing these two sectors from the others is that imports exceed exports.

Figure 3. Turkey's Food Sector Export and Import Data on a Country Basis for the First 10 Months of 2022



Source: TUIK.

As shown in Table 3, selected countries with which foreign trade is conducted in the food sector are compared. The top destination countries for food sector exports are listed, in order, as Iraq, Russia, Germany, and Syria, while the leading origin countries for imports are shown as Russia, Ukraine, the USA, and Germany, respectively. Four major trading partners stand out:

- Examining Russia; it holds a prominent position both among the top export destinations and as the primary source of imports.
- Examining Iraq; it tops the list of export destinations, whereas imports from this country are virtually nonexistent.

- Examining Germany; it ranks fourth among the top export destinations while also being among the leading sources of imports.
- Examining Ukraine; while its export volume remains notably low, it ranks second after Russia in terms of imports.

2. DATA SET

Examining the sectoral distribution of foreign capital investments in the Turkish economy throughout history, it is observed that prior to the proclamation of the Republic, investments were predominantly concentrated in infrastructure sectors (railways, ports, and highways).

In 1924, there were 94 foreign-capitalized companies operating in the Turkish economy. Their sectors of activity were as follows:

- 23 in banking,
- 11 in electricity,
- 12 in the manufacturing industry,
- 35 in trade,
- 6 in maritime shipping (DPT, 1983: 12).

Foreign investments made following the proclamation of the Republic generally took the form of joint ventures, primarily in sectors such as food, cement, and textiles. By 1929, the number of foreign-capitalized companies increased by 20 within a five-year period, reaching 114, which resulted in a foreign currency inflow of $30 million into the Turkish economy (Şahinöz, 1998: 336).

Examining the distribution of foreign-capitalized companies investing in the Turkish economy between 1951 and 1960, the share of the food sector stood at 15.12% (Selik, 1961: 31).

By 1965, foreign-capitalized companies directed their largest investments toward the pharmaceutical sector, while the share of foreign capital entering the food sector was recorded at 7.2% (Central Bank of the Republic of Turkey [MB], 1965).

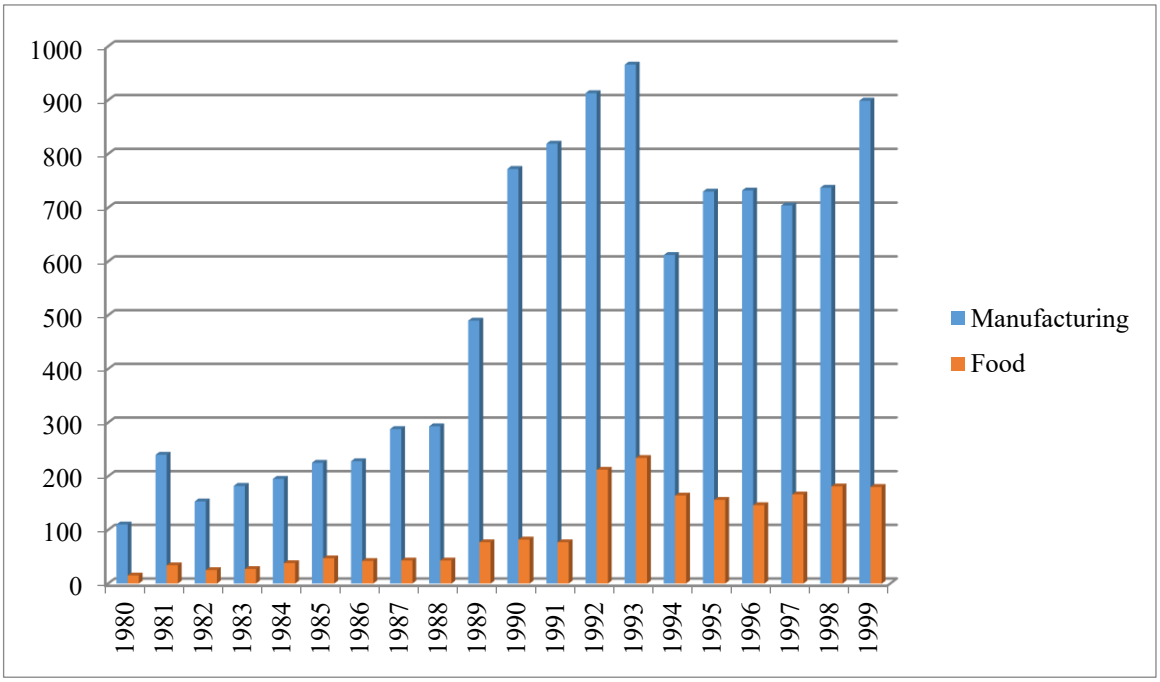
Looking at the distribution of investment permits granted by decrees issued after 1972 across production sectors, an investment of $11 million was made in the food sector (Şahin, 1975: 55).

Following 1980, the role of foreign capital in agricultural production and the food sector expanded significantly. The enactment of the January 24, 1980 decisions and regulatory reforms targeting foreign capital led to an increase in foreign capital investment levels and, in parallel, raised the permitted amount of foreign capital in the manufacturing sector. While foreign capital investment in the food sector alone was $15 million in 1980, it rose to $77 million just nine years later. Between 1980 and 1984, permits were granted to 84 foreign-capitalized companies, 8 of which operated in the food sector. Between 1985

and 1989, while total capital permits across 11 sub-manufacturing industries reached $944 million, 81 foreign-capitalized companies received approval to invest in the food sector (Turan, 2013: 80).

Investments made in the manufacturing industry between 1980 and 1998 are presented in detail in the graph below. The graph illustrates investments in the food sector during the same period. It is observed that investments directed toward the food sector varied in parallel with investments made in the manufacturing industry.

Figure 4. Investments Made in the Manufacturing Industry and the Food Sector Between 1980–1998



Source: TCMB.

Among the sub-sectors of the manufacturing industry, the Food and Beverage sector was the highest recipient of foreign investment in 1985, attracting $47 million. A similar trend was observed in 1989, 1992, and 1998, respectively. Due to its high profitability, this sector has consistently remained a preferred choice for foreign investors.

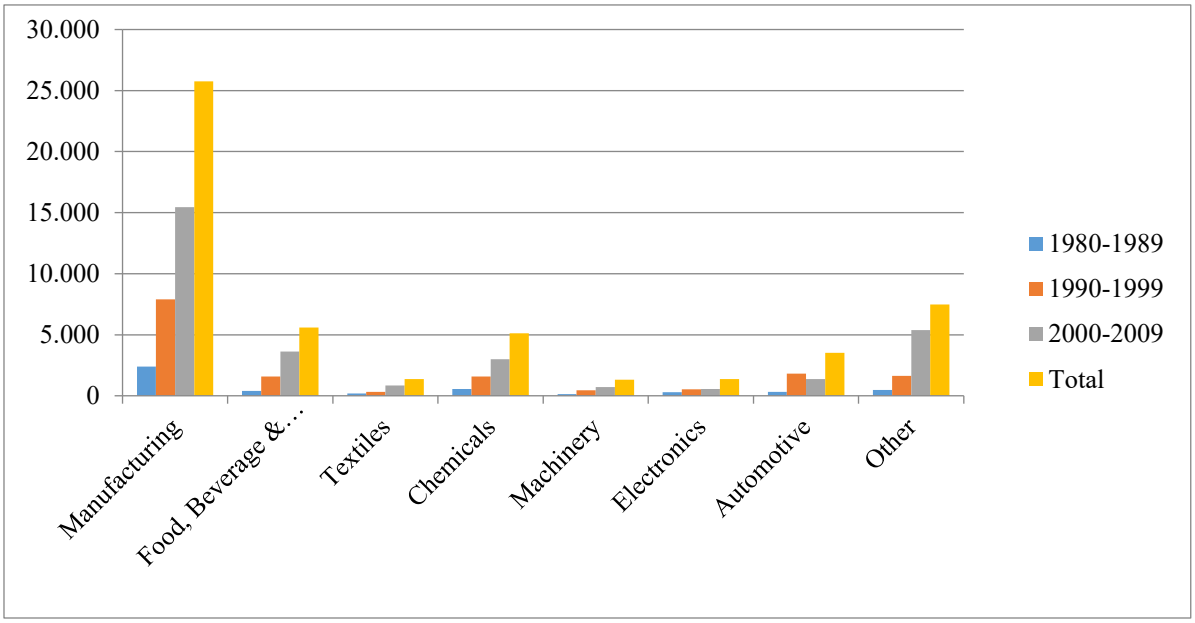
In 1989, a substantial increase in foreign capital was recorded across all sectors. The underlying cause was that the measures implemented in 1989 to encourage foreign currency inflows had a positive impact on foreign capital entry.

Examining the period between 1987 and 1998, an increase is observed in the number of domestic companies forming partnerships with foreign entities. The number of foreign-capitalized enterprises rose from 32 to 65 in the agricultural sector, from 38 to 139 in the food sector, and from 8 to 198 in the catering services sector. Prominent domestic capital groups in the Turkish economy began operating in various branches of the food sector by establishing joint ventures with foreign companies.

In the 1990s, alongside privatizations, state-owned enterprises belonging to the Dairy Industry Corporation (*SEK*), Feed Industry Inc. (*YEMSAN*), and the Meat and Fish Institution (*Et ve Balık Kurumu*) were privatized (Turan, 2013: 81-82).

Table 5 presents the distribution of foreign capital investments within the manufacturing industry between 1980 and 2009. As shown, the food, beverage, and tobacco sector received the largest share of foreign capital investment within the manufacturing distribution during this period.

Figure 5. Distribution of Foreign Capital Within Manufacturing Sectors Between 1980–2009 ($ Million)



Source: TUSIAD, TCMB, Ministry of Treasury and Finance.

3. METHODOLOGY

3.1. Case Studies On Foreign Direct Investments In The Food Sector

Foreign direct investments encompass various forms, such as long-term investments made by foreign investors in our country, establishing a new enterprise, expanding an existing one, or acquiring an existing business. In recent years, this type of investment has generally been executed through the acquisition of existing enterprises or by means of mergers. To illustrate, firm mergers and acquisitions accounted for 85% of foreign direct capital investments made in 2000 (Demir, 2003: 65).

A decline occurred in mergers and acquisitions during the years 2001, 2002, and 2003; however, following 2003, they resumed an upward trend in parallel with global developments. In 2006, the number of mergers and acquisitions rose to 215, and in 2007, mergers and acquisitions exceeding $1 billion were realized, with 78% of foreign direct investments being executed through this channel in that year (Yaşar, 2011: 79).

In this section, the objective is to demonstrate examples of corporate acquisitions in the Turkish food sector and to illustrate the brand names under which these companies entered the market.

Table 1. Domestic Companies Acquired in the Food Sector Between 2015–2021

Year	TARGET COMPANIES			
	Company Name	**Acquiring Company/Companies**	**Acquirer's Country**	**Share Acquired(%)**
2015	Ak Gıda	Lactalis	France	%80
	Bahar Su	DyDoDrinco	Japan	%90
	Della Gıda			
	İlk Mevsim Meyve Suları			
	Ekol Gıda	Cargil	USA	%51
	Oruçoğlu Yağ	Trans AtlanticGroup DMCC	USA	%100
2016	Ana Gıda	Bunge	Netherlands	%100
	Bizim Mutfak	Ajinomoto	Japan	%100
	Mado	Al Sraiva Holding/ VentureCapital Bank	Qatar / Bahrain	Not Available
	Peyman	Bridge Point	UK	%100
	Polen Gıda	Dr. Oetker	Germany	%55
	Rito Tohumculuk	TakiiSeed	Japan	%100
	Vitamin Unlu Mamulleri	MunifAlnahdiGroup	UAE	%45
2017	Banvit	BRF / QİA	Brazil / Qatar	%79,48
	Kemal Kükrer	Ajnomoto	Japan	%50
	KFC Türkiye	TheAbraajGroup	UAE	%100
	May Agro	ZaadHoldings	South Africa	%35
	Simit Sarayı	AlhokairGroup	Saudi Arabia	%10
	Yem Vit	DevenishNutrition	İrlanda	%50

2018	D.ream	Temasek MetricCapital	Singapore UK	%17,34
	Demak Gıda	TransmedLebanese Holding	Lebonan	%80
	Ekol Gıda	Cargill	USA	%49
	IkonAgro	EW Nutrition	Germany	%51
	Kellogg Med Gıda	Kellogg's	USA	%50
	Oba Makarnacılık	VentureCapital Bank First Energy Bank	Bahrain	%50
	Ofçay	Jacobs	USA	%100
2019	Bonfilet	PashaİnvestmentS	Azerbaijan	Not Available
	Beta Tarım	CCPA Group	France	Not Available
	Glutensiz Ada	DrSchar	Austria	%50
	Turkaş Gıda	CompassGroup	UK	%100
2020	İz Hayvancılık	Alpha Venture	UK	%49,5
	Polonez	SinioraFood	Jordan	%77
	SelJel Jelatin	GelitaİnternationaI	Germany	%50
	Tiryaki Agro	QatarİnvestmentAuthority	Qatar	%23
2021	Assan Gıda	Kraft Heinz	USA	%100
	Della Gıda	DyDoGroup	Japan	%10
	Diket Vitamin	Nestle	France	Not Available
	Ege Tarım Hayvancılık	NH Foods	Japan	%40
	Şahmar Gıda	Azad Hüseynov (Private investor)	Azerbaijan	%100

Source: ErnstandYoung, 2015-2021.

Table 2. Selected Foreign Direct Capital Investment Companies in the Food Sector

Leading Companies In The Sector		
Company Name	**Ultimate Owner**	**Country of Origin**
Arbella Makarna	AGT FoodandIngredients	Canada
Barilla Makarna	Barilla S.P.A.	Italy
Filiz Makarna	Barilla S.P.A.	Italy
Yudum Yağ	Savola Gıda San. Ve Tic. A.Ş.	Saudi Arabia
Kırlangıç Yağ	KoninklijkeBunge B.V.	USA
Komili Yağ	KoninklijkeBunge B.V.	USA
Hayat Su	Danone	France
Erikli Su	Nestle	Switzerland
Damla Su	Coca Cola Company	USA
Coca Cola	Coca Cola Company	USA
Fanta	Coca Cola Company	USA
Cappy	Coca Cola Company	USA
Çamlıca Gazoz	DyDoDrinco	Japan
Algida	Unilever PLC	UK
Nutella	FerreroGroup	Italy
Milka	Mondelez International	USA
Danone	Danone	France
İçim	Lactalis	France
CP	CP Group	Thailand
Yeni Rakı	Diageo	UK
Dr. Oetker	Dr. Oetker	Germany

Source: ErnstandYoung, 2002-2021.

4. CONCLUSION

In general, when the period before and after the proclamation of the Republic is considered, the presence of foreign-capital companies in the country has gradually increased. Through regulations introduced over the years, the number of foreign investments has increased, and these investments have also been observed in the food sector.

Between 2015 and 2021 alone, 39 domestic companies underwent mergers or acquisitions involving foreign direct investment. The majority of the largest companies operating in our country consist of foreign-capital companies. This situation can be summarized by examining three sectors.

First, when the vegetable oil sector is considered, Yudum, Kırlangıç, and Komili are among the most important vegetable oil companies operating in our country. However, it can be observed that these companies are no longer owned by domestic firms but by foreign-capital companies.

Second, when the pasta sector is considered, pasta is one of the most widely consumed food products in our country. Therefore, it may be assumed that the share of domestic production is high. However, it can be seen that one of the best-known brands in our country, "Filiz Pasta," was sold and subsequently became part of the Barilla Group.

Third, when the beverage sector is considered, The Coca-Cola Company stands out. This company produces various types of beverages, such as Coca-Cola, Fanta, and carbonated soft drinks, both in our country and worldwide, and it also has a production facility in our country. Since the consumption of these products is quite high, a significant amount of investment has been made in our country by this company.

As a result, foreign companies, as well as domestic companies, have a significant presence in the food sector market in our country. However, the greater their presence, the greater their potential to influence prices, since they have considerable control over the supply of their products. Therefore, it is necessary to encourage the consumption and production of domestic products.

REFERENCES

Balu, Melih, Hakkı Eraslan, and Mehmet Barca (2007). "Analysis of the International Competitiveness Level of the Turkish Food Industry." *Afyon Kocatepe University Journal of Economics and Administrative Sciences*, 9(1): 313.

Başar, A. Banu, Arman A. Karagül et al. (2008). *Analysis of Selected Sectors in Eskişehir in Light of Social, Economic, and Financial Indicators*. Eskişehir: T. C. Anadolu University Publications.

Demir, Sevhan Gülten (2003). "Centralization/Concentration of Capital: Firm Mergers." *Journal of Economics, Business and Finance*, 18(206): 60–80.

State Planning Organization (DPT) (1983). *Foreign Capital in Turkey*. Ankara: DPT Publications.

EY (2022). Available at: https://www.ey.com/tr_tr/strategy-transactions/mergers-acquisitions-services/birlesme-satin-alma-islemleri-raporlar.

Güneş, Erdoğan, Mevhibe Albayrak, and Bülent Gülçubuk (2002). *Food Industry in Turkey*. Ankara: TEKGIDA-İŞ Trade Union.

Export Promotion Center of Turkey (İGEME) (2004). *Export Potential of the Agriculture and Food Sector*. Research and Development Department, Agriculture Division, November 2004, Ankara.

Istanbul Chamber of Industry (İSO) (2006). *Food Sector: Sector Strategies Development Project of the Professional Committees of the Istanbul Chamber of Industry during the Full Membership Process to the European Union*. Istanbul: İSO Publications.

Istanbul Chamber of Commerce (İTO) (2006). *The Competitiveness of the Turkish Food Sector in International Markets and the Criteria Required for Exports*. Istanbul: İSO Publications.

Ministry of Finance (1965). *Annual Economic Data*.

Selik, Mehmet (1961). *Private Foreign Capital in Turkey (1923–1960)*. Ankara: SBF Publications.

Susmuş, Türker, and Mengü H. Özan (2011). "Evaluation of Turkish Food Industry Data, Break-Even Point and Operating Leverage Analysis." *Izmir Chamber of Certified Public Accountants*, (111): 111.

Şahin, Mehmet (1975). *Foreign Capital Investments in Turkey: Economic and Social Publications*. Ankara: Ayyıldız Printing House.

Şahinöz, Ahmet (1998). *Sectoral Analysis of the Turkish Economy*. Istanbul: Turhan Bookstore.

T. C. Prime Ministry State Planning Organization (DPT) (n.d.). *Ninth Development Plan: Report of the Specialization Commission on the Food Industry*, pp. 52–53.

Turan, Hatice Naz (2013). *The Role of International Capital in the Turkish Food Sector*. Master's Thesis, Marmara University, Institute of Social Sciences, Istanbul.

Turkish Federation of Food and Beverage Industry Associations (TGDF) (2022). Available at: https://www.tgdf.org.tr/turkiye-gida-ve-icecek-sektorleri-dis-ticaret-verileri/.

TÜSİAD (2007). *International Competitiveness Strategies: Turkish Food Industry*. Istanbul: TÜSİAD. TÜSİAD/T-2007-09-442.

Yaşar, Ercan (2011). "The Global Trend of Financial Liberalization and Foreign Direct Investments 1." *Dumlupınar University Journal of Social Sciences*, (29): 65–86.

Yulafçı, Ahmet, and Hüseyin Avni Cinemre (2005). "Problems of Food Industry Enterprises in Samsun Province." *Ondokuz Mayıs University Faculty of Agriculture Journal*, 20(3): 60–63.

AI ADOPTION AND TRANSPARENCY IN FINANCIAL REPORTING: THE DIGITAL ILLUSION IN EMERGING ECONOMIES AN ANALYTICAL PERSPECTIVE FROM ALBANIA

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ABSTRACT

This study examines the relationship between Artificial Intelligence (AI) adoption and financial reporting transparency in an emerging-economy context, using Albania as an analytical case. Drawing on a structured review of contemporary academic literature and institutional evidence, the paper distinguishes general digital transformation from substantive AI integration in accounting and financial reporting. The analysis indicates that Albania has made visible progress in digital public services, enterprise connectivity, and financial-data infrastructure, while available evidence points to uneven and still limited adoption of advanced AI applications within firms and specialized reporting functions. To explain this gap, the study develops the Digital Illusion Framework, which links Digital Transformation, AI Readiness, Substantive AI Adoption, and Financial Reporting Transparency. The framework proposes that digitalization creates enabling conditions but does not automatically generate AI-enabled transparency; outcomes depend on technological capability, organizational readiness, human capital, data governance, regulation, explainability, and professional oversight. The study contributes a conceptual perspective for assessing digital maturity in emerging economies and establishes a basis for future empirical testing in Albania.

Keywords: *Artificial Intelligence, Financial Reporting, Financial Transparency, Digital Illusion, Albania.*

JEL Codes: *M41, O33, D82*

1. INTRODUCTION

1.1. Background

The rapid advancement of digital technologies has fundamentally transformed the financial and accounting landscape, reshaping the way financial information is generated, processed, analyzed, and communicated. Digital transformation has moved accounting practices beyond traditional, predominantly manual processes toward increasingly automated and technology-driven reporting environments, characterized by the use of cloud computing, big data analytics, robotic process automation, and other advanced digital technologies. Within this transformation, Artificial Intelligence (AI) has emerged as one of the most significant technologies, offering the potential to fundamentally

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alter accounting and financial reporting processes through automation, predictive analytics, intelligent data processing, anomaly detection, and decision-support capabilities (Sanz Martín et al., 2026).

The growing integration of AI into financial activities is particularly relevant to financial reporting, where the ability to process large volumes of complex information rapidly and accurately may contribute to greater efficiency, reliability, and timeliness of reported information. At the same time, the increasing complexity of financial markets and the growing information needs of investors, regulators, creditors, and other stakeholders have intensified the demand for transparent, reliable, comparable, and timely financial reporting. Consequently, transparency is no longer viewed solely as a fundamental characteristic of high-quality financial reporting, but also as an increasingly important outcome of digital transformation (Astika et al., 2026). However, the existence of digital technologies does not necessarily imply their effective or substantive adoption. The distinction between digitalization in general and the actual integration of advanced technologies such as AI into financial reporting therefore represents an important area of investigation, particularly in emerging economies where technological development may coexist with institutional, infrastructural, regulatory, and human-capital constraints.

1.2 Research Problem

Despite the growing availability of digital technologies and the increasing recognition of Artificial Intelligence as a transformative force in accounting and financial reporting, the relationship between technological adoption and actual improvements in financial transparency remains complex. Existing evidence suggests that digital technologies can enhance the accuracy, timeliness, accessibility, and transparency of financial information; however, these benefits are not automatic and depend on the extent and quality of their implementation. Recent research indicates that AI adoption can contribute to improvements in financial reporting accuracy and reductions in information asymmetry, while the adoption of digital reporting technologies such as XBRL has also been associated with improved financial information transparency and reporting quality, particularly in emerging-market contexts (Astika et al., 2026). Nevertheless, a distinction must be made between the general digitalization of accounting processes and the substantive adoption of AI within financial reporting.

An organization may operate within a highly digitalized environment, use electronic reporting systems, cloud-based accounting platforms, or automated processes, while still making limited use of genuinely intelligent technologies capable of learning, predicting, detecting anomalies, or supporting complex accounting decisions. This distinction becomes particularly important in emerging economies, where digital transformation frequently develops alongside limitations in technological infrastructure, regulatory capacity, organizational readiness, and specialized human capital. Consequently, the visible presence of digital technologies may create an impression of advanced technological transformation without necessarily reflecting a comparable level of AI integration into financial reporting practices. This potential discrepancy between perceived digital progress and substantive technological adoption

constitutes the central research problem addressed in this study and provides the foundation for the concept of the "Digital Illusion" proposed in the following sections.

1.3 Research Gap

Although the literature increasingly highlights the potential of Artificial Intelligence (AI) to improve accounting processes, reporting efficiency, and financial information quality, important gaps remain. Existing studies primarily focus on the technological capabilities and potential benefits of AI, while comparatively limited attention has been given to how AI adoption translates into greater financial reporting transparency (Astika et al., 2026). Furthermore, most empirical evidence originates from developed and technologically advanced economies, whereas emerging economies remain underrepresented despite facing distinct institutional, technological, and human-capital challenges that may influence the effectiveness of AI implementation (OECD, 2024).

This gap is particularly relevant in the Albanian context. Albania has made significant progress in digital transformation through the expansion of e-government services, digital infrastructure, and national digitalization initiatives, while also taking initial steps toward developing an AI policy framework (OECD, 2024). However, limited research has examined whether these visible advances in digitalization are accompanied by substantive AI adoption within accounting and financial reporting practices. As a result, the distinction between digital transformation and actual AI integration remains insufficiently explored. This study addresses this gap by introducing the concept of "Digital Illusion", which refers to the potential discrepancy between perceived digital progress and the depth of AI adoption in financial reporting. Using Albania as an illustrative case within the broader context of emerging economies, the study develops a conceptual framework for understanding how technological, institutional, regulatory, and human-capital factors shape the relationship between AI adoption and financial reporting transparency.

1.4 Research Objectives and Research Questions

1.4.1 Research Objectives

The primary objective of this study is to examine the relationship between Artificial Intelligence (AI) adoption and transparency in financial reporting within the context of Albania, while situating the analysis within the broader literature on emerging economies. The study seeks to assess whether the ongoing process of digital transformation in Albania is accompanied by substantive adoption of AI technologies in accounting and financial reporting, and whether such adoption has the potential to contribute to greater transparency, reliability, timeliness, and quality of financial information (Astika et al., 2026).

Rather than statistically estimating the causal relationship between AI adoption and financial reporting transparency, the study employs an analytical and comparative approach based on a structured

review of contemporary academic literature and the examination of Albania's evolving digital, institutional, regulatory, and technological environment. This approach enables the study to identify the main opportunities and constraints associated with AI adoption and to assess Albania's position within the broader transformation of financial reporting in emerging economies.

More specifically, the study pursues four objectives. First, it examines the main applications of AI in accounting and financial reporting and the benefits identified in the contemporary literature. Second, it analyses the potential mechanisms through which AI adoption may enhance financial reporting transparency and quality. Third, it identifies the technological, organizational, regulatory, institutional, and human-capital factors that may facilitate or constrain AI adoption in Albania. Finally, it develops the Digital Illusion Framework to conceptualize the potential gap between Albania's visible progress in digitalization and the substantive integration of AI into financial reporting practices.

1.4.2 Research Questions

The study addresses the following research questions:

RQ1: What does the contemporary literature reveal about the role of Artificial Intelligence in accounting and financial reporting?

RQ2: Through which mechanisms can AI adoption contribute to greater transparency and quality in financial reporting?

RQ3: What technological, organizational, regulatory, institutional, and human-capital factors influence AI adoption in financial reporting within emerging economies and, specifically, Albania?

RQ4: To what extent does Albania's progress in digitalization correspond to substantive adoption of AI in financial reporting, and how can the potential gap be understood through the concept of Digital Illusion?

These research questions guide the subsequent literature review, comparative analysis, and development of the proposed conceptual framework. Albania constitutes the central country context of the study, while evidence from other emerging and more technologically advanced economies is used comparatively to contextualize Albania's position and identify similarities, differences, opportunities, and structural constraints. Accordingly, the study does not claim to provide statistical evidence of a causal relationship between AI adoption and transparency in Albania; rather, it provides an analytical assessment of the phenomenon based on contemporary literature and the country's broader digital and institutional context.

1.5 Contribution of the Study

This study contributes to the growing literature on Artificial Intelligence (AI), accounting, and financial reporting in three main ways. First, it integrates the concepts of AI adoption, digital

transformation, and financial reporting transparency, which are often examined separately in the existing literature. While prior studies have highlighted the potential of AI to improve accounting processes and reporting quality, less attention has been given to its implications for financial reporting transparency, particularly in emerging economies (Astika et al., 2026).

Second, the study introduces the concept of Digital Illusion, which describes the potential gap between visible digital transformation and the substantive adoption of AI in financial reporting. The framework distinguishes between general digitalization and the actual integration of advanced AI technologies, providing a new perspective for analyzing technological progress and transparency.

Third, by using Albania as an illustrative case, the study highlights the importance of contextual factors such as digital infrastructure, regulatory capacity, institutional development, and human capital in shaping AI adoption (OECD, 2024). In doing so, it offers both a conceptual foundation for future research and practical insights for policymakers, regulators, organizations, and accounting professionals seeking to promote the effective use of AI in financial reporting.

2. LITERATURE REVIEW

2.1 Theoretical Foundations of AI Adoption and Financial Reporting

The relationship between Artificial Intelligence (AI) adoption and financial reporting transparency is shaped by several complementary theoretical perspectives. Financial reporting represents a fundamental mechanism through which organizations communicate information to external users and reduce uncertainty surrounding their financial position and performance. Consequently, technological changes affecting the generation, processing, verification, and communication of financial information may have implications not only for accounting efficiency but also for the quality and transparency of information available to stakeholders. Recent literature on AI and accounting increasingly emphasizes that advanced technologies can transform financial reporting processes, while also highlighting the importance of governance, explainability, human expertise, and institutional conditions in determining whether these technological capabilities translate into meaningful improvements in reporting outcomes (Astika et al., 2026; Sanz Martín et al., 2026).

2.2 Technology–Organization–Environment Framework

The Technology–Organization–Environment (TOE) framework provides a useful theoretical basis for explaining why organizations adopt or fail to adopt AI. It proposes that technology adoption is shaped by three dimensions: the technological context, including compatibility, complexity, and readiness; the organizational context, including resources, management support, and capabilities; and the environmental context, including regulation, competition, institutional conditions, and external pressures (Tornatzky et al., 1990).

Applied to the present study, the TOE perspective highlights that the transition from digitalization to substantive AI adoption depends on the interaction between technological readiness, organizational resources and capabilities, and the surrounding regulatory and institutional environment. This perspective is particularly relevant to emerging economies, where infrastructure, financial resources, digital skills, regulatory preparedness, institutional capacity, and organizational readiness may determine whether digitalization develops into substantive AI adoption.

2.3 Digital Transformation and AI Adoption in Albania

Albania has made considerable progress in digital transformation, particularly through digital public services, ICT infrastructure, and digital government. The Digital Agenda of Albania 2022–2026 identifies digital government, advanced technologies, artificial intelligence, cybersecurity, and digital infrastructure as strategic priorities, while the OECD highlights digitalization, connectivity, digital skills, and technology adoption as important for Albania's competitiveness and convergence with EU standards (National Agency for Information Society [NAIS], 2022; OECD, 2024).

The development of e-Albania illustrates this progress. World Bank evidence shows that applications through the e-Albania portal and mobile application increased by 40% by 2025, with further investments planned in e-Albania 2.0, open data, and AI-supported public services (World Bank, 2025). However, the expansion of digital public services does not necessarily indicate widespread AI adoption within Albanian businesses or specialized functions such as accounting and financial reporting.

A similar distinction can be observed among enterprises. In 2025, 99.4% of Albanian enterprises with 10 or more employees had Internet access for business purposes, while only 31.8% reported employing ICT specialists (INSTAT, 2025). This gap suggests that basic digital connectivity has developed faster than specialized technological capabilities. Evidence from Baholli, Plasari, and Dibra (2026) further supports this observation: based on a survey of 85 Albanian SMEs, the authors found that most firms did not use AI, while existing applications were concentrated mainly in marketing and customer service. They characterize AI adoption as fragmented and opportunistic rather than deeply integrated into organizational processes (Baholli et al., 2026).

Albania has also moved toward a more explicit AI policy framework through the National Artificial Intelligence Strategy for 2025–2030. Nevertheless, policy development and digital infrastructure represent enabling conditions rather than evidence of actual AI adoption. Human capital remains particularly important, as the OECD identifies digital skills as essential for businesses to benefit from advanced technologies (OECD, 2024). In accounting and financial reporting, AI adoption requires not only technical infrastructure but also the skills necessary to interpret outputs, identify potential errors or biases, and maintain professional oversight (INSTAT, 2025).

The institutional and financial environment is also becoming increasingly digital. The implementation of ISO 20022 by the Bank of Albania in 2025 strengthened the standardization, quality,

transparency, and efficiency of financial data (Bank of Albania, 2025). However, standardized digital data should not be confused with AI adoption: while ISO 20022 facilitates structured data exchange, AI involves more advanced capabilities such as prediction, anomaly detection, pattern recognition, and intelligent decision support.

Taken together, the evidence points to a contrast between Albania's progress in digitalization and the more limited and uneven adoption of AI among businesses (INSTAT, 2025; OECD, 2024; World Bank, 2025; Baholli et al., 2026). This distinction between digitalization, AI readiness, and substantive AI adoption is central to the present study and provides an important basis for examining whether Albania's visible digital progress has extended to specialized areas such as accounting and financial reporting.

2.4 Financial Reporting Environment in Albania

Albania's financial reporting environment has developed through regulatory reform, convergence with international accounting standards, and institutional strengthening. Law No. 25/2018 on Accounting and Financial Statements provides the principal legal framework. Albania applies National Accounting Standards (NAS) and International Financial Reporting Standards (IFRS), with public interest entities required to apply IFRS Accounting Standards (IFAC, 2026). The IFRS Foundation similarly confirms Albania's adoption of IFRS Standards and the role of Law No. 25/2018 in establishing financial reporting requirements (IFRS Foundation, 2021).

The development of Albania's accounting framework has also been closely linked to European integration. Miti et al. (2018) highlight the development of National Accounting Standards consistent with IFRS as an important component of accounting reform. However, formal convergence with international standards does not automatically ensure high-quality and transparent reporting, which also depends on professional competence, institutional oversight, enforcement, and disclosure practices.

Financial statement disclosure represents an important component of this environment. Miti et al. (2018) emphasize the relevance of disclosures for the quality and usefulness of financial reporting in Albania. This is particularly relevant to AI because its potential contribution extends beyond the preparation of financial statements to the processing, classification, verification, and communication of financial information.

Institutional capacity is another important determinant. The World Bank's Accounting and Auditing Report on the Observance of Standards and Codes (A&A ROSC) highlights the importance of accounting standard-setting, auditing oversight, professional competence, and institutional enforcement in Albania's financial reporting environment (World Bank, 2019). These conditions are relevant because the transparency benefits of AI depend partly on the regulatory and professional environment in which AI-supported information is prepared and assessed.

The digitalization of Albania's financial ecosystem adds another dimension. The implementation of ISO 20022 in 2025 has improved the standardization, exchange, quality, and security of financial data (Bank of Albania, 2025). Such infrastructure may facilitate future AI applications, but standardized digital data should be distinguished from AI-enabled reporting. AI requires additional technological and organizational capabilities to analyze data, identify patterns, detect anomalies, and support decision-making.

Digitalization, AI adoption, and financial reporting transparency should therefore not be understood as a simple linear sequence. Digital technologies can improve processing speed, electronic submission, accessibility, and data management, while AI may further support anomaly detection, predictive analytics, natural language processing, and intelligent classification. At the same time, AI introduces challenges related to explainability, algorithmic bias, data governance, and human oversight. Its contribution to transparency consequently depends on how deeply it is integrated into the accounting and reporting environment.

Albania's financial reporting environment thus reflects regulatory, institutional, and technological modernization occurring in parallel. The country has developed a framework based on NAS and IFRS, strengthened accounting and auditing institutions, and expanded financial digitalization (Miti et al., 2018; World Bank, 2019; IFAC, 2026). Nevertheless, country-specific evidence on substantive AI adoption in financial reporting remains limited. This makes Albania a relevant context for examining whether digital transformation has translated into AI-enabled reporting and greater transparency.

These characteristics make Albania a relevant setting in which to examine the proposed Digital Illusion framework. While the country demonstrates visible progress in digital public services, enterprise connectivity, financial-data standardization, and AI policy development, the depth of technological transformation within specialized functions such as financial reporting may remain less visible. The central issue is whether digital and institutional progress has translated into substantive AI adoption capable of improving financial reporting transparency.

3. METHODOLOGY

3.1 Research Approach

This study adopts a qualitative, analytical, and comparative research approach to examine the relationship between Artificial Intelligence (AI) adoption and financial reporting transparency, with particular emphasis on Albania. Rather than statistically estimating causal relationships, the study synthesizes contemporary academic literature and relevant institutional and policy evidence to assess how technological, organizational, regulatory, and human-capital factors may influence the transition from digitalization to substantive AI adoption. This approach is consistent with recent research that uses systematic and structured literature reviews to examine the development, applications, benefits, and

challenges of AI in accounting and financial reporting (Astika et al., 2026; Abdo-Salloum & Chehade, 2026). The Albanian context is examined in relation to broader evidence from emerging and more digitally advanced economies, allowing the study to identify similarities, differences, and contextual constraints.

3.2 Literature Review and Evidence Selection

The analysis is based primarily on contemporary peer-reviewed literature concerning AI adoption, digital transformation, accounting, financial reporting, transparency, and emerging economies. Relevant academic studies were identified through established scholarly databases and complemented by reports and policy documents from institutions including the OECD, World Bank, INSTAT, the Bank of Albania, and other relevant national and international organizations. Priority was given to recent literature addressing AI applications, adoption determinants, financial reporting quality, digital transformation, and the challenges associated with AI implementation. Systematic literature reviews in the field were also considered in order to identify recurring themes and research gaps (Astika et al., 2026; Abdo-Salloum & Chehade, 2026).

For the Albanian case, particular attention was given to evidence concerning digital infrastructure, digital public services, enterprise digitalization, ICT skills, AI policy, financial reporting regulation, and financial-data infrastructure. This contextual evidence is important because digital transformation in Albania has progressed considerably, while the depth of AI adoption remains less clearly documented (OECD, 2024; INSTAT, 2025). The study therefore distinguishes between evidence of digital readiness and evidence of actual AI adoption.

3.3 Analytical and Comparative Framework

The selected evidence was analyzed thematically around four interconnected dimensions: (1) digital transformation and infrastructure, (2) AI readiness, including technological, organizational, human-capital, and regulatory conditions, (3) substantive AI adoption in accounting and financial reporting, and (4) potential implications for financial reporting transparency. The analysis then compares Albania with evidence from other emerging and digitally advanced economies to contextualize the country's position.

The comparative analysis does not seek to establish statistical differences between countries. Instead, it is used to identify recurring patterns and contextual relationships that may explain why high levels of digitalization do not necessarily result in equivalent levels of AI adoption. This distinction is particularly relevant in Albania, where progress in digital public services, enterprise connectivity, and digital infrastructure coexists with limitations in specialized ICT capabilities and evidence of uneven AI adoption (OECD, 2024; INSTAT, 2025; Baholli et al., 2026).

3.4 Development of the Conceptual Framework

The findings from the literature and the Albanian contextual analysis are integrated into the proposed Digital Illusion Framework. The framework conceptualizes digital transformation as a potential foundation for AI readiness, while recognizing that readiness does not necessarily lead to substantive AI adoption. Substantive adoption is subsequently considered in relation to potential improvements in financial reporting transparency, including accuracy, timeliness, reliability, accessibility, and completeness.

The framework therefore does not assume a direct or automatic relationship between digitalization and transparency. Instead, it proposes that the relationship is conditioned by technological, organizational, human-capital, and regulatory factors. The concept of Digital Illusion refers to the potential situation in which visible digital progress exceeds the actual depth of AI adoption, particularly within specialized functions such as accounting and financial reporting. The framework is consequently proposed as a conceptual basis for future empirical research rather than as a statistically tested model in the present study.

4. PROPOSED CONCEPTUAL FRAMEWORK: THE DIGITAL ILLUSION FRAMEWORK

4.1 Conceptual Rationale and Framework Structure

The reviewed evidence indicates that digital transformation and Artificial Intelligence (AI) adoption are related but distinct processes. Digital infrastructure, connectivity, e-services, and digital data provide important foundations for advanced technologies, but they do not necessarily indicate substantive AI integration. This distinction is particularly relevant to Albania, where digitalization has progressed significantly, while the depth of advanced technology adoption remains more limited (INSTAT, 2025; OECD, 2026). The proposed Digital Illusion Framework therefore conceptualizes the relationship as a gradual process: Digital Transformation → AI Readiness → Substantive AI Adoption → Financial Reporting Transparency.

Digital Transformation represents the development of digital infrastructure, e-services, connectivity, and structured financial data. AI Readiness refers to the technological, organizational, human-capital, and regulatory conditions required to move beyond basic digitalization. This distinction is supported by recent evidence showing that Albanian SMEs generally use digital tools, but their adoption remains concentrated in basic and operational applications, while skills and organizational capacity remain important constraints (OECD, 2026). Substantive AI Adoption therefore refers to the actual integration of AI into business processes, including applications such as predictive analytics, anomaly detection, intelligent automation, and natural language processing. In accounting and financial reporting, such applications may improve the processing and analysis of financial information, although

their effectiveness depends on data quality, governance, human expertise, and appropriate oversight (Astika et al., 2026; Abdo-Salloum & Chehade, 2026).

4.2 The Digital Illusion

The central concept of the framework is the Digital Illusion, defined as a situation in which visible digital progress exceeds substantive AI adoption. In Albania, the expansion of digital public services and enterprise connectivity demonstrates significant progress in digital transformation, with 99.4% of enterprises with more than 10 employees reporting Internet access for business purposes in 2025 (INSTAT, 2025). However, OECD evidence indicates that the digitalization of Albanian SMEs remains limited in depth and that more advanced technologies are less widely integrated (OECD, 2026). Therefore, visible digital development should not automatically be interpreted as evidence of AI adoption in specialized functions such as accounting and financial reporting.

Accordingly, the framework does not assume a direct progression from digital transformation to greater financial reporting transparency. Digitalization may create the conditions for AI adoption, but the potential transparency benefits depend on whether organizations possess the technological, organizational, human, and institutional capacity to integrate AI substantively. The Digital Illusion therefore represents the potential gap between visible digital progress and actual AI integration, providing the conceptual basis for examining Albania's digital transformation without assuming that digitalization has already produced AI-enabled financial reporting.

4.3 Conceptual Propositions

Based on the proposed framework, the study advances the following propositions:

P1: Digital transformation creates enabling conditions for AI adoption but does not necessarily result in substantive AI integration.

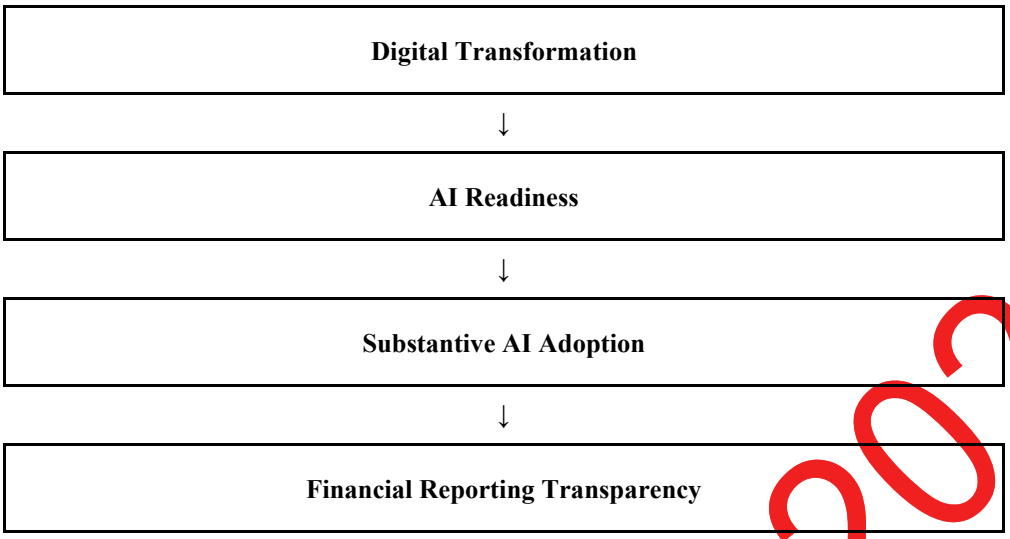
P2: AI readiness depends on technological infrastructure, organizational capabilities, human capital, and institutional and regulatory conditions.

P3: Substantive AI adoption has the potential to improve the accuracy, timeliness, reliability, and accessibility of financial reporting.

P4: The transparency benefits of AI depend on data quality, governance, explainability, and human oversight.

P5: A Digital Illusion may emerge when visible digital transformation substantially exceeds substantive AI adoption, particularly in emerging economies such as Albania.

Figure 1. The Digital Illusion Framework



Digital Illusion: Visible Digital Progress > Substantive AI Adoption

Source: Author's conceptualization based on the reviewed literature.

5. DISCUSSION

The reviewed evidence positions Albania as a useful case for examining the gap between digital transformation and substantive AI adoption. The country has achieved substantial progress in digital connectivity and public digital services; for example, 99.4% of enterprises with more than 10 employees reported Internet access for business purposes in 2025 (INSTAT, 2025). However, OECD evidence indicates that digitalization among Albanian SMEs remains largely concentrated in basic and operational applications, while more advanced technologies and digital capabilities remain less developed (OECD, 2026). This supports the central assumption of the Digital Illusion Framework: visible digital progress does not necessarily imply equivalent AI integration.

The evidence from Albania also draws attention to organizational capacity and human capital. Despite widespread connectivity, the share of enterprises employing ICT specialists remains considerably lower, while skills shortages and limited organizational capacity continue to constrain deeper digital transformation (INSTAT, 2025; OECD, 2026). Firm-level evidence further suggests that AI adoption among Albanian SMEs remains uneven, with many firms reporting no AI use and adoption often concentrated in relatively simple applications (Baholli et al., 2026). These findings indicate that access to digital technologies represents only the first stage of transformation; moving toward substantive AI adoption requires appropriate skills, data capabilities, organizational readiness, and the capacity to integrate AI into core business processes.

This distinction is especially relevant to financial reporting. AI may potentially improve the accuracy, timeliness, reliability, and efficiency of reporting through applications such as anomaly detection, predictive analysis, intelligent classification, and automated verification. However, these

benefits cannot be assumed solely from the existence of digital infrastructure or general AI use. They depend on data quality, governance, explainability, professional competence, and human oversight (Astika et al., 2026; Abdo-Salloum & Chehade, 2026). In Albania, therefore, the available evidence does not support the conclusion that digitalization has already produced substantive AI-enabled financial reporting. Rather, it indicates the existence of enabling conditions alongside important gaps in advanced adoption.

Taken together, these conditions are consistent with the proposed Digital Illusion: visible digital transformation may advance faster than substantive AI integration. This does not imply that Albania has failed in its digital transformation; rather, it suggests that digital maturity should be assessed at different levels, distinguishing infrastructure and digital services from organizational AI readiness and actual AI adoption. For policymakers and professional institutions, the findings highlight the need to complement digital infrastructure with AI and digital skills, organizational capabilities, data governance, regulatory clarity, and professional training. Future empirical research should build on this conceptual analysis by measuring AI adoption specifically within Albanian accounting and financial reporting and testing whether deeper AI integration is associated with measurable improvements in transparency.

6. CONCLUSION

This study examined the relationship between Artificial Intelligence (AI) adoption and financial reporting transparency through an analytical and comparative approach, with Albania as the central country context. Rather than statistically testing a causal relationship, the study synthesized contemporary literature and assessed Albania's technological, organizational, institutional, regulatory, and human-capital conditions.

The analysis indicates that Albania has made substantial progress in digital transformation, particularly in digital public services, enterprise connectivity, and digital infrastructure (INSTAT, 2025; OECD, 2024, 2026). However, available evidence suggests that AI adoption among Albanian businesses remains uneven and that digital connectivity does not necessarily translate into substantive AI integration (Baholli et al., 2026; OECD, 2026). This distinction is particularly relevant to specialized functions such as accounting and financial reporting.

To address this gap, the study proposes the Digital Illusion Framework, which distinguishes between digital transformation, AI readiness, substantive AI adoption, and financial reporting transparency. The framework suggests that digitalization creates enabling conditions for AI adoption, but transparency benefits depend on the depth and quality of implementation, including data quality, organizational readiness, human capital, governance, explainability, and human oversight (Astika et al., 2026; Abdo-Salloum & Chehade, 2026).

In the Albanian context, Digital Illusion refers to the possibility that visible digital progress may develop faster than substantive AI adoption within specialized professional functions. This concept does

not imply that Albania's digital transformation is superficial; rather, it highlights the need to distinguish between digital infrastructure, AI readiness, and actual AI integration.

The study contributes by connecting AI adoption, digital transformation, and financial reporting transparency within an emerging-economy context that remains relatively underexplored. Its main contribution is conceptual rather than statistical, providing a basis for future empirical research in Albania. Future studies should develop measurable indicators of AI adoption and financial reporting transparency and test the relationships proposed by the Digital Illusion Framework using firm-level data.

The Albanian case therefore indicates that the transition from digital transformation to AI-enabled financial reporting depends on more than the availability of digital infrastructure. Digital infrastructure can create the necessary foundations, but meaningful improvements in financial reporting transparency ultimately depend on whether AI is substantively integrated into organizational processes and supported by appropriate technological, organizational, institutional, and human-capital capabilities.

REFERENCES

Abdo-Salloum, A. M., & Chehade, S. (2026). The role of artificial intelligence in transforming accounting and auditing practices: A systematic review. *SAGE Open, 16*(1). https://doi.org/10.1177/21582440251403296

Astika, I. W., Sinarwati, N. K., & Purnamawati, I. G. A. (2026). Artificial intelligence in accounting and financial reporting: A systematic literature review and research agenda. *Research Horizon, 6*(3), 1399–1414. https://doi.org/10.54518/rh.6.3.2026.1132

Baholli, I., Plasari, E., & Dibra, R. (2026). Artificial intelligence adoption among small and medium-sized enterprises in Albania: Evidence from a survey study. In *2nd edition of Technology & Business Update Conference proceedings book*(pp. 337–348).

Bank of Albania. (2025, April 4). *Bank of Albania implements the new international standard of payments and financial reporting ISO 20022*.

IFAC. (2026). *Albania: Member country profile*. International Federation of Accountants.

IFRS Foundation. (2021). *Use of IFRS Standards by jurisdiction: Albania*.

INSTAT. (2025). *Usage of information and communication technologies in enterprises, 2025*. Institute of Statistics of Albania.

Miti, M. U., Çika, N., & Dhamo, S. (2018). Information of the financial statements disclosures—Case of Albania. *European Journal of Economics and Business Studies, 4*(3), 74–84. https://doi.org/10.26417/ejes.v4i3.p74-84

National Agency for Information Society. (2022). *Digital agenda of Albania 2022–2026*. Government of Albania.

OECD. (2024). *Western Balkans competitiveness outlook 2024: Albania*. OECD Publishing. https://doi.org/10.1787/541ec4e7-en

OECD. (2026). *SME policy index for Western Balkans and Türkiye 2026: Economy profile for Albania*. OECD Publishing. https://doi.org/10.1787/ab22c29c-en

Sanz Martín, L., Parra Domínguez, J., Corchado, J. M., Zafra-Gómez, E., Castillo-Ramos, V., & Zafra-Gómez, J. L. (2026). Recent evolution and growth of AI and advanced technologies in accounting and finance: Systematic review and bibliometric analysis. *Spanish Journal of Finance and Accounting/Revista Española de Financiación y Contabilidad, 55*(1), 47–88. https://doi.org/10.1080/02102412.2025.2582120

Tornatzky, L. G., Fleischer, M., & Chakrabarti, A. K. (1990). *The processes of technological innovation*. Lexington Books.

World Bank. (2019). *Albania accounting and auditing report on the observance of standards and codes (A&A ROSC)*.

World Bank. (2025). *Transforming institutions for inclusive services and human development in Albania*.

THE IMPACT OF FINANCIAL INCLUSION AND DIGITAL FINANCE ON AGRICULTURAL PRODUCTIVITY IN ALBANIA

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ABSTRACT

Agriculture remains a vital sector of the Albanian economy, contributing significantly to employment, rural livelihoods, and food security. However, limited access to financial services continues to constrain farmers' ability to invest in productive technologies, modern inputs, and risk-management tools. In recent years, the expansion of digital financial services, including mobile banking, electronic payments, and digital lending platforms, has created new opportunities to enhance financial inclusion among rural populations. This study examines the impact of financial inclusion and digital finance on agricultural productivity in Albania. Specifically, it investigates how access to formal financial services and the adoption of digital financial technologies influence farmers' production efficiency, investment decisions, and overall farm performance. Using survey data collected from Albanian farmers and employing quantitative techniques, the study analyzes the relationship between financial access, digital finance utilization, and key productivity indicators. The findings are expected to demonstrate that greater financial inclusion and the use of digital financial services positively affect agricultural productivity by facilitating access to credit, reducing transaction costs, improving financial management, and supporting investment in modern farming practices. Furthermore, the study highlights the role of digitalization in overcoming geographical and institutional barriers that have traditionally limited farmers' participation in the formal financial system.

Keywords: *Financial Inclusion, Digital Finance, Agricultural Productivity, Financial Performance*

JEL Codes: *G53, Q14, F63.*

1. INTRODUCTION

Agriculture remains one of the most important sectors of the Albanian economy, contributing significantly to employment, rural livelihoods, and food security. Despite its socio-economic importance, the sector continues to face structural constraints, including fragmented landholdings, limited access to financial services, low investment capacity, technological gaps, and vulnerability to climate-related risks. These challenges have constrained agricultural productivity and the competitiveness of Albanian farms, particularly among smallholder producers who dominate the agricultural landscape. Enhancing productivity has therefore become a strategic priority for achieving

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sustainable rural development and supporting Albania's integration into the European Union. Access to appropriate financial services has long been recognized as a key driver of agricultural development. Financial inclusion, defined as the availability and effective use of affordable financial products and services by individuals and businesses, enables farmers to mobilize savings, obtain credit, manage production risks, and invest in productivity-enhancing technologies. Improved access to finance allows agricultural producers to purchase high-quality inputs, adopt modern irrigation systems, mechanize production processes, and diversify their activities, ultimately contributing to higher yields and increased farm income. However, financial exclusion remains a persistent challenge in many developing and transition economies, where rural populations often face barriers related to geographical distance, high transaction costs, insufficient collateral, and limited financial literacy. In recent years, digital finance has emerged as a transformative instrument for expanding financial inclusion and improving the efficiency of financial service delivery. The rapid diffusion of mobile banking, digital payment systems, electronic wallets, online lending platforms, and other financial technologies (FinTech) has reduced traditional barriers to accessing financial services. Digital financial services enable faster, cheaper, and more transparent financial transactions while facilitating access to credit, insurance, savings products, and government support schemes. For agricultural producers, digital finance offers opportunities to reduce transaction costs, strengthen market participation, improve cash-flow management, and increase resilience to economic shocks. Consequently, digital finance has become an important component of sustainable agricultural transformation, particularly in developing countries where conventional banking infrastructure remains limited. The relationship between financial inclusion, digital finance, and agricultural productivity has attracted increasing attention in recent years. Existing empirical studies generally suggest that greater financial access encourages farm investment, technology adoption, and productivity growth. Likewise, digital financial services have been associated with improved resource allocation, greater market efficiency, and enhanced financial resilience among rural households. Nevertheless, empirical evidence remains mixed due to differences in institutional environments, financial infrastructure, levels of digitalization, and socio-economic characteristics across countries. Moreover, much of the existing literature focuses on large developing economies in Asia and Africa, while relatively little evidence is available for transition economies in the Western Balkans. Albania represents a particularly relevant context for investigating these relationships. Although the country has experienced considerable progress in financial sector development and digital transformation over the last decade, important disparities persist between urban and rural areas in terms of access to financial institutions and digital financial services. Small-scale farmers continue to rely heavily on informal financing, while the adoption of digital banking and electronic payment systems remains uneven across agricultural regions. Understanding whether improved financial inclusion and digital finance contribute to agricultural productivity is therefore essential for designing effective rural development policies and strengthening the resilience and competitiveness of the Albanian agricultural sector. This study addresses this research gap by examining the impact of financial inclusion and digital finance on

agricultural productivity in Albania. Using primary survey data collected from 207 farmers across the regions of Korçë and Divjakë, the study investigates how access to financial services, the use of digital financial instruments, and farmers' financial capabilities influence agricultural performance. Unlike previous studies that primarily examine financial inclusion in isolation, this research jointly considers traditional financial access and digital financial services within a unified analytical framework. By doing so, it provides a more comprehensive understanding of the mechanisms through which financial development influences agricultural productivity in a transition economy. The findings of this research contribute to both the academic literature and policy discussions. From a theoretical perspective, the study expands existing evidence on the role of inclusive and digital financial systems in promoting agricultural development within emerging economies. From a practical perspective, the results provide valuable insights for policymakers, financial institutions, and development agencies seeking to design policies that enhance financial inclusion, promote digital financial innovation, and improve agricultural productivity in Albania. Ultimately, strengthening financial inclusion and accelerating the adoption of digital financial services can play a crucial role in fostering sustainable agricultural growth, increasing rural incomes, and supporting long-term economic development.

2. LITERATURE REVIEW

When Financial inclusion has become a central pillar of sustainable development and inclusive economic growth, particularly in developing and transition economies where agriculture remains an important source of employment and income (World Bank, 2022). It refers to the availability, accessibility, and effective use of affordable financial products and services, including savings, credit, insurance, and payment systems, provided in a responsible and sustainable manner. Financial inclusion enables farmers to mobilize financial resources, invest in productive assets, manage risks, and improve household welfare. Several theoretical perspectives explain the relationship between financial inclusion and agricultural productivity. According to the credit constraint theory, farmers with limited access to formal financial services are unable to invest optimally in agricultural production because of liquidity shortages (Stiglitz & Weiss, 1981). Similarly, financial intermediation theory argues that efficient financial markets facilitate capital allocation toward productive investments, thereby stimulating economic growth and agricultural modernization (Levine, 2005). Empirical evidence generally supports these theoretical arguments. Awotide et al. (2015) found that access to formal credit significantly increased cassava productivity among Nigerian smallholder farmers by facilitating investment in improved inputs and production technologies. Similarly, Kumar et al. (2023) concluded that financial inclusion contributes to agricultural growth through increased access to agricultural loans, savings products, and insurance services. Financial services reduce production risks, improve capital accumulation, and enable farmers to adopt modern technologies that increase productivity. Recent literature also recognizes that financial inclusion extends beyond access to credit. Comprehensive financial inclusion includes payment systems, savings instruments, agricultural insurance, and financial

advisory services, all of which strengthen farmers' resilience against market and climate shocks while supporting long-term agricultural development (Aggarwal et al., 2026). Digital finance has transformed financial service delivery by integrating financial products with digital technologies such as mobile banking, electronic payments, digital wallets, online lending platforms, and financial technology (FinTech). Digital financial services significantly reduce transaction costs, improve accessibility, enhance transparency, and facilitate financial inclusion among previously underserved populations (Ozili, 2018). The agricultural sector has particularly benefited from digital financial innovation because rural populations traditionally face geographical and institutional barriers to accessing formal financial institutions. Mobile financial services allow farmers to receive payments, purchase agricultural inputs, access credit remotely, and participate more efficiently in agricultural markets. Several empirical studies demonstrate the positive effects of digital finance on agricultural productivity. Zhang et al. (2025) reported that digital financial inclusion promotes agricultural productivity primarily by alleviating credit constraints and facilitating access to both formal and informal financial services. Digital financial services also improve resource allocation and encourage the development of family farms and agricultural enterprises. Similarly, Kitoto (2024), analysing panel data from eighteen Sub-Saharan African countries, concluded that digital financial inclusion significantly increases agricultural productivity through wider adoption of mobile financial services. The study emphasizes that digital payment systems and mobile money facilitate investment decisions and improve production efficiency by reducing transaction costs. Despite these benefits, digital finance adoption remains constrained by limited digital infrastructure, inadequate internet coverage, low digital literacy, cybersecurity concerns, and unequal access to smartphones, particularly in rural areas. These challenges continue to limit the potential benefits of digital financial services in many developing economies (Akzar et al., 2024). Recent literature increasingly views financial inclusion and digital finance as complementary rather than independent drivers of agricultural productivity. Financial inclusion expands farmers' access to financial resources, whereas digital finance enhances the efficiency, affordability, and accessibility of those services. Together, these mechanisms improve investment decisions, reduce financing costs, and strengthen farmers' resilience against production risks. Research suggests several mechanisms through which financial inclusion and digital finance influence agricultural productivity. First, improved access to credit enables farmers to purchase machinery, irrigation systems, fertilizers, improved seeds, and other productivity-enhancing inputs. Second, savings products facilitate capital accumulation and improve financial resilience during adverse production seasons. Third, agricultural insurance encourages investment in higher-value agricultural activities by reducing production uncertainty. Finally, digital financial services reduce transaction costs, improve market access, and facilitate participation in agricultural value chains (Aggarwal et al., 2026). Studies from China further indicate that digital finance indirectly increases agricultural productivity by promoting technological innovation, improving financial accessibility, and stimulating regional economic development (Chen et al., 2025). However, empirical findings remain heterogeneous across countries because the effectiveness of

financial inclusion depends on institutional quality, financial infrastructure, digital readiness, education levels, and public policy support. Consequently, country-specific evidence remains essential for understanding how financial inclusion affects agricultural performance. Although research on financial inclusion has expanded considerably in Albania during the past decade, empirical studies focusing specifically on agriculture remain relatively limited. Albanian agriculture is characterized by fragmented landholdings, limited collateral availability, relatively low financial literacy, and restricted access to formal financial institutions. These structural characteristics limit farmers' investment capacity and constrain agricultural productivity. Recent evidence from Albania indicates that financial literacy is one of the strongest determinants of financial inclusion among farmers. Using survey data from 207 farmers in Korçë and Divjakë, (Gjoni et al., 2026) found that financially literate farmers exhibit significantly higher levels of financial inclusion and greater use of formal financial services. Complementary research based on interviews with financial institutions demonstrates that limited availability of specialized agricultural financial products and conservative lending practices continue to restrict farmers' access to finance in Albania. The authors argue that stronger cooperation between financial institutions and agricultural producers is necessary to improve financial inclusion and promote sustainable agricultural development (Gjoni et al., 2026). At the regional level, Gashi and Jupe (2025) reviewed evidence from the Western Balkans and concluded that inadequate agricultural financing, land fragmentation, institutional weaknesses, and limited investment remain the principal barriers to productivity growth. The review emphasizes that strengthening financial inclusion and expanding digital financial services should become strategic priorities for agricultural policy across the region. Nevertheless, empirical evidence examining the combined impact of financial inclusion and digital finance on agricultural productivity in Albania remains scarce. Most existing studies investigate financial literacy, access to finance, or institutional barriers separately, while few simultane The existing literature clearly demonstrates that financial inclusion and digital finance contribute to agricultural development by reducing financial constraints, facilitating investment, and promoting technological adoption. Nevertheless, three important research gaps remain. First, most empirical studies analyse financial inclusion and digital finance independently, despite their complementary roles in improving agricultural performance. Second, evidence from transition economies, particularly the Western Balkans, remains considerably more limited than that from Asia and Sub-Saharan Africa. Third, within the Albanian context, there is little empirical evidence examining the direct relationship between financial inclusion, digital finance, and agricultural productivity at the farm level. This study addresses these gaps by analysing primary survey data collected from 207 farmers in the Korçë and Divjakë regions of Albania. It develops an integrated framework that simultaneously examines financial inclusion and digital finance as determinants of agricultural productivity, thereby contributing new evidence to the literature on sustainable agricultural development in transition economies.

3. RESULTS

The survey findings indicate that financial inclusion among Albanian farmers remains moderate, while the adoption of digital financial services is still at an early stage. Most respondents reported having access to at least one formal financial service, primarily a bank account. However, the use of more sophisticated financial products, such as agricultural insurance, digital lending platforms, and electronic payment systems, remained relatively limited. The majority of farmers continued to rely on traditional banking services and cash transactions for their agricultural activities. Mobile banking was the most frequently used digital financial service, whereas internet banking, electronic wallets, and online agricultural payment systems were adopted by a considerably smaller proportion of respondents. These findings suggest that although digital financial infrastructure has expanded in Albania, significant barriers remain to the widespread adoption of digital finance in rural areas. Regarding farm characteristics, most respondents operated small- and medium-sized farms, reflecting the fragmented structure of Albanian agriculture. Farmers with higher educational attainment generally demonstrated greater use of formal financial services and digital financial applications than those with lower levels of education. The OLS regression results indicate that financial inclusion has a positive and statistically significant effect on agricultural productivity. Farmers with greater access to formal financial services reported higher levels of agricultural performance, suggesting that access to credit, savings, and other financial products facilitates investment in productive agricultural inputs and technologies. Similarly, digital finance exhibits a positive association with agricultural productivity. Farmers using digital financial services—including mobile banking and electronic payment systems—were more likely to report improvements in farm management, reduced transaction costs, and greater efficiency in financial operations. Digital financial services also appeared to facilitate faster access to financial resources and improve interactions with financial institutions. Among the control variables, education was positively associated with agricultural productivity, indicating that more educated farmers are better able to utilize financial resources and adopt improved agricultural technologies. In contrast, farming experience exhibited a weaker relationship with productivity, suggesting that experience alone may not compensate for limited financial access or technological adoption. Farm income showed a positive but relatively modest contribution to productivity, while farm size and regional location displayed limited statistical significance. Overall, the regression model supports the hypothesis that both financial inclusion and digital finance contribute positively to agricultural productivity. These findings reinforce the argument that improving farmers' access to formal financial services and promoting the adoption of digital financial technologies can enhance investment capacity, increase production efficiency, and strengthen the competitiveness of Albanian agriculture.

4. METHODOLOGY

This study employs a quantitative research design to examine the relationship between financial inclusion, digital finance, and agricultural productivity in Albania. Primary data were collected through a structured questionnaire administered to 207 farmers operating in the agricultural regions of Korçë

and Divjakë. These regions were selected because they represent two of the country's most important agricultural production areas, characterized by diverse farming activities, including crop cultivation, horticulture, and livestock production. The survey was conducted through face-to-face interviews between year 2025 and 2026. Farmers were selected using a purposive sampling approach, ensuring that respondents were actively engaged in agricultural production. Participation was voluntary, and respondents were informed about the confidentiality and anonymity of their responses. The questionnaire consisted of four sections. The first collected demographic and farm characteristics, including age, gender, education, farming experience, farm size, and annual agricultural income. The second assessed financial inclusion by examining farmers' access to bank accounts, formal credit, savings products, insurance, and other financial services. The third section evaluated the adoption of digital financial services, including mobile banking, internet banking, digital payments, and electronic money transfers. The final section measured agricultural productivity through indicators related to production performance, investment, technology adoption, and perceived improvements in farm efficiency. Data were analysed using the Statistical Package for the Social Sciences. Descriptive statistics were first used to summarize the characteristics of the respondents and their level of financial inclusion and digital finance adoption. Subsequently, Ordinary Least Squares (OLS) regression analysis was employed to estimate the effect of financial inclusion and digital finance on agricultural productivity while controlling for farmers' socio-economic characteristics, including education, farming experience, farm size, income, and geographical location. Agricultural productivity was specified as the dependent variable, while financial inclusion and digital finance represented the principal explanatory variables. Education, farming experience, annual income, farm size, and region were included as control variables to account for structural differences among farms.

5. CONCLUSION

The results are consistent with previous studies demonstrating that financial inclusion reduces liquidity constraints and enables farmers to invest in productivity-enhancing technologies (Levine, 2005; Ozili, 2018). Likewise, the positive contribution of digital finance supports recent evidence indicating that digital financial services improve financial accessibility, reduce transaction costs, and facilitate participation in agricultural value chains (Zhang et al., 2025). For Albania, the findings suggest that expanding digital financial infrastructure should complement traditional agricultural finance policies. Strengthening financial literacy, increasing access to digital banking services, and developing financial products tailored to agricultural producers could significantly improve agricultural productivity and contribute to sustainable rural development.

REFERENCES

Aggarwal, V., Walz, M., & Guenther, E. (2026). Financial inclusion for smallholders: Integrating a resource nexus approach into agricultural finance systems. *Sustainable Development*. https://doi.org/10.1002/sd.71118

Akzar, R., Peralta, A., & Tang, W. D. (2024). Impacts of digital financial services in agriculture: A systematic literature review. *Proceedings of the Australasian Agricultural and Resource Economics Society Conference*.

Awotide, B. A., Abdoulaye, T., Alene, A., & Manyong, V. M. (2015). Impact of access to credit on agricultural productivity: Evidence from smallholder cassava farmers in Nigeria. *International Conference of Agricultural Economists*.

Gashi, F., & Jupe, A. (2025). Agricultural financing and farm productivity in the Western Balkans: A systematic review and lessons for Kosovo. *Albanian Journal of Agricultural Sciences, 24*(1), 1–10.

Gjoni, A., Fejzaj, E., Pomianek, I., & Muça Dashi, E. (2026a). The impact of financial literacy on financial inclusion among farmers in Albania. *Annals of the Polish Association of Agricultural and Gribusiness Economists, 28*(2), 69–83.

Gjoni, A., Fejzaj, E., Muça Dashi, E., Mullaymeri, X., Uku, S., Nakuçi, S., & Fortuzi, S. (2026b). The impact of financial institutions and services on the financial inclusion of farmers and the sustainability of agricultural farms in Albania. *International Journal of Ecosystems and Ecology Science, 16*(1), 207–214.

Kitoto, P. A. O. (2024). Inclusion financière numérique et productivité agricole. *Revue Internationale des Études du Développement, 254*, 89–116.

Levine, R. (2005). Finance and growth: Theory and evidence. In P. Aghion & S. Durlauf (Eds.), *Handbook of economic growth* (Vol. 1, pp. 865–934). Elsevier.

Ozili, P. K. (2018). Impact of digital finance on financial inclusion and stability. *Borsa Istanbul Review, 18*(4), 329–340.

Stiglitz, J. E., & Weiss, A. (1981). Credit rationing in markets with imperfect information. *American Economic Review, 71*(3), 393–410.

World Bank. (2022). *World development report 2022: Finance for an equitable recovery*.

Zhang, L., Azam, S. M. F., & Tham, J. (2025). Impact of digital inclusive finance on the high-quality development of rural economy: Evidence from China. *Research on World Agricultural Economy, 6*(2), 192–210. https://doi.org/10.36956/rwae.v6i2.1630

EXCHANGE RATE AND STOCK MARKET – A COMPREHENSVE LITERATURE[1]

(2022–2026)

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ABSTRACT

The complex interaction connecting currency market fluctuations to local stock pricing remains an enduring dilemma within financial economics. This is especially true for developing nations with deep-seated import reliance, as clarifying these linkages is essential to understanding how currency volatility cascades through macroeconomic systems and influences capital allocation. To explore this, the study traces how exchange rate shifts—specifically the Turkish Lira against the US Dollar and Euro—propagate into Turkey's stock market, focusing on how the BIST All Shares Index performed throughout the highly volatile 2022–2026 era. Grounded in established macro-financial theories, this assessment contrasts two primary frameworks: the model centered on flow-orientation, which argues that currency fluctuations alter stock values by reshaping trade competitiveness, and the portfolio-balance hypothesis, which suggests that equity investments naturally generate demand for the currency. Although existing academic research thoroughly documents these dynamics during prior crises, there remains a distinct analytical void regarding the 2022–2026 period. This interval is highly unusual, characterized by profound institutional reorganization, runaway inflation, and swift shifts toward orthodox monetary policy. To resolve this empirical gap, the study provides a thematic synthesis of literature. Rather than employing econometric calculations, it synthesizes current conceptual models of directional influence, asymmetric shock transmission, and causal directionality, mapping how distinct economic sectors respond. By reconciling divergent theoretical arguments, this synthesis outlines the primary pathways through which exchange rate volatility interacts with domestic market trust. Ultimately, this systematic overview provides vital conceptual and operational insights for managing systemic hazards, designing international investment portfolios, and calibrating monetary policy in high-inflation developing economies navigating structural transformations.

Keywords: *Emerging Economies, Exchange Rate, Portfolio-Balance Hypothesis, Stock Market.*

JEL Codes: *F31, C58, C32.*

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1. INTRODUCTION

The structural transmissions, dynamic interactions, and feedback mechanisms between foreign exchange regimes and equity markets represent a principal area of inquiry within modern financial economics. For an open emerging economy like Türkiye, evaluating how currency shocks affect stock returns is of vital importance. The interaction between these asset classes shapes macroeconomic stability, investment behaviors, and the transmission of central bank monetary policy. This chapter develops a systematic, theoretically grounded literature review, focusing on the Borsa Istanbul All Shares Index (XUTUM) to provide a comprehensive, market-wide assessment of equity-side responses to currency fluctuations in the Turkish financial landscape.

The empirical investigation is contextualized within the volatile macroeconomic timeframe of 2022 to 2026. This period features intense transitions in Turkish monetary policy, global inflationary pressures, and severe exchange rate oscillations in the USD/TRY and Euro/TRY pairs. To analyze these interactions, the study employs the Generalized Autoregressive Conditional Heteroskedasticity with Dynamic Conditional Correlation (GARCH-DCC) framework. This advanced econometric model is essential for distinguishing short-run transitory volatility spillovers from persistent, long-run cointegrated equilibrium relationships within the Turkish financial landscape.

To prevent descriptive fragmentation, the literature is organized thematically rather than chronologically. Reviewed studies are grouped according to theoretical paradigms, causality directions, cointegration evidence, and the presence of volatility transmission between foreign exchange and stock markets. This thematic structure permits a rigorous synthesis of the literature, highlighting consistent historical trends, identifying empirical contradictions, and locating unresolved research gaps. Ultimately, this review establishes an empirical foundation for assessing the transmission of currency shocks onto the BIST All Shares (XUTUM) index during the highly turbulent 2022–2026 window.

2. SELECTION RATIONALE: THE BIST ALL SHARES (XUTUM) INDEX, GARCH-DCC, AND THE 2022–2026 PERIOD

In financial econometrics, the selection of the benchmark index, econometric framework, and observation period is critical to model validity. This study leverages a synergistic triad: the BIST All Shares (XUTUM) Index, the GARCH-DCC methodology, and the 2022–2026 period. Preliminary diagnostics confirm that this triad possesses exceptional structural compatibility, enabling a highly reliable analysis of exchange rate volatility transmissions in Türkiye.

Furthermore, multivariate GARCH models require broad-based equity aggregates for parameter consistency and statistical efficiency. The BIST All Shares (XUTUM) Index serves as an exceptional proxy for the Turkish equity market, integrating a highly diversified set of publicly traded corporations across various sectors and market capitalizations. Unlike narrow sector indices that are susceptible to idiosyncratic shocks, the XUTUM index captures systemic risk and generalized market fluctuations.

This comprehensive structure mathematically bolsters the parameter consistency and explanatory power of the DCC framework.

Concurrently, the confluence of daily data and the broad-based index minimizes standard errors, reinforcing the predictive robustness of modeled volatility forecasts. The high-frequency sampling provides sufficient data points to ensure maximum likelihood convergence, while the index's diversification filters out asset-specific noise, allowing the model to focus on macro-level systematic linkages. Consequently, this precise alignment establishes a mathematically stable, empirically defensible framework for analyzing currency contagion in Türkiye.

3. THEORETICAL FRAMEWORK: EXCHANGE RATE VOLATILITY AND STOCK MARKETS

The dynamic relationship between foreign exchange and equity markets is a central pillar of financial economics. For an emerging market like Türkiye, which is heavily integrated into global trade and capital flows, understanding how currency shocks transmit to stock prices is of paramount importance. This review is anchored in the foundational contributions of eight pioneering scholars: Irving Fisher, John Maynard Keynes, Eugene Fama, Harry Markowitz, James Tobin, Rudiger Dornbusch, Robert Engle, and Clive Granger. By synthesizing their frameworks, we construct a comprehensive conceptual foundation that explains the macroeconomic linkages, portfolio reallocations, and econometric methodologies required to evaluate volatility transmission in Türkiye.

The literature conceptualizes the exchange rate-stock market relationship through several competing models: the Flow-Oriented (Traditional) Approach, the Stock-Oriented (Portfolio Balance) Approach, the Arbitrage Pricing Theory (APT), and the Asset Market Model. The Flow-Oriented Theory, articulated by Dornbusch and Fischer (1980), argues that exchange rates drive stock prices through current account and trade balance channels. Exchange rate movements alter firm competitiveness, production costs, and export profit margins, which are subsequently capitalized into stock returns. Currency depreciation enhances export competitiveness and export revenues in local currency terms, but in net-importing and import-dependent developing economies like Türkiye, depreciation elevates imported intermediate and raw material costs, compressing corporate margins and depressing stock prices.

Conversely, the Stock-Oriented (Portfolio Balance) Model, associated with Branson et al. (1977), Branson (1983), and Frankel (1983), reverses this causality direction, focusing on capital accounts and portfolio reallocations. Rising domestic stock prices attract foreign portfolio inflows, increasing demand for the local currency and causing appreciation. Declining equity returns trigger capital outflows, as global portfolio managers liquidate holdings and convert capital back to foreign denominations, causing currency depreciation. Additionally, the Arbitrage Pricing Theory (APT) treats exchange rates, interest rates, and inflation as co-determining systematic risk factors, whereas the Asset Market Model of

Frenkel (1976) treats the exchange rate as an asset price driven by independent expectations. Empirical findings for Türkiye reflect this theoretical ambiguity. Studies such as Çığır (2023) and Gasimova (2021) find evidence consistent with the Flow-Oriented Approach, where currency depreciation has a positive impact on stock indices. In contrast, Demir (2020) and Yurttançıkmaz (2012) document a negative relationship, aligning with the Portfolio Balance model and highlighting the adverse cost-push effects of depreciation in an import-dependent economic structure.

Table 1. Theoretical Frameworks and Transmission Channels Linking Exchange Rate Volatility to Equity Valuations

Theoretical Approach	Direction of Causality	Core Mechanism	Expected Stock Market Response
Flow-Oriented (Traditional)	Exchange Rate → Stock Prices	Trade Competitiveness, Cash Flows, Input Costs	Depreciation (+/-), Appreciation (-/+)
Portfolio Balance (Stock)	Stock Prices → Exchange Rate	Capital Accounts, Global Portfolio Rebalancing	Equity Boom → Lira Appreciation
Monetary/Financial Channel	Bidirectional (Exchange Rate ↔ Stock)	Balance Sheet Exposure, Financial Frictions	Volatility Amplification & Contagion
Nonlinear & Asymmetric	State-Dependent / Regime-Specific	Risk Perception, Systemic Policy Uncertainty	Asymmetric, State-Dependent Responses

3.1. Macroeconomic and Econometric Contributions of Key Scholars

Irving Fisher established that nominal interest rates adjust to expected inflation differentials, maintaining real interest rate parity. In the Turkish context from 2022 to 2026, Fisher's framework is critical. Because the USD/TRY and EUR/TRY exchange rates are driven by inflation and interest rate differentials between Türkiye and global economies, Fisher's theory shows that domestic monetary policy shifts alter the discount rates applied to corporate cash flows, immediately repricing the BIST All Shares (XUTUM) index.

While Fisher provided the rational equilibrium for interest rates and inflation, John Maynard Keynes introduced systemic uncertainty, employment, and investor psychology. Keynes argued that financial markets are driven by the expectations, risk appetites, and "animal spirits" of economic agents. In evaluating Turkish Lira and BIST volatility, Keynesian uncertainty explains why markets frequently overreact to macroeconomic shocks. During the 2022–2026 window of intense policy transition, currency instability heightens systemic uncertainty, prompting investors to demand larger risk premiums and triggering capital flight, which simultaneously drives down stock prices and depreciates the local currency.

Eugene Fama's Efficient Market Hypothesis (EMH) provides the mechanism through which macroeconomic shocks are rapidly assimilated into asset valuations. Fama argued that stock prices reflect all available, relevant market information, acting as unbiased estimates of expected corporate profitability. For the BIST All Shares (XUTUM) index, which contains the most liquid and large-cap Turkish firms, EMH dictates that stock prices adjust rapidly and continuously to daily fluctuations in the USD/TRY and EUR/TRY exchange rates. A sudden exchange rate shock—such as Lira depreciation—is immediately evaluated by rational investors who re-examine corporate balance sheets and future cash flows, driving the index to a new equilibrium. High-frequency daily data is essential to capture this rapid adjustment, which would be smoothed out and lost in low-frequency monthly observations.

Harry Markowitz formalized Modern Portfolio Theory (MPT), proving that rational investors construct optimal portfolios that maximize expected returns for a given level of risk (variance) by diversifying across assets with imperfect correlations. Under MPT, exchange rate volatility is a critical systematic risk factor that alters the efficient frontier for international portfolio managers. Because foreign investors evaluate their Turkish equity returns in USD or Euro terms, elevated volatility in the Lira introduces severe currency risk. To maintain their portfolio's optimal risk profile, managers must either demand higher equity returns or liquidate their BIST holdings, linking currency turbulence directly to stock market sell-offs.

James Tobin expanded portfolio theory into macroeconomics through his Liquidity Preference framework and the Portfolio Balance Theory, modeling how wealth is distributed among money, risk-free assets, and risky equities. Under Tobin's framework, causality often flows from the stock market to the exchange rate. A booming BIST All Shares (XUTUM) attracts foreign capital inflows, increasing demand for the Turkish Lira and causing exchange rate appreciation. Conversely, when equity risk rises, investors liquidate holdings and convert wealth back to foreign exchange, causing the Lira to depreciate, proving that the currency and stock markets are bound in a continuous capital rebalancing feedback loop.

While portfolio models focus on the capital account, Rudiger Dornbusch provided the definitive framework for the current account transmission. Dornbusch's Flow-Oriented approach models how exchange rate fluctuations alter trade balances and export competitiveness. This theory explains the differential impacts of USD/TRY and EUR/TRY on the BIST All Shares (XUTUM) index. For export-oriented firms (predominantly exporting to the Eurozone), Lira depreciation against the Euro (rising EUR/TRY) inflates export revenues and boosts stock prices. In contrast, for firms reliant on imported raw material and energy inputs (typically priced in USD), Lira depreciation against the Dollar (rising USD/TRY) drives up input costs, compressing margins and depressing stock returns. Furthermore, Dornbusch's work on expectations and 'overshooting' explains why short-term asset prices display excessive volatility in response to sudden monetary policy adjustments.

Empirically measuring these theoretical transmission channels requires advanced time-series econometrics. Clive Granger fundamentally altered the field by formulating the concepts of cointegration and Granger causality. Before Granger, empirical research often suffered from 'spurious regression' when evaluating non-stationary variables. Granger's cointegration tests allow researchers to determine if the BIST All Shares (XUTUM) and exchange rates share a genuine, long-run equilibrium despite short-run transitory deviations, while Granger causality tests identify the direction of informational flow, showing whether shocks originate in the currency market (Flow-Oriented) or the stock market (Portfolio Balance).

However, measuring causality depends on modeling conditional volatility. Financial time series exhibit volatility clustering, violating the constant variance assumption of linear models. Robert Engle pioneered the Autoregressive Conditional Heteroskedasticity (ARCH) methodology, modeling variance as a time-varying condition dependent on past shocks. For cross-market risk transmission, univariate models are insufficient, leading Engle to develop the Dynamic Conditional Correlation (DCC) GARCH framework. The DCC model allows the correlation between the XUTUM and exchange rates to fluctuate continuously over time, capturing how market integration intensifies during policy shifts and crises.

A rigorous literature review must synthesize these isolated theories into a cohesive argument.

4. EMPIRICAL EVIDENCE: TURKISH AND GLOBAL PERSPECTIVES

The international empirical literature examining foreign exchange and stock market interactions in emerging markets documents significant but heterogeneous volatility spillovers and cross-market integration.

The empirical literature focusing on Türkiye presents a rich and multifaceted body of evidence.

A key recurring finding is the dominance of the USD/TRY exchange rate over the Euro/TRY parity in explaining stock market movements.

At the sector level, Yılmaz and Güzel (2021) provided a critical currency distinction using Panel GMM.

Additionally, sectoral input structures and firm-level hedging mechanisms play a decisive role.

4.1. Empirical Studies on Emerging Markets

The structural and dynamic interdependence between foreign exchange and stock markets is a core research area within emerging market financial economics. Emerging market economies are characterized by high capital mobility, chronic current account imbalances, and frequent exposure to external and domestic shocks. Within this context, Türkiye represents a critical and illustrative case due to its floating exchange rate regime, high level of liability dollarization, and structural reliance on foreign

capital. Since the early 2000s, Borsa Istanbul—particularly the BIST All Shares (XUTUM) index—has exhibited intense sensitivity to Lira fluctuations against the USD and Euro.

Table 2. Comparative Synthesis of International Methodological Approaches and Cross-Market Linkages

Author(s) / Year	Market Context	Methodology	Core Empirical Findings
Bekaert & Harvey (1995)	20 Emerging Markets	Time-varying integration	Partial segmentation; market-wide crisis sensitivity.
Kanas (2000)	Emerging Markets	EGARCH Model	Unidirectional volatility spillovers from FX to Stock.
Carrieri et al. (2007)	Emerging Markets	Conditional ICAPM	Exchange rate risk is actively priced in equity returns.
Aydemir & Demirhan (2009)	Türkiye	Toda-Yamamoto	Bidirectional causality with negative stock response.
Reboredo et al. (2016)	Emerging Markets	Copula-CoVaR	Downside risk spillovers dominate upside risk.
Çevik (2024)	Türkiye	Johansen / VECM	Exchange rates drive inflation; BIST acts as inflation hedge.

Empirical findings across emerging markets reveal substantial heterogeneity. Research on BRICS, E7, and ASEAN economies documents positive, negative, or bidirectional linkages depending on financial depth and economic structure. Studies supporting the flow-oriented model are common in export-driven economies where currency stability supports equity earnings, while research in markets like Malaysia and the Philippines often identifies negative correlations consistent with the portfolio balance approach. Recent empirical studies increasingly employ non-linear, regime-switching, and quantile-based approaches. Markov-switching models demonstrate that the currency-equity relationship intensifies during high-volatility regimes, and Copula-CoVaR analyses reveal that downside risk spillovers consistently dominate upside spillovers, validating the presence of leverage effects and flight-to-safety behavior during global crises.

Historically, early studies such as Bekaert and Harvey (1995) documented limited integration and partial segmentation in 20 emerging markets, noting that liberalization increased comovement but did not eliminate idiosyncratic risks. Subsequently, researchers integrated volatility transmission. Kanas (2000), using EGARCH models, identified unidirectional volatility spillovers from exchange rates to stock returns during turbulent periods. Carrieri et al. (2007), using a conditional ICAPM, demonstrated that exchange rate risk is actively priced in emerging equity returns, unlike in developed markets. More recently, Bahmani-Oskooee and Saha (2015) applied panel NARDL models, identifying asymmetric

stock responses to currency fluctuations and proving that methodological advancements are essential to capture the complex, state-dependent dynamics of emerging markets.

5. SHORT-RUN AND LONG-RUN DYNAMICS OF CURRENCY SHOCKS IN TURKIYE

The short-run impact of currency fluctuations on Borsa Istanbul's benchmark index (BIST All Shares - XUTUM) remains a highly contested issue in the Turkish financial literature. Empirical findings vary based on the theoretical framework, econometric design, observation period, and sectoral composition. In contrast to stable long-run cointegrated comovements, short-run dynamics are characterized by asymmetry, state dependency, and frequent statistical insignificance, reflecting the structural complexity of the Turkish economy.

Two primary paradigms shape this debate. The Flow-Oriented (Traditional) Model, originally developed by Dornbusch and Fischer (1980), suggests that appreciation harms export-oriented sectors by reducing international price competitiveness, depressing stock prices. Conversely, the Portfolio Balance (Stock-Oriented) Model of Branson et al. (1977) and Branson (1983) posits that causality runs from stock returns to exchange rates, where a strong currency signals macroeconomic stability, policy credibility, and investor confidence. A third perspective, the Asset Market Approach, suggests that the currency-equity relationship may be weak or driven by independent fundamentals.

A major body of research finds that appreciation exerts a negative or insignificant short-run impact. NARDL studies by Çakır (2021, 2022) demonstrate that positive currency shocks (Lira appreciation) have a statistically significant negative short-run impact on XUTUM and BIST-30 returns, reflecting immediate losses in trade competitiveness. Similarly, Ceylan and Ceylan (2023), using panel NARDL for the Fragile Five, show that appreciation negatively impacts stock returns due to export competitiveness loss, and Çığır (2023) and Gasimova (2021) document positive correlations with USD/TRY, implying that Lira appreciation dampens returns. Other studies find no statistically significant impact, suggesting that imported input advantages and competitive disadvantages offset each other at the aggregate index level. Kartal et al. (2022), using Markov Switching Regression, show that exchange rate movements are insignificant in low-volatility regimes, becoming influential only during turbulent periods.

In contrast, several studies identify a positive short-run effect of currency appreciation on stock returns, driven by cost-reduction and investor confidence. Agrawal (2010) and Yau and Nieh (2006) argue that in import-dependent economies like Türkiye—where approximately 75% of imports are USD-denominated intermediate goods—Lira appreciation significantly lowers production costs, boosting corporate profit margins and stock returns. El-Diftar (2023), examining E7 economies, finds that currency appreciation is perceived positively by global investors, attracting foreign capital. Mechri et al. (2018) similarly show that exchange rate stability supports returns by mitigating macroeconomic uncertainty. Yurttançıkmaz (2012), Gençtürk (2009), and Belen and Karamelikli (2016) also document

negative relationships between exchange rate levels and BIST returns, implying that appreciation stimulates equity markets, while Alimi and Adediran (2023) note that under high inflation and systemic uncertainty, stock prices and exchange rates may move in the same direction.

Regarding short-run depreciation, the dominant empirical consensus converges on a highly significant, negative short-run impact of currency depreciation on BIST All Shares (XUTUM) returns. This is primarily driven by the cost-push channel of Türkiye's import-dependent production structure. Early studies by Aktaş et al. (2018) and Belen and Karamelikli (2016) show that exchange rate shocks immediately suppress stock returns, and Aydemir and Demirhan (2009) find negative causal effects from the exchange rate to all major BIST indices. More recent studies reinforce this: Çakır (2020, 2021, 2022) finds significant short-run negative impacts of depreciation, and Bulut and Şimşek (2023) find that during the pandemic, depreciation systematically undermined stock performance. Beyond mean returns, depreciation significantly enhances conditional volatility. Guler (2020), employing a BAQ-GARCH model, and Öztürk (2007) demonstrate a pronounced leverage effect, where depreciation (representing bad news) increases stock volatility far more than appreciation. This volatility clustering is highly persistent (Polat, 2022; Altun, 2020), though Sensoy and Sobaci (2014) show that crisis-induced correlation spikes are temporary.

Short-run depreciation pressures typically persist for approximately one month before partial stabilization occurs (Kartal et al., 2022), and their impact is highly regime-dependent (Gokmenoglu et al., 2021). Sectorally, Doğukanlı et al. (2010) find the Services sector is highly sensitive, while Kasman (2003) reports unidirectional causality from exchange rates to the Industrial index. Demir (2022) finds that industrial sub-sectors exhibit highly negative exposures to USD and Euro shocks, and Yılmaz and Güzel (2021) highlight that USD depreciation negatively affects stock indices while Euro depreciation has different impacts. Methodologically, there is strong convergence: variables are non-stationary at levels and stationary at first differences, I(1), necessitating cointegration and VECM econometric frameworks.

5.1. Long-Run Effects of Currency Shocks

The long-run relationship between exchange rates and the BIST All Shares (XUTUM) is a central question in Turkish financial economics. The prevailing conclusion is that currency appreciation is associated with higher long-run stock returns, driven by reduced import costs and improved corporate profitability. Çakır (2020, 2021) shows that long-run appreciation positively affects XUTUM and BIST-30 indices, attributing this to Türkiye's net-importing manufacturing structure. El-Diftar (2023) corroborates this for E7 countries, arguing that appreciation signals policy credibility and macroeconomic stability, which attracts foreign portfolio inflows. Cointegration-based studies (Akel and Gazel, 2014; Yılmaz, 2006; Kasman, 2003; Acikalin et al., 2008) identify stable, long-run equilibrium relationships, indicating that both markets share a common stochastic trend.

However, some studies fail to identify long-run cointegration or find that appreciation harms export-oriented sectors by reducing price competitiveness. Bahmani-Oskooee and Domac (1997), İşcan (2011), and Benli (2015) find no stable long-run relationship, concluding that the interaction is predominantly short-term and shock-driven, while Eyüboğlu and Eyüboğlu (2018) show that appreciation negatively affects export-intensive sectors like textiles. Sectoral heterogeneity and exchange-rate denomination further complicate this, where USD/TRY typically has a negative long-run impact, while Euro/TRY exhibits positive export-revenue-driven relationships (Yılmaz and Güzel, 2021). Volatility spillovers are also highly significant (Mwambuli, 2016; Basarir, 2018; Altun, 2020; Parlayan, 2024), indicating that currency market uncertainty has predictive power over stock volatility, with Guler (2020) confirming that depreciation has a stronger long-term volatility impact than appreciation.

The long-run impact of currency depreciation is similarly contested. A dominant strand of the literature supports the view that depreciation exerts a negative long-run impact on BIST returns due to cost-push inflation and balance sheet channels. Aydemir and Demirhan (2009) and Belen and Karamelikli (2016) find significant negative causal and long-run relationships running from exchange rates to major BIST indices. Çakır (2021) demonstrates that depreciation fails to generate positive effects, as import dependency neutralizes export gains. Gokmenoglu et al. (2021) find negative correlations across frequencies using wavelet coherence, and Aslan (2021) and Kassouri and Altintas (2020) show that exchange rate increases negatively affect stock returns, while Ceylan and Ceylan (2023) find that depreciation increases sovereign risk premiums. In contrast, several studies aligned with the Flow-Oriented model find positive long-run depreciation effects. Gasimova (2021), Yıldırım (2020), and Çığır (2023) estimate positive coefficients, arguing that depreciation boosts export-oriented firm valuations. Sectoral studies (Akel and Gazel, 2014; Boyacıoğlu and Çürük, 2016; Çelik, 2023; Yılmaz and Güzel, 2021) find positive industrial and service-sector effects from real depreciation, reflecting the complex and heterogeneous structure of the Turkish corporate sector.

5.2. Integrated Analogical Framework and Conceptual Interpretations

To integrate these divergent short-run and long-run findings, the literature utilizes several powerful conceptual and analytical analogies.

Alternatively, the BIST All Shares (XUTUM) can be viewed as a factory operating within an import-dependent economy, while currency appreciation functions as a reduction in raw material costs.

From a behavioral and mechanical perspective, the interaction resembles two dancers responding to shifting musical tempos, where abrupt changes trigger herding behavior, amplifying short-run deviations, while long-run VECM cointegration reveals their underlying, synchronized trajectory.

Finally, the mechanical interaction can be conceptualized through a piston engine.

6. GAPS IN EXISTING LITERATURE AND METHODOLOGICAL CONTRIBUTIONS

A systematic analysis of the academic literature reveals several distinct research gaps concerning the exchange rate-stock market relationship in Türkiye. First, there is a pronounced temporal gap. Almost all empirical studies conclude their datasets prior to 2022. This represents a major empirical blind spot because the 2022–2026 period constitutes a unique macroeconomic regime in Türkiye, featuring hyper-inflation, a pivot toward aggressive monetary policy tightening, policy-driven exchange rate depreciation, and the systemic exit from unconventional instruments like the FX-protected deposit scheme (KKM). Earlier studies centered on the 2001, 2008, 2018, or COVID-19 crises cannot be extrapolated to this contemporary environment.

Second, there is a structural and index-level gap. While the literature extensively analyzes the BIST All Shares (XUTUM) index, there is a lack of research examining the BIST National Index within a unified econometric framework. This restricts the ability to evaluate whether exchange rate volatility affects large-cap, highly liquid firms differently from the wider universe of listed companies. Third, a currency composition gap persists: research heavily prioritizes USD/TRY volatility, neglecting the Euro/TRY exchange rate despite Türkiye's deep trade and invoicing integration with the Euro Area. Fourth, there is a methodological gap: previous studies utilize inconsistent specifications, leading to contradictory findings on causality and spillovers, with a notable absence of forward-looking conditional correlation analyses. This study addresses these gaps by evaluating both the XUTUM and BIST National indices, comparing USD/TRY and Euro/TRY volatility, and utilizing a highly unified Unit Root, Johansen Cointegration, and DCC-GARCH VECM framework specifically for the post-2022 policy transition.

Selecting an appropriate econometric methodology is vital to capturing the transmission of currency shocks. Traditional linear frameworks like OLS, standard VAR, and linear VECM assume homoskedasticity (constant variance). This assumption is empirically invalid for Turkish financial data, which exhibits intense volatility clustering. Directly applying linear models to daily data from the turbulent 2022–2026 period yields biased, inefficient estimators and spurious regressions. This limitation prompted a shift toward conditional volatility models, notably the ARCH and GARCH frameworks. In Türkiye, the parsimonious GARCH(1,1) model has been widely validated for modeling return volatility in stock prices (Yurttagüler, 2024) and exchange rates (Fenkli et al., 2024). However, while univariate models capture isolated asset volatility, they cannot evaluate cross-market risk spillovers, necessitating multivariate extensions.

Early multivariate models like the BEKK-GARCH are theoretically robust but suffer from the 'curse of dimensionality,' where parameters grow exponentially, causing maximum likelihood convergence failures. The Constant Conditional Correlation (CCC) MGARCH model (Altun, 2020) bypasses this but assumes static correlations over the sample period. As Gayaker (2025) argues, this

static assumption is invalid for emerging markets like Türkiye, where relationships are highly fluid and prone to structural shifts and 'inverse correlation' effects during crises. To resolve these limitations, this thesis deploys Engle's (2002) Dynamic Conditional Correlation (DCC) GARCH model, which uses a two-stage maximum likelihood estimation process. It captures time-varying conditional correlations that adjust to policy shifts, as demonstrated by Bostancı and Doğru (2023) and Sobacı (2014).

Furthermore, we address key econometric vulnerabilities. Bad news has a significantly larger volatility impact than good news in Türkiye (Mujaddadi and Sönmezer, 2025; Guler, 2020). Thus, the DCC-GARCH model integrates asymmetric variance equations, such as the EGARCH (Kılıç, 2021). We also reject the standard Gaussian distribution in favor of Skewed Student-t and Skewed GED distributions, which Girgin (2023) proved drastically improve estimation accuracy by accommodating the leptokurtosis (fat tails) and skewness characteristic of Turkish data. Finally, despite aggregation risks (Abdul-Rahman and Kaplan, 2024), we utilize daily closing data, which provides the optimal balance by capturing rapid shock adjustments while avoiding the micro-structural noise of intraday estimates. This robust methodology delivers a highly precise empirical assessment of currency contagion during the post-2022 orthodox policy transition.

7. CONCLUSION

In conclusion, the academic literature concerning the transmission of exchange rate volatility to the Turkish equity market presents a complex tapestry of competing theoretical models and empirical findings. The dynamic interplay between the Turkish Lira (USD/TRY and Euro/TRY) and the Borsa Istanbul All Shares Index (XUTUM) during the 2022–2026 period is characterized by short-run asymmetry, regime-dependency, and stable long-run cointegration. While traditional models like the Flow-Oriented Approach emphasize trade competitiveness and imported cost-push inflation channels—confirming that currency depreciation severely compresses profit margins in import-dependent industries—the Stock-Oriented Portfolio Balance Approach highlights capital accounts and investment rebalancing feedback loops, proving that stock prices also drive currency demand during periods of heightened market interest.

By analyzing the extensive research on these interactions, this review highlights the critical gaps that persist in the existing literature. Specifically, the post-2022 macroeconomic tightening regime, the comparative analysis between the broad-based XUTUM and the large-cap BIST National indices, the inclusion of Euro-denominated fluctuations, and the implementation of a unified DCC-GARCH and VECM framework represent essential frontlines for empirical advancement. Our proposed methodology directly addresses these vulnerabilities by accounting for volatility clustering, leverage effects, and non-Gaussian fat-tailed distributions, ensuring that estimators remain efficient and unbiased.

Ultimately, this systematic literature review confirms that currency and equity markets in Türkiye do not operate in isolation. Rather, they are structurally bound through trade channels, portfolio

decisions, and policy interventions. Understanding the exact pathways through which currency shocks propagate is essential for maintaining portfolio efficiency and designing robust macroeconomic policies. This chapter establishes the robust theoretical, conceptual, and empirical framework required to interpret the empirical findings in the subsequent stages of this thesis, providing a comprehensive foundation for analyzing the dynamics of Turkish financial markets during a pivotal era of economic rebalancing.

REFERENCES

Abdul-Rahman, M., Khan, A. U. I., & Kaplan, M. (2024). Beyond GARCH: Intraday insights into the exchange rate and stock price volatility dynamics in Borsa Istanbul sectors. *FWU Journal of Social Sciences, 18*(3), 1–13.

Acikalin, S., Aktas, R., & Unal, S. (2008). Relationships between stock markets and macroeconomic variables: An empirical analysis of the Istanbul Stock Exchange. *Investment Management and Financial Innovations, 5*(1), 8–16.

Agrawal, G., Srivastav, A. K., & Srivastava, A. (2010). A study of exchange rates movement and stock market volatility. *International Journal of Business and Management, 5*(12), 62–73.

Akel, V., & Gazel, S. (2014). Döviz kurları ile BİST sanayi endeksi arasındaki eşbütünleşme ilişkisi: Bir ARDL sınır testi yaklaşımı. *Erciyes Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi*, (44), 23–41.

Aktaş, H., Kayalıdere, K., & Karataş, Y. (2018). Petrol, dolar kuru ve hisse senedi piyasası arasındaki ortalama-oynaklık yayılım etkisi: BIST100 üzerine bir uygulama. *Muhasebe ve Vergi Uygulamaları Dergisi, 11*(3), 354–377.

Alimi, A. S., & Adediran, I. A. (2023). A new look at stock price-exchange rate nexus: Analysis of COVID-19 pandemic waves in advanced and emerging economies. *Finance Research Letters, 47*, 102639.

Altun, Ö. (2020). *Döviz kuru ve pay piyasası getiri oynaklığının modellenmesi ve yayılımı* [Yüksek lisans tezi, Şırnak Üniversitesi Lisansüstü Eğitim Enstitüsü].

Aslan, M. (2021). *Effects of exchange rate volatility and firm-specific features on the rates of returns of the manufacturing firms listed in Borsa İstanbul: A CAPM approach* [Master's thesis, Middle East Technical University].

Aydemir, O., & Demirhan, E. (2009). The relationship between stock prices and exchange rates: Evidence from Türkiye. *International Research Journal of Finance and Economics, 23*, 207–215.

Bahmani-Oskooee, M., & Domac, I. (1997). Turkish stock prices and the value of Turkish lira. *Canadian Journal of Development Studies/Revue Canadienne d'Études du Développement, 18*(1), 139–150.

Bahmani-Oskooee, M., & Saha, S. (2015). Do exchange rate changes have symmetric or asymmetric effects on stock prices? *Global Finance Journal, 31*, 57–72.

Başarır, Ç. (2018). Döviz kurları ile hisse senedi piyasası arasındaki ilişkinin incelenmesi: Türkiye örneği. *Uluslararası İktisadi ve İdari İncelemeler Dergisi*, (Özel Sayı), 599–610.

Bekaert, G., & Harvey, C. R. (1995). Time-varying world market integration. *Journal of Finance, 50*(2), 403–444.

Belen, M., & Karamelikli, H. (2016). Türkiye'de hisse senedi getirileri ile döviz kuru arasındaki ilişkinin incelenmesi: ARDL yaklaşımı. *İstanbul Üniversitesi İşletme Fakültesi Dergisi, 45*(1), 34–42.

Benli, Y. K. (2015). Döviz kuru ile Borsa İstanbul 100 ve sektör endeksleri arasındaki ilişkinin ampirik analizi. *Uluslararası Hakemli Beşeri ve Akademik Bilimler Dergisi, 4*(12), 55–72.

Bostancı, A. B., & Doğru, E. (2023). DCC-GARCH modeli ile döviz kuru, petrol fiyatları ve BIST sektör endeksleri arasındaki volatilite yayılımının analizi. *Doğuş Üniversitesi Dergisi, 24*(2), 559–577.

Boyacıoğlu, A. M., & Çürük, D. (2016). Döviz kuru değişimlerinin hisse senedi getirisine etkisi: Borsa İstanbul 100 endeksi üzerine bir uygulama. *Muhasebe ve Finansman Dergisi*, 143–156.

Branson, W. H. (1983a). A model of exchange-rate determination with policy reaction: Evidence from monthly data. *National Bureau of Economic Research*.

Branson, W. H. (1983b). Macroeconomic determinants of real exchange risk. In R. J. Herring (Ed.), *Managing foreign exchange risk* (pp. 33–74). Cambridge University Press.

Branson, W. H., Halttunen, H., & Masson, P. (1977). Exchange rates in the short run: The dollar-Deutschemark rate. *European Economic Review, 10*(3), 303–324.

Bulut, E., & Şimşek, A. (2023). The relationship between the stock market volatility, liquidity, exchange rate return, and stock return during the COVID-19 period: The case of the BIST 100 Index. *Bingöl University Journal of Economics and Administrative Sciences, 7*(1), 121–135.

Carrieri, F., Errunza, V., & Hogan, K. (2007). Characterizing world market integration through time. *Journal of Financial and Quantitative Analysis, 42*(4), 915–940.

Ceylan, I. E., & Ceylan, F. (2023). Symmetric and asymmetric effects of exchange rate changes on stock prices in fragile five economies: Analysis of the global crisis and pandemic period. *Journal of Economic Integration, 38*(4), 646–669.

Çakır, M. (2021). The impact of exchange rates on stock markets in Türkiye: Evidence from linear and non-linear ARDL models. In *Linear and non-linear financial econometrics—Theory and practice* (pp. 154–171). IntechOpen.

Çakır, Ö. (2022). *Türkiye'de döviz kuru oynaklığı ile borsa endeks oynaklığı arasındaki etkileşim* [Yüksek lisans tezi, Süleyman Demirel Üniversitesi].

Çelik, S. (2023). *Döviz kuru ve faiz oranlarının BIST hizmet endeksi üzerindeki etkisi* [Yüksek lisans tezi, Dicle Üniversitesi].

Çevik, M. (2024). *Hisse senedi getirisi, enflasyon oranı ve döviz kuru arasındaki ilişki: Türkiye üzerine ampirik bir analiz* [Yüksek lisans tezi, Afyon Kocatepe Üniversitesi].

Çığır, M. S. (2023). *Hisse senedi fiyatları ile döviz kuru ilişkisi: Borsa İstanbul endekslerinde uygulama [The relationship between stock prices and exchange rates: An application in Borsa Istanbul indices]* [Master's thesis, Pamukkale Üniversitesi].

Demir, Ç. (2022). *Türkiye'de döviz kuru riski: BİST100'de işlem gören sanayi alt sektör endekslerinin Forex betalarının ölçümü* [Master's thesis, Çukurova University].

Demir, E. (2020). *Türkiye ekonomisinde döviz kuru oynaklığı ve finansal piyasa etkileşimi [Exchange rate volatility and financial market interaction in the Turkish economy]* [Master's thesis, Necmettin Erbakan Üniversitesi].

Doğukanlı, H., Özmen, M., & Yücel, E. (2010). İMKB'de sektörel açıdan döviz kuru duyarlılığının incelenmesi. *Çukurova Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 19*(3), 63–86.

Dornbusch, R., & Fischer, S. (1980a). Exchange rates and the current account. *The American Economic Review, 70*(5), 960–971.

Dornbusch, R., & Fischer, S. (1980b). The flow-oriented model/exchange rates and the current account. *The American Economic Review, 72*(4), 852–965.

El-Diftar, D. (2023). The impact of exchange rates on stock market performance of the Emerging 7. *Journal of Capital Markets Studies, 7*(2), 125–139.

Engle, R. F. (2002). Dynamic conditional correlation: A simple class of multivariate generalized autoregressive conditional heteroskedasticity models. *Journal of Business & Economic Statistics, 20*(3), 339–350.

Eyüboğlu, S., & Eyüboğlu, K. (2018). Tüketici güven endeksi ile Borsa İstanbul sektör endeksleri arasındaki ilişkinin araştırılması. *Dokuz Eylül Üniversitesi İktisadi ve İdari Bilimler Dergisi, 33*(1), 235–259.

Fenkli, M., Çırak, A. N., & Uysal, D. (2024). Analyzing exchange rate volatility: A comparative study of ARCH and GARCH methods. *Aksaray Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi, 16*(3), 121–142.

Frenkel, J. A. (1976). A monetary approach to the exchange rate: Doctrinal aspects and empirical evidence. *The Scandinavian Journal of Economics, 78*, 200–224.

Frankel, J. A. (1983). Monetary and portfolio balance models of exchange rate determination. In J. S. Bhandari & B. H. Putnam (Eds.), *Economic interdependence and flexible exchange rates* (pp. 84–115). MIT Press.

Gasimova, Z. (2021). *Döviz kurunun hisse senetleri üzerinde etkisi: Türkiye örneği* [Yüksek lisans tezi, İstanbul Aydın Üniversitesi].

Gasimova, Z., & Ojaghlou, M. (2021). Asymmetric impact of exchange rate to Istanbul stock market: A nonlinear ARDL approach. *Journal of Social and Humanities Sciences Research, 8*(69), 1248–1254.

Gayaker, S. (2025). The relationship between interest rates and exchange rates in Türkiye: The DCC-GARCH approach. *EKOIST Journal of Econometrics and Statistics, 43*, 219–232.

Gençtürk, M. (2009). Finansal kriz dönemlerinde makroekonomik faktörlerin hisse senedi fiyatlarına etkisi. *Süleyman Demirel Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi, 14*(1), 127–136.

Girgin, Y. (2023). *Modeling exchange rate volatility using ARMA-GARCH approach with non-Gaussian distribution* [Master's thesis, Middle East Technical University].

Gokmenoglu, K., Eren, B. M., & Hes, S. (2021). Exchange rates and stock markets in emerging economies: New evidence using the quantile-on-quantile approach. *Quantitative Finance and Economics, 5*(1), 94–110.

Gokmenoglu, K. K., & Fazlollahi, N. (2021). Co-movement of foreign exchange rate returns and stock market returns in an emerging market. *International Journal of Finance & Economics*.

Guler, D. (2020). The impact of the exchange rate volatility on the stock return volatility in Türkiye. *Eurasian Journal of Business and Management, 8*(2), 106–123.

İşcan, E. (2011). Döviz kurları ve hisse senedi piyasası arasındaki etkileşim: Türkiye örneği, Aralık 2001–Aralık 2009. *Elektronik Sosyal Bilimler Dergisi, 10*(35), 237–251.

Kanas, A. (2000). Volatility spillovers between stock returns and exchange rate changes: International evidence. *Journal of Business Finance & Accounting, 27*(3–4), 447–467.

Kartal, M. T., Ayhan, F., & Kirikkaleli, D. (2022). Regime-switching effect of COVID-19 pandemic on stock market index: Evidence from Türkiye as an emerging market example. *Macroeconomics and Finance in Emerging Market Economies, 17*(1), 189–206.

Kasman, S. (2003). The relationship between exchange rates and stock prices: A causality analysis. *Dokuz Eylül Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 5*(2), 1–15.

Kassouri, Y., & Altintas, H. (2020). Threshold cointegration, nonlinearity, and frequency domain causality relationship between stock price and Turkish lira. *Research in International Business and Finance, 52*.

Kılıç, E. (2021). *Hisse senedi ve döviz kuru arasındaki getiri ve volatilite etkileşimi: BRICS ve MIST ülkeleri örneği* [Doktora tezi, Bingöl Üniversitesi].

Mechri, N., Ben Hamad, S., De Peretti, C., & Charfi, S. (2018). The impact of the exchange rate volatilities on stock markets dynamics: Evidence from Tunisia and Türkiye. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3304040

Mujaddadi, N. A., & Sönmezer, S. (2025). Dynamic interactions and volatility analysis between stock prices and exchange rates in Türkiye: Evidence from ARDL, NARDL and ARCH models (2020–2024). *Akademik Hassasiyetler, 12*(28), 146–168.

Mwambuli, E. L., Xianzhi, Z., & Kisava, Z. S. (2016). Volatility spillover effects between stock prices and exchange rates in emerging economies: Evidence from Türkiye. *Business and Economic Research, 6*(2), 343–359.

Öztürk, K. (2007). *Exchange rate volatility the case of Türkiye* [Master's thesis, Middle East Technical University].

Parlayan, B. (2024). *Hisse senedi fiyatları ile döviz kurları arasındaki dinamik ilişki: Türkiye örneği* [Yüksek lisans tezi, Karadeniz Teknik Üniversitesi].

Polat, U. (2022). Exploring the long-term exchange rate volatility in Türkiye: Evidence from a GARCH-MIDAS model. *Finans Politik & Ekonomik Yorumlar, 59*(662), 39–69.

Reboredo, J. C., Rivera-Castro, M. A., & Ugolini, A. (2016). Downside and upside risk spillovers between exchange rates and stock prices. *Journal of Banking & Finance, 62*, 76–96.

Sensoy, A., & Sobaci, C. (2014). Effects of volatility shocks on the dynamic linkages between exchange rate, interest rate and the stock market: The case of Türkiye. *Research in International Business and Finance, 31*, 46–56.

Yau, H.-Y., & Nieh, C.-C. (2006). Interrelationships among stock prices of Taiwan and Japan and NTD/Yen exchange rate. *Journal of Asian Economics, 17*(3), 535–552.

Yıldırım, A. (2020). *Döviz kuru dalgalanmalarının üretim yapan firmaların performansına etkisi: BİST 100 üzerine bir uygulama* [Yüksek lisans tezi, Kayseri Üniversitesi].

Yılmaz, Ö., Güngör, B., & Kaya, V. (2006). Hisse senedi fiyatları ve makro ekonomik değişkenler arasındaki eş-bütünleşme ve nedensellik. *İMKB Dergisi, 9*(34), 1–16.

Yurttagüler, İ. (2024). Analysis of Istanbul stock market returns volatility with ARCH and GARCH models. *İstanbul İktisat Dergisi, 74*(1), 37–58.

Yurttançıkmaz, Z. Ç. (2012). Döviz kuru ve enflasyonun hisse senedi getirileri üzerindeki etkisi. *EKEV Akademi Dergisi, 16*(51), 393–410.

THE ROOTS OF HOPE: A MICROECONOMETRIC ANALYSIS OF PERSONAL AND ECONOMIC FACTORS

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ABSTRACT

Understanding what sustains hope for the future matters for individual well-being and societal resilience, particularly in developing economies under prolonged economic stress. This study asks whether objective economic shocks or subjective satisfaction better accounts for optimism in Türkiye. Using weighted microdata from the 2024 Life Satisfaction Survey of the Turkish Statistical Institute (n = 9,462), hope is modelled as a four-category ordered outcome. The Brant test rejects proportional odds for eight of sixteen constructs, so a partial proportional odds model is estimated, with ordered and multinomial logit as reference specifications. A grouped Shapley decomposition quantifies relative importance. Income and health satisfaction together account for 64.9 percent of the explained variance, against 3.5 percent for an actual income decrease. Effects are cut-point specific: indebtedness depresses the bottom of the distribution, while health satisfaction and income gains drive the top. More-educated respondents report systematically lower hope.

Keywords: *Hope, Partial Proportional Odds, Shapley Value Decomposition, Subjective Well-Being, Türkiye.*

JEL Codes: *I31, D84, C45.*

1. INTRODUCTION

Hope for the future occupies a peculiar place in social science. Psychologists treat it as a cognitive resource that mobilises goal-directed action (Snyder et al., 1991; Snyder, 2002), while welfare economists read it as a forward-looking complement to current life satisfaction, useful for anticipating consumption, saving, and political behaviour (Diener et al., 1999; Frey & Stutzer, 2002). Across both traditions, an empirical regularity has accumulated: people who expect better days are more likely to invest, persist, and cooperate, even when their current conditions are objectively unfavourable (Becchetti & Castriota, 2010). What is less settled is the relative weight that different life domains carry in shaping that expectation, and whether the picture drawn from objective shocks aligns with the picture drawn from subjective perceptions.

The Turkish setting offers a sharp test bed. Year-on-year consumer price inflation stood between roughly 44 and 65 percent at successive year-ends from 2022 to 2024 before easing through 2025, and household purchasing power eroded over multiple cycles of currency depreciation (World Bank, 2024; OECD, 2025). Against that macro backdrop, the 2024 Life Satisfaction Survey of the Turkish Statistical

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Institute reports that 64.3 percent of adults still describe themselves as hopeful about the future (Turkish Statistical Institute [TurkStat], 2025). Two questions follow. Why does roughly two-thirds of the population remain forward-looking under such pressure, and once the household-level micro-data are opened up, which experiences and perceptions carry the heaviest weight in that figure?

Answering the second question well turns out to depend on three modelling choices that are easy to make badly. The first is measurement scale: marital status and employment status are nominal categories, and treating them as equally spaced numeric scales imposes an ordering the data do not contain. The second is the proportional-odds restriction that the standard ordered logit imposes, which forces every covariate to shift the odds by the same amount at each threshold of the outcome. The third is the sampling design: the Life Satisfaction Survey is a weighted probability sample, and unweighted estimates describe the respondents rather than the population. This study takes all three seriously, and the substantive conclusions turn out to depend on them.

Standard regression interpretations also rely on coefficient magnitudes or t-statistics; both are sensitive to multicollinearity and scaling, and neither cleanly quantifies how much of the variation a single regressor explains. In well-being research, where predictors tend to be correlated (income satisfaction co-moves with health satisfaction, debt with reduced consumption, education with employment status), this conditions the answer to the very question being asked. Shapley value decomposition (LMG method) addresses it by assigning each variable an importance score equal to the average of its marginal contribution to the model's coefficient of determination across all orderings of the predictors (Lipovetsky & Conklin, 2001; Grömping, 2007). Here the decomposition is computed with each construct — a categorical variable together with all of its indicator columns, or a single numeric regressor — treated as one player, so that a variable's importance is not split across its dummies.

Three contributions follow. First, the paper provides a weighted, nationally representative microeconometric analysis of hope determinants in Türkiye and disentangles three explanatory channels that are often tangled together in policy discourse: objective economic shocks, major life events, and subjective evaluations. Second, it shows that the proportional-odds restriction is decisively rejected in this setting and that relaxing it changes the reading of several effects: indebtedness operates at the bottom of the hope distribution while health satisfaction and income gains operate at the top. Third, it applies a grouped Shapley decomposition to hope-for-the-future as a stand-alone outcome, recovering a relative-importance ranking that is not contaminated by the multicollinearity of subjective and objective measures.

The remainder of the paper is organised as follows. The second section reviews the relevant literature. The third introduces the data, the sampling weights, and the variable construction. The fourth describes the methodology. The fifth presents and discusses the results. The sixth concludes.

2. LITERATURE REVIEW

2.1. Hope, Optimism, and Subjective Well-being

The modern measurement of hope rests largely on Snyder et al. (1991), who reconceptualised it as a cognitive set built around two interacting components: agency, the perceived capacity to initiate and sustain goal-directed action, and pathways, the perceived capacity to construct routes to those goals. Subsequent work refined the construct (Snyder, 2002) and embedded it within the broader subjective well-being literature, where it sits alongside life satisfaction and positive affect as part of a forward-looking dimension of welfare (Diener et al., 1999). For economists, the appeal is that hope and optimism predict behaviours that matter for aggregate outcomes, such as saving, labour supply, fertility and civic participation, even after current income is controlled for (Frey & Stutzer, 2002).

How economic conditions shape that forward-looking dimension has been debated for nearly half a century. Easterlin (1974) argued that, beyond a basic threshold, sustained income growth does not lift average happiness, a claim later challenged on broader datasets by Stevenson and Wolfers (2008). The narrower question addressed here — how short-run economic shocks register in expectations — has more direct evidence behind it: exploiting a sudden and unanticipated currency devaluation in Botswana as a natural experiment, Hariri et al. (2016) find a large and significantly negative effect of the shock on reported subjective well-being. What is less agreed upon is whether such an effect runs primarily through the objective event itself or through the perceptions and adjustments that follow it.

2.2. Ordinal Models and the Proportional-odds Restriction

Ordered outcomes in survey research are conventionally modelled with the ordered logit, which assumes proportional odds: a covariate shifts the log-odds of being above a threshold by the same amount at every threshold. The assumption is testable. Brant (1990) proposed comparing the ordered model with a set of separate binary logits estimated at each cut-point, using the full between-equation covariance structure to construct a Wald statistic for the equality of coefficients. When the restriction fails, the generalized ordered logit, or partial proportional odds model, relaxes it selectively: coefficients are allowed to vary across cut-points for the variables that violate the assumption and are held constant for the rest (Williams, 2006). This retains the ordinal structure of the outcome, which a multinomial logit discards, while avoiding a restriction the data reject. The cost is that cumulative probabilities are no longer guaranteed to be monotone, so fitted probabilities must be inspected.

2.3. Shapley Value Decomposition in Econometrics

The use of Shapley values to allocate explained variance among correlated predictors traces back to Lindeman et al. (1980), whose LMG metric averages the marginal contribution of each regressor over all permutations. The properties of the decomposition were formalised by Lipovetsky and Conklin (2001) and Grömping (2007), and the technique has become a standard tool in regression-based

importance analysis. Its advantage over conventional t-statistics or standardised betas is that the resulting weights are robust to the order of variable entry and sum exactly to the model's coefficient of determination. Grömping (2007) also notes that when a construct is represented by several columns, the decomposition should be computed over groups rather than individual columns, since otherwise a categorical variable's importance is arbitrarily divided among its indicators.

2.4. Subjective Well-being in Türkiye

The Turkish literature on subjective well-being has grown alongside the TurkStat Life Satisfaction Survey, fielded annually since 2003. Early work was descriptive; later contributions traced links between income, employment, and reported happiness, often using ordered logit or probit specifications. Hope-for-the-future is a routine item in the survey but is rarely modelled as the main outcome. The 2024 wave is particularly informative because it was administered during a period of high inflation and sustained monetary tightening following the mid-2023 shift in the policy stance of the Central Bank, conditions under which the gap between objective economic stress and self-reported optimism becomes empirically visible (TurkStat, 2025; OECD, 2025).

3. DATA AND VARIABLES

3.1. Data Source, Sample and Weights

The analysis uses the individual-level micro-dataset of the 2024 Life Satisfaction Survey (Yaşam Memnuniyeti Araştırması) conducted by the Turkish Statistical Institute. The survey is a probability sample representative of the non-institutional population aged 18 and above. The release contains 9,462 observations; restricting the variable set to the sixteen constructs required by the analysis produces no further loss, so the analytical sample retains n = 9,462.

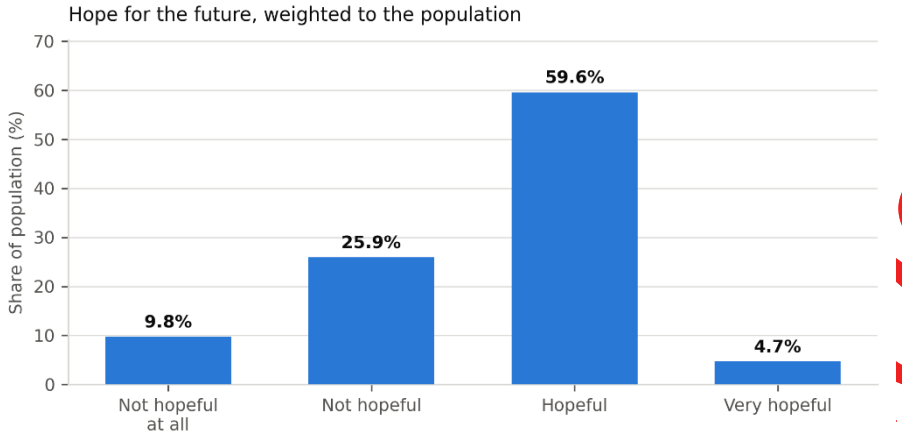
All estimates reported below are weighted by the individual sampling weight supplied with the release, and all standard errors are linearised (sandwich) estimators that account for the weighting. Weighting is not cosmetic here. The unweighted share of respondents expressing positive hope is 63.7 percent, whereas the weighted share is 64.3 percent, which reproduces the figure published in the official release (TurkStat, 2025). Because the public-use file does not carry stratum or primary-sampling-unit identifiers, the variance estimates capture the effect of unequal selection probabilities but not the full clustering structure of the design; the reported standard errors are therefore likely to be mildly conservative in the sense of understating design effects. This is stated as a limitation rather than resolved.

3.2. Dependent Variable

The outcome is hope for the future, captured by the survey item asking whether the respondent feels hopeful about life in the period ahead. The original coding (1 = very hopeful, 4 = not hopeful at

all) was reversed so that higher values denote greater optimism. The weighted distribution is shown in Figure 1.

Figure 1. Weighted Distribution of Hope for the Future, Türkiye Life Satisfaction Survey 2024



Source: Authors' calculations from the 2024 TurkStat Life Satisfaction Survey micro-data, weighted.

The two positive categories together account for 64.3 percent of the population. The modal category dominates at 59.6 percent, while the extreme positive category remains a thin tail at 4.7 percent. This compression toward a moderate positive response is characteristic of forward-looking survey items and is precisely the configuration in which a single set of proportional-odds coefficients is likely to misrepresent behaviour at the extremes.

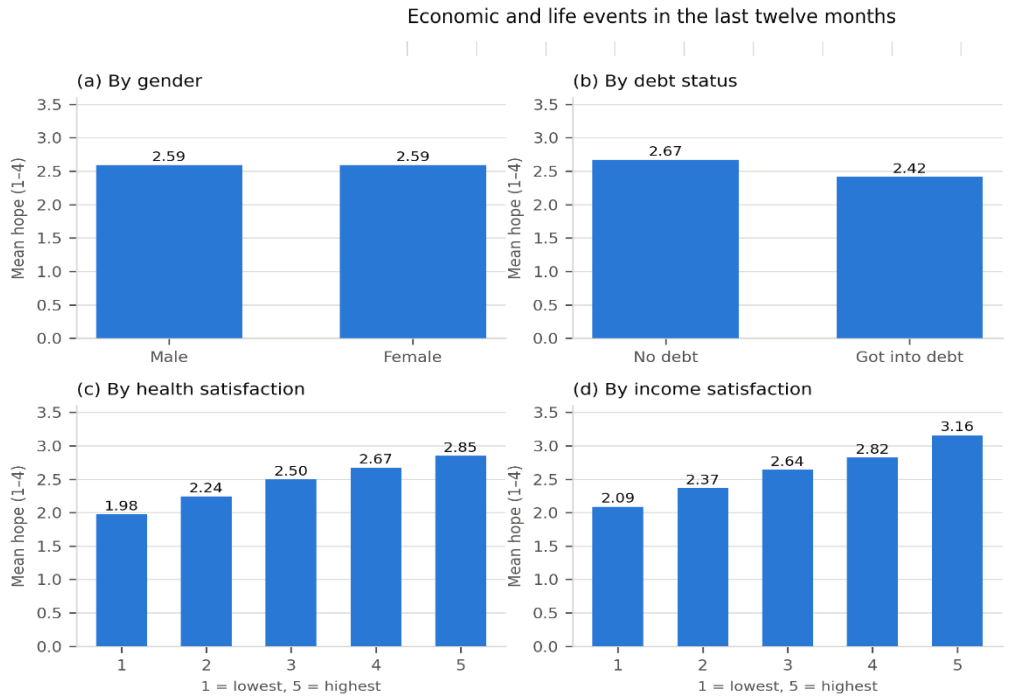
3.3. Independent Variables and Coding

Sixteen constructs enter the model in four blocks. The demographic block contains gender, age, marital status, education level, and employment status. The economic-shocks block records, for the past twelve months, whether the respondent saw income rise or fall, took on debt, watched savings shrink, switched to cheaper products, started saving, or lost a job. The life-events block records the appearance of a health problem and the death of a family member. The subjective block records satisfaction with health and with income on five-point scales, each reversed so that higher values indicate higher satisfaction.

Marital status, employment status and education level are entered as sets of indicator variables rather than as numeric scales, with never-married, employed and no-formal-schooling as the reference categories. This matters substantively. Coding employment status as 1, 2, 3 would assert that the distance from employed to has-a-job-but-not-working equals the distance from there to not-working, and coding marital status as 1 to 4 would assert an ordering among never-married, married, divorced and widowed that does not exist. Education is the one construct for which a linear trend is defensible, since its categories are genuinely ordered; it is nonetheless entered as indicators in the main specification, and

the linear-trend restriction is reported separately as a robustness check in Section 5.5. Figure 2 shows the weighted prevalence of the binary events.

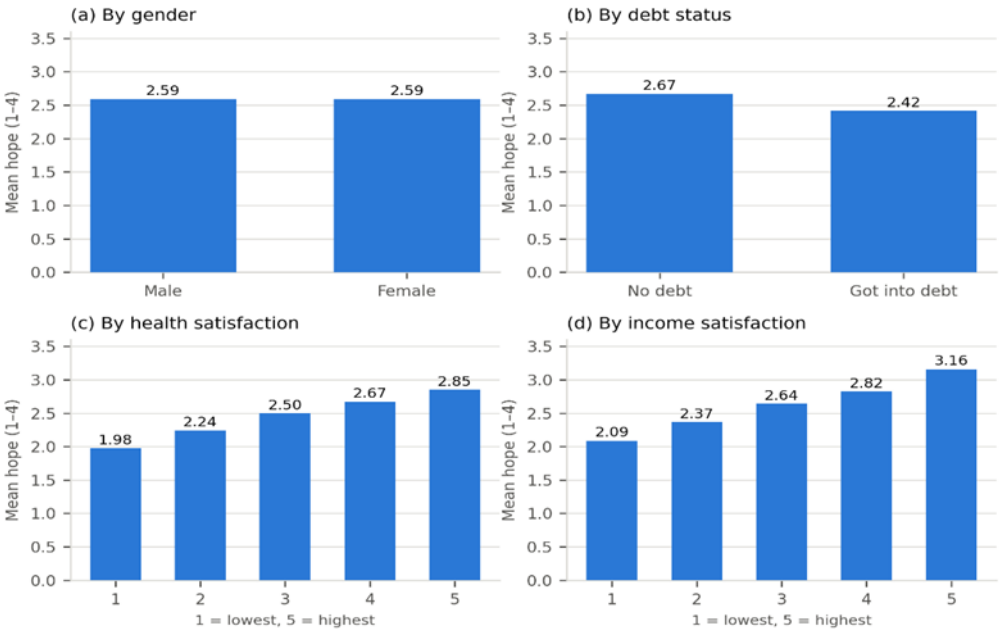
Figure 2. Weighted Prevalence of Economic and Life Events Reported in the Last Twelve Months



Source: Authors' calculations, weighted. Adverse and favourable events are distinguished by shading.

Adverse events are markedly more frequent than favourable ones, consistent with the inflationary backdrop of the survey period. Switching to cheaper products is reported by 74.8 percent of the population, followed by a decrease in savings (42.4 percent), a decrease in income (31.7 percent) and taking on debt (30.7 percent). Favourable movements are rarer: 21.8 percent report income gains and 13.9 percent report starting to save. Figure 3 reports weighted mean hope by gender, debt status, health satisfaction and income satisfaction.

Figure 3. Weighted Mean Hope by Gender, Debt Status, Health Satisfaction, and Income Satisfaction



Source: Authors' calculations, weighted. Hope is scored 1 (not hopeful at all) to 4 (very hopeful).

Once the sampling weights are applied the gender gap disappears entirely: mean hope is 2.59 for both men and women. The debt gap is visible, and both satisfaction gradients are steep, climbing by roughly one point on the four-point hope scale as satisfaction moves from its lowest to its highest level. These descriptive patterns motivate the modelling that follows.

4. METHODOLOGY

4.1. Ordered Logit and the Proportional-odds Restriction

Hope is a four-category ordinal outcome. The ordered logit specification assumes a latent linear index partitioned by three estimated thresholds. The probability that respondent i falls into category j or below is given by Equation (1):

$$Pr(Y_i \leq j|x_i) = \Lambda(\tau_j - x_i'\beta) \quad (1)$$

Here Y_i is the hope category, x_i the vector of covariates, β the parameter vector, τ_j the cut-points, and $\Lambda(\cdot)$ the standard logistic distribution function. The specification imposes proportional odds: the effect of any covariate on the log-odds of being in a higher category is identical at every cut-point. This restriction is tested with the Brant (1990) test, implemented with the full between-equation covariance structure, $Cov(b_m, b_n)$ derived from the binary logits fitted at each cut-point. The test is applied at the level of constructs rather than individual columns, so that a categorical variable is assessed jointly across all of its indicators.

4.2. Partial Proportional Odds Model

Where the restriction fails, the partial proportional odds model of Equation (2) relaxes it selectively:

$$Pr(Y_i \leq j|x_i) = \Lambda(\tau_j - x'_{1i}\beta - x'_{2i}\gamma_j) \quad (2)$$

The covariates are partitioned into a set x_1 whose coefficients β are constrained to be equal across cut-points and a set x_2 whose coefficients γ_j are free to vary by cut-point. Membership of x_2 is determined by the Brant test at the five-percent level rather than by inspection. Because the cumulative probabilities implied by Equation (2) are not guaranteed to be monotone in j, the fitted values are checked directly; in the estimated model no observation violates monotonicity and the smallest fitted cell probability is 0.0009, so the specification is admissible throughout the covariate space observed in the sample.

4.3. Multinomial Logit and Marginal Effects

The multinomial logit is estimated as a further reference specification. It abandons the ordinal structure altogether, estimating a separate log-odds equation for each non-baseline category. The ordered logit is not a parameter restriction of the multinomial logit — the two are non-nested, because the cumulative-link structure of Equation (1) does not correspond to any restriction on multinomial coefficients — so they are compared by information criteria rather than by a likelihood-ratio test. The partial proportional odds model, by contrast, does nest the ordered logit, and the two are compared by a likelihood-ratio test. Because raw multinomial coefficients are difficult to read, average marginal effects on each outcome probability are reported instead.

4.4. Grouped Shapley Value Decomposition

To recover relative importance in a multicollinearity-robust way, the analysis applies the LMG decomposition (Lindeman et al., 1980; Lipovetsky & Conklin, 2001; Grömping, 2007). For each construct i the contribution is the Shapley value of the cooperative game whose characteristic function is the model's coefficient of determination on a subset of constructs, as given in Equation (3):

$$\varphi_i = \sum_{S \subseteq F \setminus \{i\}} \frac{|S|!(|F|-|S|-1)!}{|F|!} (R^2(S \cup \{i\}) - R^2(S)) \quad (3)$$

F is the full set of constructs, S any subset not containing i, and $R^2(S)$ the weighted coefficient of determination of the regression using the columns belonging to the constructs in S. Each categorical variable enters as a single player together with all of its indicator columns, so that its importance is not divided among its dummies. The decomposition is computed on a weighted linear-probability approximation in which the four-category outcome is treated as numeric, because the coefficient of determination is not defined for the ordinal model in the same way. This is a genuine limitation: the ranking describes a linear approximation of the conditional mean, not the ordinal model itself, and it should be read alongside the marginal effects rather than in place of them.

5. RESULTS AND DISCUSSION

5.1. Testing the Proportional-odds Restriction

Table 1 reports the Brant test at the construct level. Eight of the sixteen constructs violate proportional odds at the five-percent level: marital status, education level, age, taking on debt, income increase, health problem, health satisfaction and income satisfaction. The two subjective satisfaction measures, which turn out to be the dominant predictors, are both among the violators, so the restriction fails precisely where it matters most. Gender sits just above the threshold ($p = 0.054$) and is treated as proportional.

Table 1. Brant Test of the Proportional-Odds Assumption, by Construct (weighted)

Construct	χ^2	df	p-value	Proportional odds
Gender	5.85	2	0.054	Not rejected
Marital status	26.60	6	0.000	Rejected
Employment status	2.75	4	0.600	Not rejected
Education level	28.26	10	0.002	Rejected
Age	6.71	2	0.035	Rejected
Income decreased	0.94	2	0.625	Not rejected
Lost job	2.87	2	0.238	Not rejected
Got into debt	8.75	2	0.013	Rejected
Savings decreased	4.92	2	0.086	Not rejected
Switched to cheaper products	5.06	2	0.080	Not rejected
Income increased	8.59	2	0.014	Rejected
Started saving	3.05	2	0.218	Not rejected
Health problem	10.22	2	0.006	Rejected
Family death	1.39	2	0.498	Not rejected
Health satisfaction	7.28	2	0.026	Rejected
Income satisfaction	9.71	2	0.008	Rejected

Note: Wald statistics from the Brant (1990) test with the full between-equation covariance structure, computed at the construct level so that categorical variables are assessed jointly across their indicators. The assumption holds if $p > 0.05$. Omnibus test: $\chi^2 = 201.9$, $df = 46$, $p < 0.001$.

5.2. Model Selection

Table 2 compares the three specifications. The likelihood-ratio test of the partial proportional odds model against the ordered logit, which it nests, rejects the restriction decisively ($\chi^2 = 175.9$, $df = 28$, $p < 0.001$). On the Akaike criterion the partial proportional odds model is preferred (17,595.4 against 17,715.2 for the ordered logit and 17,622.8 for the multinomial logit). On the Bayesian criterion, which

penalises the twenty-eight additional parameters more heavily at this sample size, the restricted ordered logit is preferred (17,901.3 against 17,981.7 and 18,137.9).

Table 2. Model Comparison (weighted, n = 9,462)

Specification	Parameters	Log-likelihood	AIC	BIC
Ordered logit (proportional odds)	26	-8831.6	17,715.2	17,901.3
Partial proportional odds	54	-8743.7	17,595.4	17,981.7
Multinomial logit	72	-8739.4	17,622.8	18,137.9

Note: The partial proportional odds model nests the ordered logit; the likelihood-ratio test between them gives $\chi^2 = 175.9$, $df = 28$, $p < 0.001$. The multinomial logit is non-nested with respect to both and is compared by information criteria only.

The two criteria disagree, and the disagreement is informative rather than embarrassing. The Bayesian criterion asks whether the extra parameters buy enough fit to justify a more complex data-generating process; the Akaike criterion asks which model predicts better out of sample. Since the Brant test rejects the restriction independently of either criterion, and since the cut-point-specific coefficients turn out to carry a clear substantive interpretation rather than noise, the partial proportional odds model is adopted as the reporting specification and the ordered logit is retained as a restricted reference. Readers who prefer the parsimonious model will find that it does not overturn any conclusion about which variables matter; what it obscures is where in the distribution they matter.

5.3. Partial Proportional Odds Estimates

Table 3 reports the constructs whose coefficients are constant across cut-points. Switching to cheaper products carries the strongest negative effect in this group ($\beta = -0.455$, OR = 0.63, $p < 0.001$), followed in the positive direction by starting to save (OR = 1.44, $p < 0.001$). Three variables that intuition might place among the strongest predictors are statistically indistinguishable from zero once satisfaction is controlled for: an actual decrease in income, a decrease in savings, and the death of a family member. Gender is likewise null, consistent with the descriptive finding that the weighted gender gap in mean hope is zero.

Table 3. Partial Proportional Odds Estimates: Constructs with Constant Effects (weighted)

Construct	Coefficient	Std. error	Odds ratio	95% CI
Gender: female	-0.085	(0.054)	0.919	[0.827, 1.021]
Employment: has job, not working	-0.302	(0.244)	0.740	[0.458, 1.194]
Employment: not working	0.274***	(0.059)	1.315	[1.172, 1.477]
Income decreased	-0.043	(0.063)	0.958	[0.847, 1.084]

Construct	Coefficient	Std. error	Odds ratio	95% CI
Lost job	-0.174	(0.114)	0.841	[0.673, 1.050]
Savings decreased	-0.040	(0.054)	0.960	[0.864, 1.068]
Switched to cheaper products	-0.455***	(0.061)	0.634	[0.562, 0.716]
Started saving	0.364***	(0.075)	1.440	[1.244, 1.666]
Family death	-0.021	(0.072)	0.979	[0.851, 1.127]

Note: Coefficients constrained equal across all three cut-points. Linearised standard errors in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.10. Reference categories: male, never married, employed, no formal schooling.

Table 4 reports the constructs whose effects vary across cut-points, and this is where the restricted model was concealing structure. Taking on debt reduces the odds of clearing the bottom threshold sharply (OR = 0.62, p < 0.001) and the middle threshold appreciably (OR = 0.71, p < 0.001), but has no detectable effect on reaching the top category (OR = 0.96, p = 0.782). Debt, in other words, pushes people into despondency rather than preventing enthusiasm. The mirror image holds for favourable news: an income increase barely moves the bottom threshold (OR = 1.26) but nearly doubles the odds of reporting the highest hope category (OR = 1.96, p < 0.001), and health satisfaction rises in strength across the thresholds (OR = 1.64, 1.72, 2.20). Income satisfaction moves in the opposite direction, strongest at the bottom (OR = 1.82) and weakest at the top (OR = 1.44), suggesting that feeling adequately paid protects against despair more than it produces exuberance.

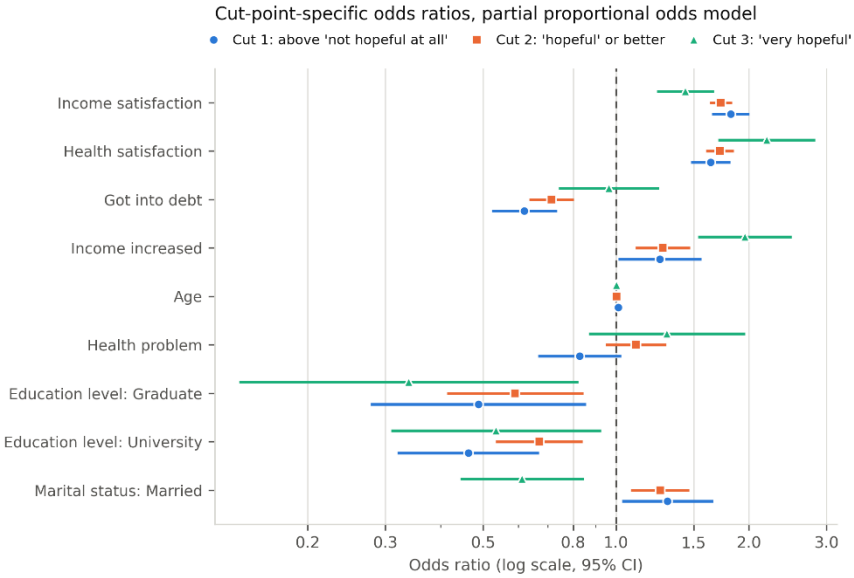
Table 4. Partial Proportional Odds Estimates: Cut-Point-Specific Effects (weighted)

Construct	Cut 1: OR (SE)	Cut 2: OR (SE)	Cut 3: OR (SE)
Marital status: married	1.309** (0.121)	1.260*** (0.078)	0.612*** (0.165)
Marital status: divorced	0.819 (0.183)	0.747** (0.141)	0.695 (0.330)
Marital status: widowed	0.778 (0.235)	1.013 (0.146)	0.410** (0.366)
Education: primary	0.591*** (0.172)	0.903 (0.103)	0.584** (0.254)
Education: secondary	0.548*** (0.204)	0.777** (0.124)	0.838 (0.279)
Education: high school	0.440*** (0.183)	0.755** (0.114)	0.692 (0.274)
Education: university	0.462*** (0.188)	0.670*** (0.116)	0.535** (0.280)
Education: graduate	0.487** (0.287)	0.591*** (0.182)	0.339** (0.452)
Age	1.013*** (0.004)	1.004 (0.002)	1.003 (0.005)
Got into debt	0.620*** (0.087)	0.714*** (0.059)	0.964 (0.134)
Income increased	1.257** (0.111)	1.277*** (0.072)	1.960*** (0.125)
Health problem	0.827* (0.111)	1.110 (0.081)	1.305 (0.208)
Health satisfaction	1.639*** (0.052)	1.719*** (0.037)	2.197*** (0.129)
Income satisfaction	1.819*** (0.050)	1.729*** (0.029)	1.437*** (0.076)

Note: Odds ratios, with the linearised standard error of the underlying coefficient in parentheses. Cut 1 contrasts 'not hopeful at all' against all higher categories; cut 2 contrasts the two lower categories against the two higher; cut 3 contrasts 'very hopeful' against all lower categories. *** p < 0.01, ** p < 0.05, * p < 0.10.

Figure 4 presents the same estimates graphically for the constructs of greatest interest.

Figure 4. Cut-Point-Specific Odds Ratios from the Partial Proportional Odds Model



Source: Authors' calculations, weighted. Horizontal lines are 95% confidence intervals; the dashed line marks an odds ratio of one.

The education gradient is present at every cut-point and is monotone in the restricted model, where the odds ratio falls steadily from 0.81 for primary education to 0.55 for graduate education relative to no formal schooling. In the unrestricted model the effect is concentrated at the extremes: graduate-educated respondents are markedly less likely to clear the bottom threshold (OR = 0.49) and markedly less likely to reach the top category (OR = 0.34) than those with no formal schooling.

5.4. Grouped Shapley Decomposition

Table 5 and Figure 5 report the grouped Shapley decomposition. The weighted linear approximation attains $R^2 = 0.175$, and the Shapley values sum exactly to that total. Income satisfaction is the dominant contributor at 41.7 percent of the explained variance, followed by health satisfaction at 23.2 percent; together the two subjective measures account for 64.9 percent. Objective shocks form a clearly secondary tier led by switching to cheaper products (8.0 percent) and taking on debt (7.3 percent).

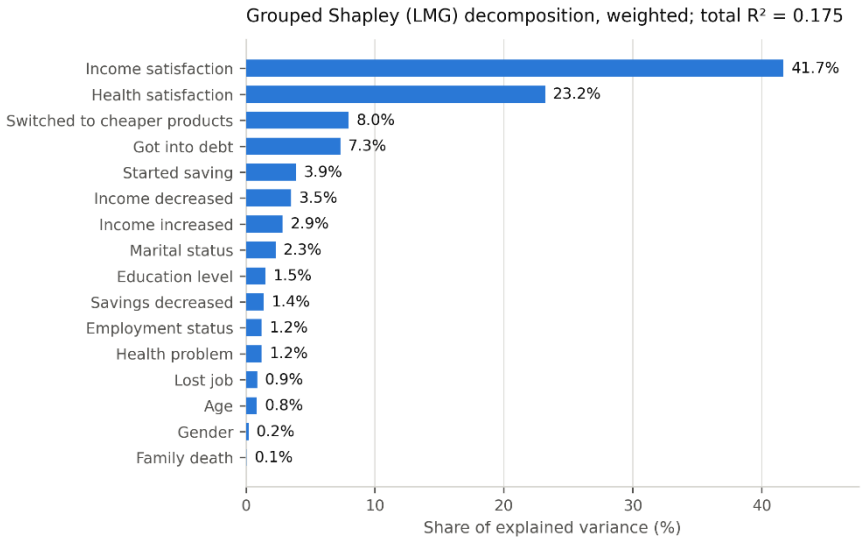
Table 5. Grouped Shapley (LMG) Decomposition of Hope (weighted)

Rank	Construct	Shapley value	% of explained variance
1	**Income satisfaction**	**0.0729**	**41.68%**
2	**Health satisfaction**	**0.0406**	**23.20%**
3	Switched to cheaper products	0.0139	7.97%

Rank	Construct	Shapley value	% of explained variance
4	Got into debt	0.0128	7.31%
5	Started saving	0.0067	3.86%
6	Income decreased	0.0061	3.52%
7	Income increased	0.0050	2.85%
8	Marital status	0.0040	2.30%
9	Education level	0.0026	1.51%
10	Savings decreased	0.0024	1.37%
11	Employment status	0.0021	1.22%
12	Health problem	0.0021	1.21%
13	Lost job	0.0015	0.88%
14	Age	0.0015	0.85%
15	Gender	0.0004	0.21%
16	Family death	0.0001	0.06%

Note: Total $R^2 = 0.175$ from the weighted linear approximation; Shapley values sum exactly to this total. Each categorical construct enters as a single player together with all of its indicator columns.

Figure 5. Grouped Shapley Decomposition: Relative Importance of Constructs for Explaining Hope



Source: Authors' calculations, weighted linear approximation, total $R^2 = 0.175$.

The sharpest contrast is between each subjective measure and its objective counterpart. Income satisfaction contributes 41.7 percent of the explained variance against 3.5 percent for an actual decrease in income, a ratio of roughly twelve to one. Health satisfaction contributes 23.2 percent against 1.2 percent for the occurrence of a health problem, a ratio of roughly nineteen to one. Objective

circumstances are not irrelevant — switching to cheaper products and taking on debt together contribute 15.3 percent — but they operate at a distinctly smaller scale than the evaluative channel.

5.5. Robustness

Four checks support the main specification. First, the multinomial logit, reported as average marginal effects in Table 6, reproduces the sign and significance of every leading effect while discarding the ordinal structure; income satisfaction raises the probability of the modal 'hopeful' category by 9.0 percentage points and lowers the probability of the two negative categories by 10.5 points combined. Second, restricting education to a linear trend in the ordered logit yields a coefficient of −0.102 per level (OR = 0.90, $p < 0.001$), and the indicator estimates in the restricted model are close to monotone, so the linear-trend summary used in much of the literature is defensible here — but it is reported as a restriction that was tested rather than assumed. Third, the fitted probabilities of the partial proportional odds model are monotone for every observation, so the flexibility gained does not come at the cost of an incoherent probability model.

Fourth, all three specifications reach a well-identified optimum. The maximum absolute gradient of the weighted log-likelihood is 1.1×10^{-8} for the ordered logit, 5.9×10^{-8} for the partial proportional odds model and 4.5×10^{-9} for the multinomial logit, so the reported log-likelihoods and information criteria are comparisons between converged models rather than between stopping points of an optimiser. The unweighted ordered logit was additionally checked against an independent implementation and reproduces it to within the tolerance of the latter, and the Brant statistics were verified against a reference implementation of the same test.

Table 6. Multinomial Logit Average Marginal Effects on Outcome Probabilities (weighted, percentage points)

Construct	Not hopeful at all	Not hopeful	Hopeful	Very hopeful
Gender: female	+1.89	-1.08	-0.24	-0.58
Marital status: married	-2.28	-1.83	+6.17	-2.06
Marital status: divorced	+1.07	+4.92	-4.79	-1.21
Marital status: widowed	+1.62	-0.72	+1.82	-2.72
Employment: has job, not working	+0.67	+8.37	-9.17	+0.13
Employment: not working	-2.55	-2.77	+4.68	+0.64
Education: primary	+4.89	-2.23	-0.27	-2.39

Construct	Not hopeful at all	Not hopeful	Hopeful	Very hopeful
Education: secondary	+6.10	+0.08	-4.98	-1.20
Education: high school	+7.94	-1.54	-4.59	-1.81
Education: university	+7.25	+1.09	-5.48	-2.86
Education: graduate	+7.17	+4.15	-7.93	-3.39
Age	-0.10	+0.02	+0.07	+0.01
Income decreased	+0.85	-0.03	-1.16	+0.35
Lost job	+1.83	+2.85	-5.55	+0.88
Got into debt	+4.16	+2.31	-6.17	-0.30
Savings decreased	-0.68	+2.38	-1.71	+0.01
Switched to cheaper products	+4.48	+3.98	-6.06	-2.41
Started saving	-2.55	-3.32	+3.12	+2.75
Income increased	-1.47	-3.18	+1.54	+3.10
Family death	-0.38	+0.80	+0.33	-0.75
Health problem	+1.61	-3.69	+0.80	+1.28
Health satisfaction	-4.02	-6.51	+7.35	+3.18
Income satisfaction	-4.55	-5.94	+9.03	+1.46

Note: Average marginal effects on the probability of each hope category, in percentage points, computed as discrete changes for binary regressors and derivatives for continuous ones. Rows need not sum to zero exactly because of rounding.

5.6. Discussion

Three findings warrant emphasis. First, hope-for-the-future in Türkiye is associated far more strongly with how people evaluate their income and health than with the objective shocks they report having experienced in the past year. The order-of-magnitude gap between subjective and objective contributions appears in both modelling routes: in the ordinal models several objective shocks lose statistical significance once satisfaction is controlled for, and in the Shapley decomposition their percentage contributions fall by roughly an order of magnitude. This is an association, not an identified effect, and the direction of causality is not recoverable from these data.

Second, relaxing the proportional-odds restriction changes the substantive reading rather than merely improving fit. The restricted model reports that debt lowers hope and that income gains raise it; the unrestricted model shows that these operate in different regions of the distribution. Adverse financial commitments are associated with the bottom of the hope distribution, while favourable news and health

satisfaction are associated with the top. A literature that reports only proportional-odds coefficients would systematically miss this asymmetry.

Third, the education gradient is robust to weighting, to indicator coding, and to the relaxation of proportional odds. In a labour market with persistent educated unemployment and uneven returns to formal credentials, additional schooling may raise both expectations and the salience of the gap between expectations and outcomes. That interpretation is consistent with the pattern but is not tested here, and competing explanations — cohort composition, differential response styles, or unobserved differences in reference groups — remain open.

Four limitations should be noted. The cross-sectional design precludes causal inference: the analysis identifies which constructs carry weight in the conditional distribution, not which ones would change hope if manipulated. The use of self-reported subjective measures alongside self-reported objective shocks raises the standard concern about common-method variance, though the size of the gap between the two channels suggests something beyond a pure reporting artefact. The public-use file lacks stratum and cluster identifiers, so the design correction is partial. And the Shapley decomposition rests on a linear approximation of an ordinal outcome, so its percentages should be read as a relative ranking rather than as exact variance shares of the estimated ordinal model.

6. CONCLUSION

This study examined the determinants of hope-for-the-future in Türkiye using the weighted micro-data of the 2024 TurkStat Life Satisfaction Survey. The Brant test rejects proportional odds for eight of sixteen constructs, so a partial proportional odds model is adopted, with ordered and multinomial logit as reference specifications and a grouped Shapley decomposition to quantify relative importance.

Three findings stand out. Subjective satisfaction with income and health dominates the explanatory landscape, accounting for 64.9 percent of the explained variance and exceeding the corresponding objective events by roughly an order of magnitude. Effects are cut-point specific in a way the standard model conceals: indebtedness is associated with the bottom of the hope distribution and has no detectable association with reaching the top, while income gains and health satisfaction are associated most strongly with the top. And more-educated respondents report systematically lower hope, a gradient that survives weighting, indicator coding and the relaxation of proportional odds.

The methodological contribution sits alongside the empirical one. Testing rather than assuming the proportional-odds restriction, coding nominal categories as indicators rather than as scales, applying the sampling weights, and decomposing importance over constructs rather than columns each changed the results in ways that would have been invisible under the conventional specification. Researchers working with ordinal well-being outcomes may find that the same sequence of checks is worth running before interpretation.

The findings suggest hypotheses for policy research rather than costed prescriptions. That perceptions track hope more closely than recorded events does not establish that interventions aimed at perceptions would raise hope, since the association may run through unobserved circumstances that shape both. Whether expectation-management, service-quality improvement, or debt-restructuring instruments actually move forward-looking optimism is an open question that would require panel data or a policy discontinuity to answer. The cut-point asymmetry documented here does suggest where to look: instruments aimed at the lower tail of the distribution and instruments aimed at the upper tail may not be substitutes, and evaluating them as though they were would be a mistake.

REFERENCES

Becchetti, L., & Castriota, S. (2010). The effects of a calamity on income and wellbeing of poor microfinance borrowers: The case of the 2004 tsunami shock. *Journal of Development Studies, 46*(2), 211–233. https://doi.org/10.1080/00220380903002947

Brant, R. (1990). Assessing proportionality in the proportional odds model for ordinal logistic regression. *Biometrics, 46*(4), 1171–1178. https://doi.org/10.2307/2532457

Diener, E., Suh, E. M., Lucas, R. E., & Smith, H. L. (1999). Subjective well-being: Three decades of progress. *Psychological Bulletin, 125*(2), 276–302. https://doi.org/10.1037/0033-2909.125.2.276

Easterlin, R. A. (1974). Does economic growth improve the human lot? Some empirical evidence. In P. A. David & M. W. Reder (Eds.), *Nations and households in economic growth: Essays in honor of Moses Abramovitz* (pp. 89–125). Academic Press.

Frey, B. S., & Stutzer, A. (2002). What can economists learn from happiness research? *Journal of Economic Literature, 40*(2), 402–435. https://doi.org/10.1257/002205102320161320

Grömping, U. (2007). Estimators of relative importance in linear regression based on variance decomposition. *The American Statistician, 61*(2), 139–147. https://doi.org/10.1198/000313007X188252

Hariri, J. G., Bjørnskov, C., & Justesen, M. K. (2016). Economic shocks and subjective well-being: Evidence from a quasi-experiment. *The World Bank Economic Review, 30*(1), 55–77. https://doi.org/10.1093/wber/lhv004

Lindeman, R. H., Merenda, P. F., & Gold, R. Z. (1980). *Introduction to bivariate and multivariate analysis.* Scott, Foresman.

Lipovetsky, S., & Conklin, M. (2001). Analysis of regression in game theory approach. *Applied Stochastic Models in Business and Industry, 17*(4), 319–330. https://doi.org/10.1002/asmb.446

OECD. (2025). *OECD economic surveys: Türkiye 2025.* OECD Publishing.

Snyder, C. R. (2002). Hope theory: Rainbows in the mind. *Psychological Inquiry, 13*(4), 249–275. https://doi.org/10.1207/S15327965PLI1304_01

Snyder, C. R., Harris, C., Anderson, J. R., Holleran, S. A., Irving, L. M., Sigmon, S. T., Yoshinobu, L., Gibb, J., Langelle, C., & Harney, P. (1991). The will and the ways: Development and validation of an individual-differences measure of hope. *Journal of Personality and Social Psychology, 60*(4), 570–585. https://doi.org/10.1037/0022-3514.60.4.570

Stevenson, B., & Wolfers, J. (2008). Economic growth and subjective well-being: Reassessing the Easterlin paradox. *Brookings Papers on Economic Activity, 2008*(1), 1–87. https://doi.org/10.1353/eca.0.0001

Turkish Statistical Institute. (2025). *Life satisfaction survey, 2024* (News Bulletin No. 53785). https://data.tuik.gov.tr/Bulten/Index?p=Yasam-Memnuniyeti-Arastirmasi-2024-53785

Williams, R. (2006). Generalized ordered logit / partial proportional odds models for ordinal dependent variables. *The Stata Journal, 6*(1), 58–82. https://doi.org/10.1177/1536867X0600600104

World Bank. (2024). *Türkiye economic monitor: Charting a course for disinflation.* World Bank.

THE ROLE OF ARTIFICIAL INTELLIGENCE IN HIGHER EDUCATION: A BIBLIOGRAPHIC ANALYSIS

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ABSTRACT

This study examines the evolving role of artificial intelligence (AI) in higher education through a comprehensive bibliometric analysis grounded in socio-technical theory. The dataset was obtained from the Web of Science (WoS) database in March 2026 and includes 10,320 peer-reviewed journal articles published in English between 1975 and 2026. The data were analyzed using VOSviewer software in order to identify the intellectual structure, collaboration patterns, thematic evolution, and emerging research trends in the field. The findings indicate that research on AI in higher education remained relatively limited until the late 2010s but experienced a significant acceleration after 2020, particularly in the post-pandemic period. Publication and citation trends demonstrate that AI has become one of the most rapidly expanding research domains in higher education. The results also reveal that the literature is increasingly shaped by interdisciplinary and collaborative research networks. Co-authorship analyses show that several authors and institutions occupy central bridging positions within the scientific collaboration structure, while citation analyses highlight the emergence of influential scholars and institutions contributing to the intellectual development of the field. Keyword co-occurrence analysis demonstrates that "artificial intelligence" and "higher education" constitute the dominant conceptual foundations of the literature. In addition, emerging themes such as "generative AI," "AI literacy," "ChatGPT," personalized learning, educational technology, and user acceptance have gained substantial visibility in recent years. Bibliographic coupling and co-citation analyses further reveal that the field is transitioning from a fragmented structure toward a more integrated and consolidated research domain. Overall, the findings suggest that AI applications are transforming higher education not only technologically but also organizationally and pedagogically. The study emphasizes that the implications of AI should be evaluated within the broader framework of digital transformation, digital leadership, and changing educational paradigms. Furthermore, the results highlight the growing importance of international collaboration, interdisciplinary integration, and ethical considerations in shaping the future of AI-driven higher education research.

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JEL Codes: *O33, M12, M10, I23.*

1. INTRODUCTION

Digital developments such as artificial intelligence, machine learning, cloud computing, blockchain, fintech, and the internet of things have radically transformed the basic dynamics of many industries (Bughin, Hazan, Sree Ramaswamy, DC, & Chu, 2017), and have also brought about different applications and transformations in the field of education (Balaha & Hassan, 2023). In the post-pandemic period, this transformation has created serious pressure on educational institutions, and educational administrators have focused on managing the digital transformation processes of educational organizations with their digital leadership skills (Leal Filho et al., 2024). Artificial intelligence has had a profound impact on all stakeholders of education at all levels of education, as it has in other areas. Continuous expansion of the capacity of AI technologies in higher education also requires an increase in global cooperation based on general democratic principles that provide mutual benefits (Kavitha, Joshith, Rajeev, & Asha, 2024, p. 1121). The fact that the phenomenon is in its infancy or incipient stage (Hinojo-Lucena, Aznar-Díaz, Cáceres-Reche, & Romero-Rodríguez, 2019) should not lead us to ignore its growing importance.

Despite this importance, it seems that studies on applications of artificial intelligence in higher education have not been addressed sufficiently in the academic field (Bearman, Ryan, & Ajjawi, 2023). Research proposals regarding this transformative role of artificial intelligence in higher education can be found in the literature (George & Wooden, 2023; Katsamakas, Pavlov, & Saklad, 2024; Lytras, Serban, Alkhaldi, Aldosemani, & Malik, 2024). A principal task in educational technology integration is to have interaction college students with unique affective traits. How generation shapes attitude and gaining knowledge of conduct is still lacking (Nazari, Shabbir, & Setiawan, 2021). Researches on using artificial intelligent in higher education institutions focus on personalization systems (Sajja, Sermet, Cikmaz, Cwiertny, & Demir, 2024), software agents and semantic web (Iqbal, Sarwar, Safyan, & Nasralla, 2024), but very little research is related to ethical issues in artificial intelligence (Bearman et al., 2023, p. 371), and other new issues. The majority of the studies involve the adaptation of intelligent systems such as virtual classroom environments, predicting student modes, and discovering students' learning styles (Ganzfried & Yusuf, 2018; Sánchez & Lama, 2007). It has been observed that this situation has led to comments that the education process has been made more efficient by making educational platforms and applications more compatible with the needs and knowledge of the students (Kuleto et al., 2021). The lifestyles of simple desires such as offering students with new competencies and offering a collaborative mastering environment in Higher Education Institutions, which have awesome implications for the close to destiny, is also obtrusive in the literature (Liu, Chen, Huang, Xiao,

& Hei, 2018). Other studies have emphasized that realistic environmental, social, and governance investments are necessary for the long-term benefits and outcomes of permanent education to be widely accepted by individuals and society in the future. However, we still lack approaches that address the phenomenon in a holistic sense, it is seen that there is no holistic and comprehensive evaluation of the transformative role of artificial intelligence applications in higher education and the research conducted is quite limited (Bahroun, Anane, Ahmed, & Zacca, 2023; Ghnemat, Shaout, & Abrar, 2022).

Focusing on this research gap is critical because in recent years, pressures for digital transformation in education have been increasing, especially on the use of AI in higher education, the provision of human resources to the sector by graduates (Pedro, Subosa, Rivas, & Valverde, 2019), human capital of future (Alexander & Belloni, 2024; George & Wooden, 2023), management of generations (Aithal & Aithal, 2020; Chan & Lee, 2023; O'Farrell & Weaver, 2024), and other potential issues. Therefore, addressing this deficiency can develop a deeper understanding of how artificial intelligence applications can lead to the next big change in education, especially for all stakeholders, and not to miss today's digital age (Luan et al., 2020; Pedro et al., 2019). In addition, examining AI applications from the perspective of higher education institutions can guide educational administrators and policy makers as well as state and private sector institutions, accelerate the integration process, and reveal different opportunities in terms of preventing digital resistance (Akarsu & Parmaksiz, 2024) to AI and potential economic and educational integration. From a theoretical perspective, it offers the potential to move socio-technical theory forward.

This research explores the implications for the use of artificial intelligence applications in higher education based on socio-technical theory. The study wants to answer the following two main questions: 1) What are the effects of artificial intelligence applications on the educational curriculum in higher education? 2) What are the main themes and debates in the literature on the use of AI in the post-pandemic period? By focusing on these questions, the study aims to provide an in-depth evaluation of studies that address AI applications from the perspective of higher education institutions through bibliometric analysis.

There is a growing trend in the use of AI in educational institutions (Wadhwani, 2023). This situation contains important opportunities for higher education institutions. Examining AI applications in the context of higher education institutions from many perspectives, from reshaping the curriculum to coping with digital illiteracy, from accreditation and compliance of programs to student assessment activities, can provide valuable contributions in theoretical and practical terms.

10320 articles obtained from the WoS database using the bibliography technique, one of the quantitative research methods, were analyzed using the Vos viewer software. In addition, digital transformation needs to be addressed in the context of artificial intelligence applications in educational institutions. Moreover, since different fields of science within higher education use different

methodologies and curricula, traces of the existence of the transformative effects of artificial intelligence in each science were found in the findings of the study.

The contributions of the research can be grouped under three headings. First, we develop the studies of recent years that emphasize the importance of artificial intelligence applications for educational institutions (Bearman et al., 2023; Crompton & Burke, 2023; Kuleto et al., 2021; Nazari et al., 2021). In this way, we have responded to calls for research in this area by providing theoretical (Yu, Xu, & Ashton, 2023) and empirical contributions (Zouhaier, 2023) to the foundations of socio-technical learning in general and flexible learning in particular. Secondly, we presented evidence that artificial intelligence can have transformative effects on educational institutions through the axis of management of generation and digital transformation. Thus, we contributed to advancing the literature on the role and implementation of artificial intelligence applications in higher education institutions. In this context, we enriched the literature by responding to calls for more research in related areas (Bond et al., 2024; Marengo, Pagano, Pange, & Soomro, 2024). Finally, we tried to integrate the view of the literature on artificial intelligence applications in higher education institutions with bibliographic methods and present an in-depth picture.

In the second section following the introduction, we present the theoretical background of using AI in higher education institutions. Brief information about socio technical theory is given which is derived from the literature. In the third section, we explain the methodology of the bibliometric study in detail. In the fourth section, we present the findings and conclusions of the study. In conclusion, this study presents its theoretical contributions, managerial implications, research limitations, and suggestions for future research.

2. THEORETICAL BACKGROUND

2.1. Socio Technic Theory

Organizational improvement efforts must consider how changes impact the various interconnected systems, as they are all interdependent (Appelbaum, 1997). When implementing technological advancements, organizational change requires a “flexible, customized change model… rooted in a socio-technical foundation” that aligns with the social structure of the organization where the technology is introduced (Emery & Trist, 1960). The technical subsystem is responsible for transforming the system’s inputs into outputs, and this process aims to increase the efficiency of the overall business system. The social subsystem includes individuals in the organization and their knowledge, skills, attitudes, values, and needs, as well as existing reward and authority structures. These two subsystems must be integrated to effectively facilitate transformation. Socio-technical systems theory asserts that achieving desired outcomes is only possible when the interdependence of these subsystems is explicitly acknowledged and managed (Bostrom, Gupta, & Thomas, 2009, p. 18). This

theory significantly contributes to work redesign in self-managed work organizations and provides a valuable framework for integrating technological advancements into businesses.

Artificial intelligence (AI) is deeply intertwined with technology, particularly connectivity and interactive systems, including smart products, intelligent machines, and autonomous operators. This necessitates a reassessment of the relationship between humans and technology, as their interaction plays a vital role in socio-technical transformation. Although this approach is rooted in an established perspective, it introduces new possibilities, such as design thinking and technological design. Complexity science represents a shift from reductionist thinking to a more holistic, systemic perspective. The idea that design must consider both social and technical aspects when implementing new technologies or organizational changes has led to the application of socio-technical systems theory across various domains, including technology development and job redesign (Sony & Naik, 2020).

2.2. Artificial Intelligent

McCarthy first introduced the term artificial intelligence (AI) in 1956 (Russell & Norvig, 2010). AI is broadly defined as computer systems that perform cognitive tasks typically associated with human intelligence, such as learning and problem-solving (Zawacki-Richter, Marín, Bond, & Gouverneur, 2019, p. 3). Artificial intelligence, defined as the ability of a system to accurately analyze and interpret large amounts of data and develop self-learning and decision-making models using existing information (Kavitha et al., 2024), finds application in many institutions today. The term AI encompasses a wide range of technologies and methodologies, including machine learning, natural language processing, data mining, neural networks, and algorithms. There are multiple definitions of artificial intelligence; however, this discussion focuses on those relevant to academic institutions. One such definition, provided by Popenici and Kerr (2017, p. 2), describes AI as computing systems capable of engaging in human-like processes such as learning, adapting, synthesizing, self-correction, and utilizing data for complex processing tasks. Luckin, Holmes, Griffiths, and Forcier (2016) classify AI applications in education into three categories: personal tutors, intelligent support for collaborative learning, and intelligent virtual environments. Adaptive learning technology enables students to tailor their educational experiences to their individual needs (Kuleto et al., 2021). Despite the growing presence of AI, Hinojo-Lucena et al. (2019) argue that research on its applications in higher education remains fragmented. This issue has become increasingly evident, particularly in the context of technology management and the restructuring of theoretical frameworks within scientific disciplines that integrate technology with digital transformation. To address this gap in the literature, a bibliometric analysis was conducted to examine the role of artificial intelligence in higher education.

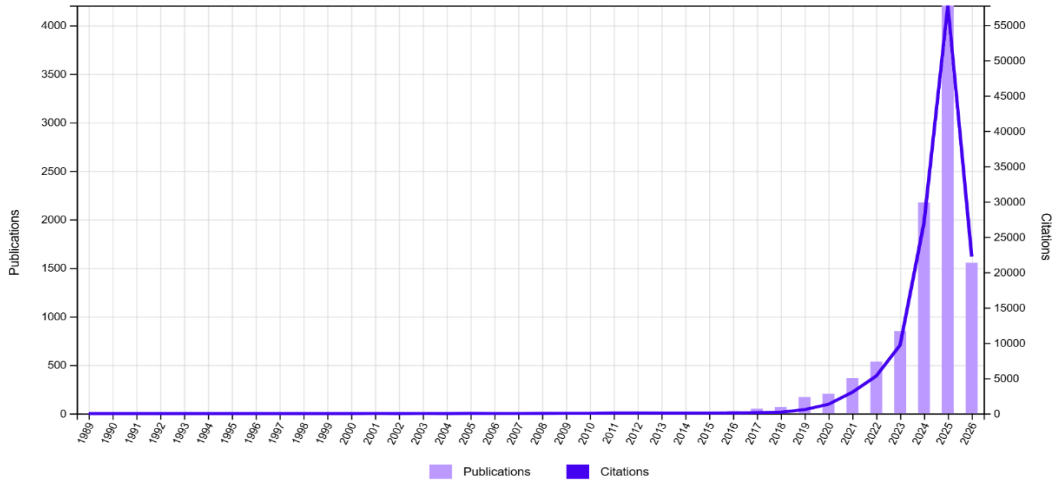
3. METHODOLOGY

3.1. Data, Methodology and Results of the Analysis Process

Bibliometrics is a widely utilized scientific method applied across various disciplines (Zhu et al., 2023). In this study, bibliometric analysis is employed to assess the impact of artificial intelligence in higher education by examining academic publications from the WOS database spanning the years 1975 to 2026. The data was processed using VOSviewer 1.6.19 software, which enables the visualization of research trends, including article and journal productivity, author collaborations, and interconnections between publications (Donthu et al., 2021; Zupic & Čater, 2015).

The process of article retrieval and data collection was carried out in March 2026 using Web of Science (WOS), a well-established and comprehensive database for bibliometric studies (Mongeon & Paul-Hus, 2016). The methodology followed three sequential phases. First, the research topic was defined, and key terms were identified, focusing on AI applications in higher education. A preliminary search was conducted using a search string designed to capture relevant studies, as outlined in Figure 1. To ensure the quality and relevance of the dataset, a set of clearly defined inclusion and exclusion criteria was applied. The analysis was limited to peer-reviewed journal articles published in English within the period from 1975 to 2026. Following this systematic filtering process, a total of 10.320 documents were identified and included in the final dataset.

Figure 1. Distribution of Publications and Cititations on the Implications of Artificial Intelligence Applications in Higher Education in the Web of Science Database According to the Year Range 1975-2026

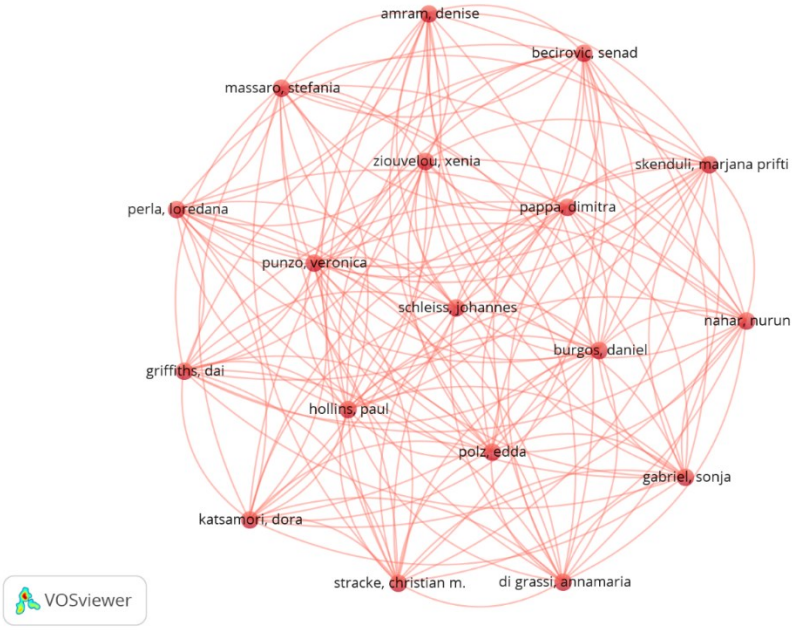


The Figure 1 represents a bibliometric trend analysis of research publications and citations over time. The bar chart (light purple) indicates the number of publications per year, while the line chart (dark blue) represents the number of citations received.

The longitudinal analysis reveals a prolonged dormant phase from 1975 to approximately 2015, during which both publication output and citation impact remained minimal. A gradual emergence is observed after 2016, followed by a notable acceleration beginning in 2020. The most significant structural shift occurs after 2022, where both publications and citations exhibit exponential growth. The

peak in 2025 indicates the highest level of research productivity and impact. The apparent decline in 2026 is attributable to incomplete data and the citation lag effect rather than a true reduction in scholarly activity.

Figure 2. Co-authorship Network

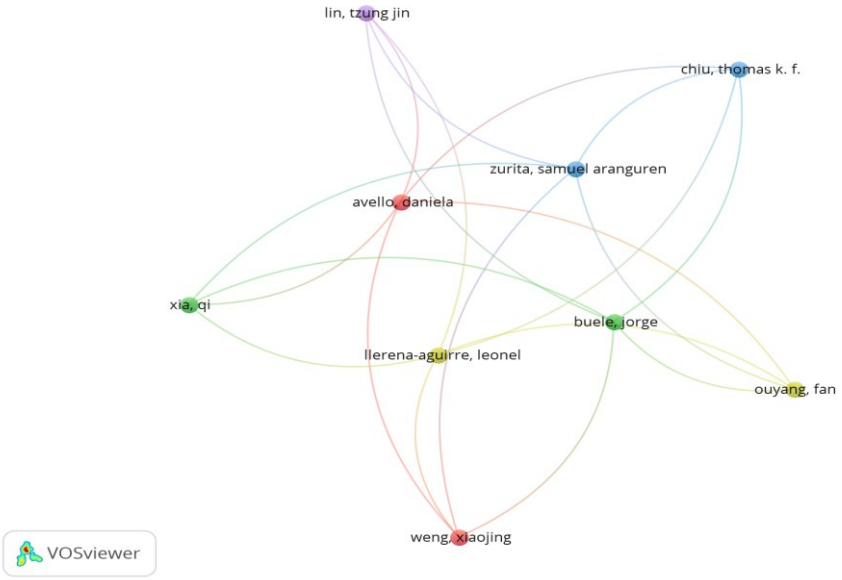


As shown in the Figure 2, the authors form a single, highly integrated cluster. This indicates that the collaboration network is not fragmented but rather concentrated around a closely connected research group. Authors such as Schleiss, Johannes; Pappa, Dimitra; Burgos, Daniel; Ziouvelou, Xenia; Polz, Edda; Nahar, Nurun; and Becirovic, Senad occupy central positions in the network. Their location in the central part of the map suggests that they play a bridging role in connecting different authors within the collaboration structure.

The high number of links among the authors indicates an intensive co-authorship pattern. Rather than isolated individual contributions, the network reflects collaborative research production. This suggests that studies in this field are increasingly shaped by team-based and interdisciplinary academic cooperation.

Overall, the co-authorship map demonstrates that the author collaboration structure is relatively cohesive. The dense connections between nodes reveal that research activity is concentrated within a collaborative author group, highlighting the importance of joint publication practices in the development of the field.

Figure 3. Citation of Authors Analysis

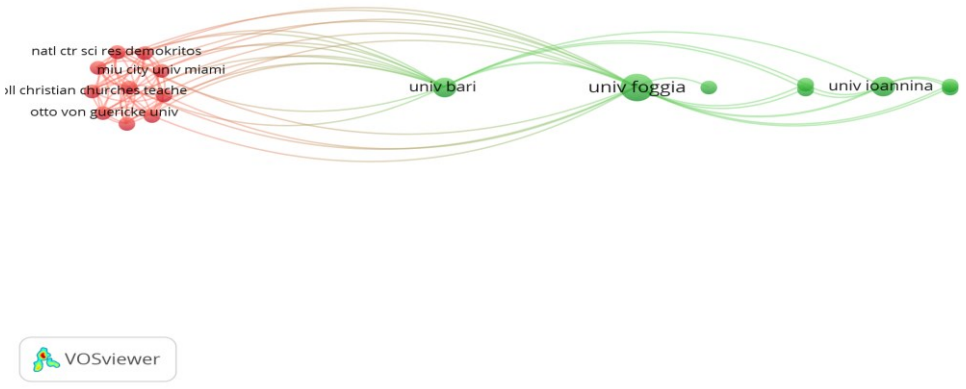


A network map was created to analyse citation relationships among authors based on the criteria that each author must have at least one publication and at least one citation. The analysis was conducted on the authors who met these thresholds and were interconnected within the citation network in Figure 3.

In the analysis, 10 authors (units) were identified as interconnected. The network structure reveals 4 clusters**,** 18 links, and a total link strength of approximately 64**.** These values indicate a relatively small but structured citation network with moderate interconnections among authors. As shown in the figure, authors such as Avello, Daniela; Zurita, Samuel Aranguren; Chiu, Thomas K. F.; and Buele, Jorge occupy central positions within the network. Their placement suggests that they play a key role in connecting different parts of the citation structure. These authors act as bridging nodes**,** facilitating citation flows between clusters. On the other hand, authors such as Lin, Tzung Jin; Xia, Qi; Ouyang, Fan; and Llerena-Aguirre, Leonel are positioned more peripherally, indicating relatively weaker citation connections compared to the central nodes.

The most cited authors in the network are Avello, Daniela**,** Zurita, Samuel Aranguren**,** and Chiu, Thomas K. F.**,** as reflected by their larger node sizes. However, similar to findings in previous studies, these authors are not necessarily the most central in terms of total link strength. Instead, authors such as Buele, Jorge and Weng, Xiaojing exhibit stronger connectivity, indicating higher integration within the citation network.

Figure 4. Citation of Organizations Analysis



The Figure 4 represents the collaboration between different researchers based on their co-authored publications.

In order to examine inter-institutional citation relationships, a network map was constructed based on the criteria that each institution must have published at least one document and received at least one citation. The analysis was conducted on the institutions that met these thresholds and were interconnected within the citation network.

The results reveal a structured network consisting of several interconnected institutions. The map indicates the presence of distinct clusters, reflecting institutional groupings based on citation relationships. In total, the network demonstrates a moderate level of connectivity, with multiple links forming between institutions and a noticeable variation in link strength.

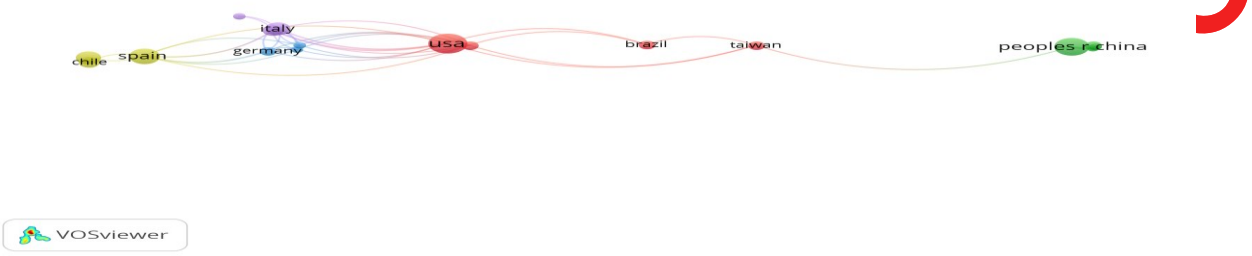
As illustrated in the Figure 4, institutions such as University of Foggia**,** University of Bari**,** and University of Ioannina occupy central positions within the network. These institutions appear to play a key role in bridging citation flows between different parts of the network. Their relatively larger node sizes indicate higher citation impact or publication output compared to other institutions.

On the other hand, a group of institutions including National Centre for Scientific Research Demokritos**,** Miami City University**,** Otto von Guericke University**,** and Christian Churches Teaching Institutions forms a separate cluster. This cluster is connected to the central network through weaker or fewer links, suggesting more limited citation interaction with the core institutions.

Overall, the network structure indicates that citation activity is partially concentrated around a core group of institutions, while peripheral institutions remain less integrated. The presence of multiple

clusters suggests that institutional collaboration and citation patterns are still developing and not yet fully consolidated.

Figure 5. Citation of Countries Analysis



In order to examine citation relationships between countries, a network map was constructed based on the criteria that each country must have at least one publication and at least one citation. The analysis was carried out on the countries that met these thresholds and were interconnected within the citation network in Figure 5.

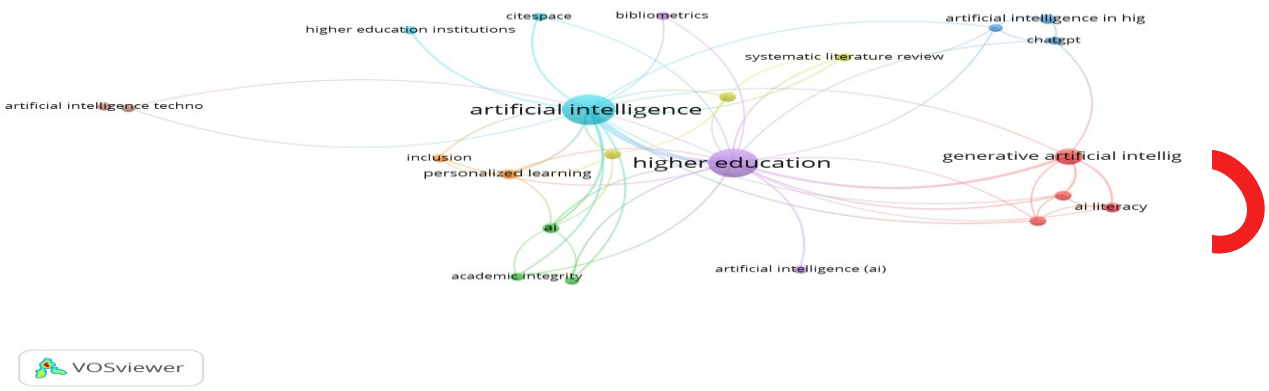
The results reveal a structured network composed of multiple interconnected countries. The map indicates the presence of distinct clusters, reflecting country groupings based on citation relationships. Overall, the network demonstrates a moderate level of connectivity, with numerous links formed between countries and varying degrees of connection strength.

As illustrated in the figure, the United States (USA) occupies the most central position within the network. Its relatively larger node size indicates both a higher number of publications and a greater citation impact. The USA also acts as a key hub, connecting several countries such as Italy, Germany, Spain, Brazil, and Taiwan, highlighting its dominant role in the global citation structure.

European countries, particularly Italy, Germany, and Spain, form a closely connected cluster with strong mutual citation links. This suggests a regional concentration of research collaboration and knowledge exchange. On the other hand, countries such as Brazil and Taiwan appear to be connected to the core network primarily through the USA, indicating a more dependent or indirect citation relationship.

Furthermore, People's Republic of China is positioned at the periphery of the network, connected through fewer but distinct links. This suggests that although it contributes to the citation network, its integration with the central cluster is relatively limited compared to other major contributors.

Figure 6. Co-occurrence of Author Key Words Analysis



A network map was created to analyse keyword co-occurrence patterns based on the criterion that each keyword must appear at least 2 times in the dataset. The analysis was conducted on the keywords that met this threshold and were interconnected within the network structure.

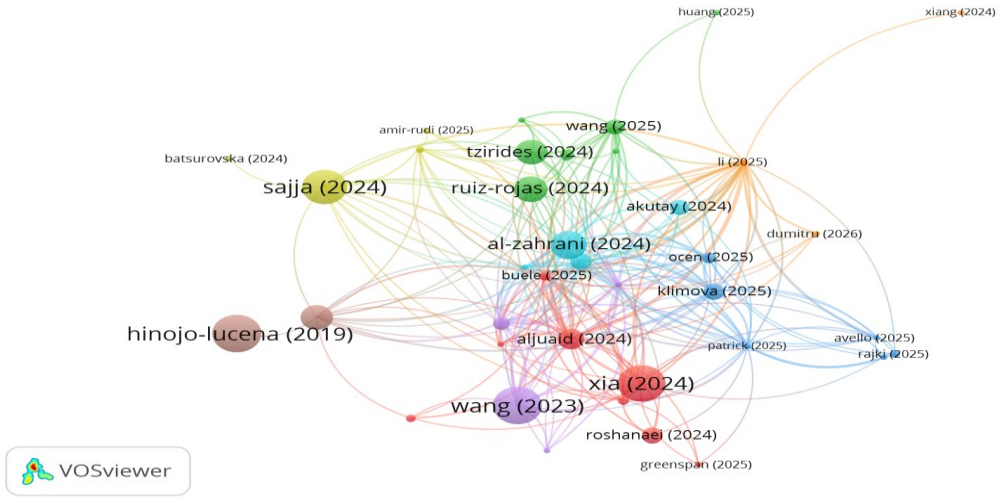
The results reveal a total of 13 keywords (units) forming 3 distinct clusters, with 32 links and a total link strength of approximately 118**.** These values indicate a moderately dense keyword network, reflecting the thematic structure of the research field.

When the most frequently used keywords are examined, “artificial intelligence” and “higher education” emerge as the dominant terms, as indicated by their larger node sizes. These keywords also demonstrate the highest total link strength, suggesting that they are the central concepts around which the literature is structured.

In terms of cluster structure, three main thematic areas can be identified. The first cluster focuses on core educational applications of artificial intelligence, including keywords such as *education, educational technology, personalized learning,* and *challenges*. The second cluster represents technology adoption and user-oriented perspectives, incorporating keywords such as *technology, user acceptance,* and *artificial intelligence in higher education*. The third cluster highlights emerging trends related to generative AI**,** including *generative artificial intelligence, generative AI,* and *AI literacy*, with “ChatGPT” appearing as a key contemporary term within this group.

The analysis also shows that keywords related to generative AI are positioned more peripherally but are strongly connected to the central concepts, indicating that this theme is relatively new but rapidly integrating into the field.

Figure 7. Bibliographic Coupling of Documents Analysis



A network map was created to examine bibliographic coupling relationships among publications based on the criterion that each document must have at least one citation and at least one link with another document. Bibliographic coupling refers to the extent to which two publications cite the same references.

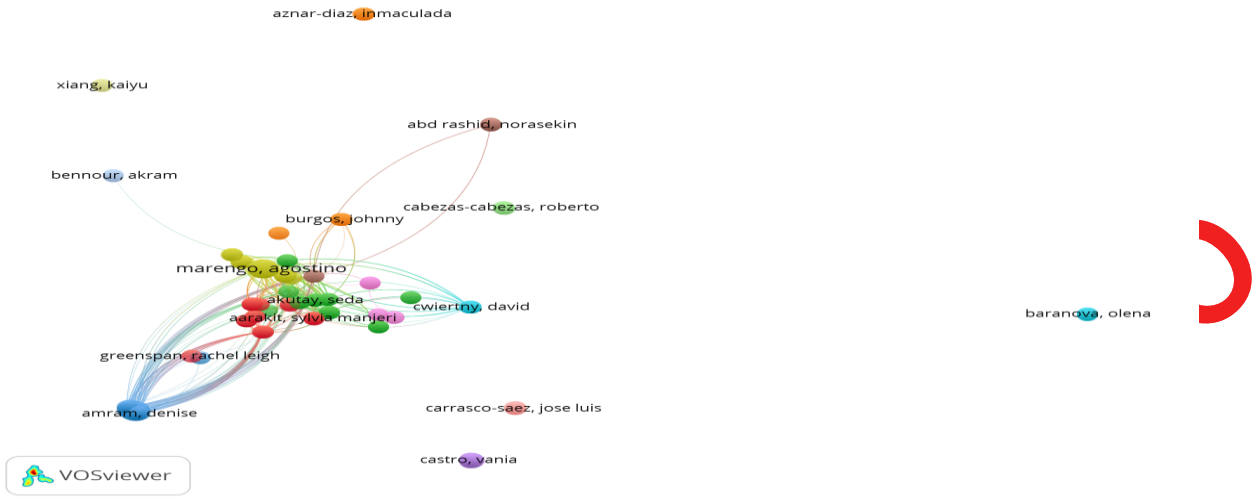
According to the analysis, a total of 731 publications (units) were identified as interconnected within the network. The structure consists of 25 clusters, 4,069 links, and a total link strength of 7,237, indicating a highly dense and strongly connected network of shared references.

As illustrated in the Figure 7, several publications occupy central positions within the network, particularly Xia (2024), Al-Zahrani (2024), Ruiz-Rojas (2024), Sajja (2024), and Wang (2025). The larger node sizes of these studies indicate a higher number of bibliographic connections, suggesting that they share a substantial number of references with other publications and thus play a key role in structuring the intellectual base of the field.

The clustering structure reveals distinct thematic groupings. While earlier works such as Hinojo-Lucena (2019) appear more peripheral, more recent publications (2023–2025) are densely interconnected, indicating a shift toward a more cohesive and rapidly expanding research front.

In terms of total link strength, the most influential works are those that are highly integrated into the network rather than necessarily the most cited. This confirms that citation count and bibliographic coupling strength do not always overlap, as some studies may be highly cited but not strongly connected through shared references.

Figure 8. Bibliographic Coupling of Authors Analysis

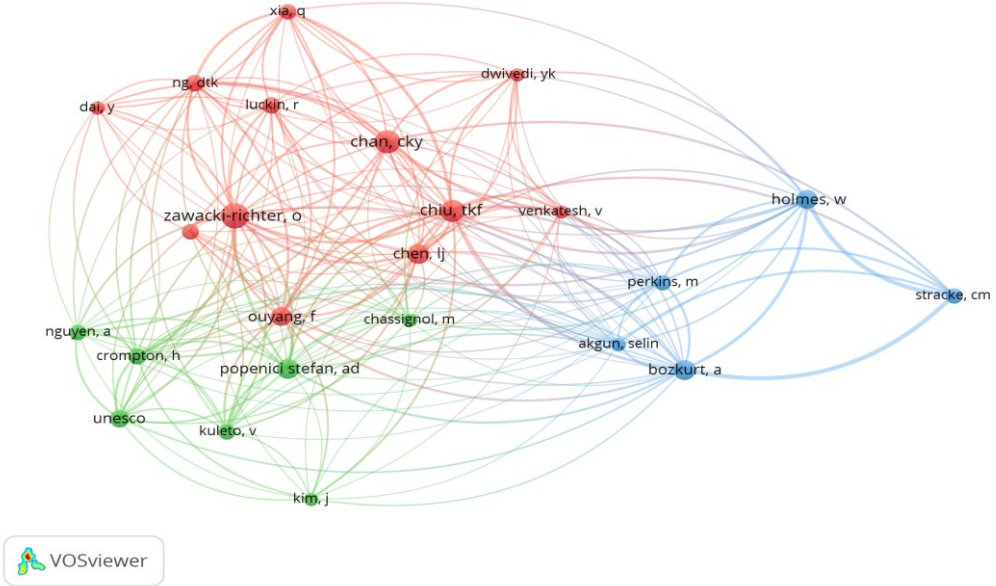


The network map shows the bibliographic coupling relationships among authors based on shared references. The structure reveals a dense central cluster and several peripheral authors**.**

Authors such as Marengo, Agostino; Amram, Denise; and Arakiti, Sylvia Manjeri are centrally positioned, indicating strong coupling and a key role in shaping the field. In contrast, authors like Baranova, Olena and Aznar-Diaz, Inmaculada are weaklier connected.

Overall, the network reflects *a* core–periphery structure, suggesting that the field is becoming more consolidated around a group of closely related studies.

Figure 9. Co-citation of Co-authors Analysis



The co-citation network map was constructed based on authors cited together in the same publications. The results show a dense and well-connected structure consisting of several clusters.

Authors such as Chan, C.K.Y.; Chiu, T.K.F.; and Chen, L.J. are positioned at the center, indicating high co-citation frequency and strong influence. In contrast, authors like Holmes, W. and Bozkurt, A. form a separate cluster with strong internal connections but fewer links to the core.

Overall, the network reflects a multi-clustered but integrated structure, suggesting that the field is built on several key intellectual groups that are increasingly interconnected.

4. CONCLUSION

This study provides a comprehensive overview of academic research on artificial intelligence in higher education based on data obtained from the Web of Science database. The descriptive and relational analyses reveal that although the roots of the field can be traced back to earlier years, the number of publications remained limited until the late 2010s. A substantial increase in research output has been observed particularly after 2022, indicating a rapid expansion of scholarly interest in this area. In terms of institutional contributions, universities such as University of Foggia, University of Bari, and University of Ioannina stand out as key actors within the network. At the same time, the most influential institutions in terms of citation impact are concentrated in a relatively small group, suggesting a partially centralized knowledge structure. The findings also show that the majority of studies are published in English, reflecting the global nature of the research field. Author-based analyses indicate that certain researchers play a central role in shaping the intellectual structure, while others remain more peripheral despite contributing to the literature. Bibliometric analyses further demonstrate that core concepts such as “artificial intelligence” and “higher education” dominate the field, while emerging themes including “generative AI,” “AI literacy,” and “ChatGPT” have recently gained prominence. This shift highlights the evolving nature of the research landscape and the increasing influence of new technological developments. Another important finding is that highly cited authors are not always the most structurally central in the network in terms of total link strength. This indicates that citation impact and network centrality do not necessarily overlap, reflecting different dimensions of academic influence. Overall, the study suggests that the field is transitioning from an emerging research area to a more structured and rapidly expanding domain. The findings of this study demonstrate that artificial intelligence has evolved from a peripheral technological topic into a central research domain within higher education.

The rapid increase in publications after the post-pandemic period indicates that universities and researchers increasingly perceive AI not only as a technological innovation but also as a transformative force reshaping educational systems, learning environments, and academic management processes. In this respect, the findings support the assumptions of socio-technical theory by showing that technological transformation in higher education is closely intertwined with organizational structures, human interaction, and institutional adaptation processes. Another important implication of the study is the growing prominence of generative AI-related themes such as ChatGPT and AI literacy. This transformation suggests that the focus of the literature is shifting from operational educational

technologies toward more strategic, ethical, and pedagogical debates. The collaborative and interdisciplinary structure observed in the co-authorship and citation networks also indicates that AI research in higher education increasingly requires cross-disciplinary knowledge integration and international cooperation. Furthermore, the findings reveal that citation impact and structural centrality do not always overlap. Some authors and institutions play a more influential role in connecting the intellectual structure of the field despite not having the highest citation counts. This highlights the importance of network-based academic influence alongside traditional citation-based measures.

4.1. Limitations

This study has several limitations. First, the analysis was limited to publications indexed in the Web of Science database and written in English, which may exclude relevant studies published in other databases and languages. Second, the study employed bibliometric methods that focus on quantitative relationships between publications rather than the in-depth qualitative content of the studies. Finally, due to the rapidly evolving nature of artificial intelligence technologies, the research landscape may continue to change significantly in a short period of time. Future research should focus on strengthening international collaboration, enhancing interdisciplinary approaches, and deepening the theoretical foundations of the field in order to sustain its long-term development.

4.2. Future Research

Future studies may expand the analysis by including different databases such as Scopus or Dimensions and by conducting comparative cross-database evaluations. In addition, qualitative and mixed-method research designs could provide deeper insights into the ethical, pedagogical, and managerial implications of AI in higher education. Future research may also focus specifically on generative AI, digital leadership, AI literacy, and the long-term institutional transformation of universities in the context of digitalization.

REFERENCES

Aithal, S., & Aithal, S. (2020). Conceptual analysis on higher education strategies for various tech-generations.

Akarsu, O., & Parmaksiz, H. (2024). Dijital Çağda Değişim ve Direnç. In Ö. H. Özcan (Ed.), *Yönetim ve Organizasyon Alanında Uluslararası Araştırmalar –III (International Research in the Field of Management and Organization III)* (pp. 113-140). Konya: Eğitim Yayınevi.

Alexander, W. R. J., & Belloni, R. (2024). Artificial Intelligence and the Sustainability of the Signaling and Human Capital Roles of Higher Education. *Sustainability, 16*(20), 8802.

Appelbaum, S. H. (1997). Socio-technical systems theory: an intervention strategy for organizational development. *Management Decision, 35*(6), 452-463.

Bahroun, Z., Anane, C., Ahmed, V., & Zacca, A. (2023). Transforming education: A comprehensive review of generative artificial intelligence in educational settings through bibliometric and content analysis. *Sustainability, 15*(17), 12983.

Balaha, H. M., & Hassan, A. E.-S. (2023). Comprehensive machine and deep learning analysis of sensor-based human activity recognition. *Neural Computing and Applications, 35*(17), 12793-12831.

Bearman, M., Ryan, J., & Ajjawi, R. (2023). Discourses of artificial intelligence in higher education: A critical literature review. *Higher education, 86*(2), 369-385.

Bond, M., Khosravi, H., De Laat, M., Bergdahl, N., Negrea, V., Oxley, E., . . . Siemens, G. (2024). A meta systematic review of artificial intelligence in higher education: A call for increased ethics, collaboration, and rigour. *International journal of educational technology in higher education, 21*(1), 4.

Bostrom, R. P., Gupta, S., & Thomas, D. (2009). A meta-theory for understanding information systems within sociotechnical systems. *Journal of management information systems, 26*(1), 17-48.

Bughin, J., Hazan, E., Sree Ramaswamy, P., DC, W., & Chu, M. (2017). Artificial intelligence the next digital frontier.

Chan, C. K. Y., & Lee, K. K. (2023). The AI generation gap: Are Gen Z students more interested in adopting generative AI such as ChatGPT in teaching and learning than their Gen X and millennial generation teachers? *Smart learning environments, 10*(1), 60.

Crompton, H., & Burke, D. (2023). Artificial intelligence in higher education: the state of the field. *International journal of educational technology in higher education, 20*(1), 22.

Emery, F. E., & Trist, E. L. (1960). Socio-technical systems. *Management science, models and techniques, 2*, 83-97.

Ganzfried, S., & Yusuf, F. (2018). Optimal weighting for exam composition. *Education Sciences, 8*(1), 36.

George, B., & Wooden, O. (2023). Managing the strategic transformation of higher education through artificial intelligence. *Administrative Sciences, 13*(9), 196.

Ghnemat, R., Shaout, A., & Abrar, M. (2022). Higher Education Transformation for Artificial Intelligence Revolution: Transformation Framework. *Int. J. Emerg. Technol. Learn., 17*(19), 224-241.

Hinojo-Lucena, F.-J., Aznar-Díaz, I., Cáceres-Reche, M.-P., & Romero-Rodríguez, J.-M. (2019). Artificial intelligence in higher education: A bibliometric study on its impact in the scientific literature. *Education Sciences, 9*(1), 51.

Iqbal, M., Sarwar, S., Safyan, M., & Nasralla, M. (2024). Personalized and adaptive e-learning systems for semantic Web: a systematic review and roadmap. *International Journal of Web Information Systems*.

Katsamakas, E., Pavlov, O. V., & Saklad, R. (2024). Artificial intelligence and the transformation of higher education institutions: A systems approach. *Sustainability, 16*(14), 6118.

Kavitha, K., Joshith, V., Rajeev, N. P., & Asha, S. (2024). Artificial intelligence in higher education: A bibliometric approach. *European Journal of Educational Research, 13*(3), 1121-1137.

Kuleto, V., Ilić, M., Dumangiu, M., Ranković, M., Martins, O. M., Păun, D., & Mihoreanu, L. (2021). Exploring opportunities and challenges of artificial intelligence and machine learning in higher education institutions. *Sustainability, 13*(18), 10424.

Leal Filho, W., Lange Salvia, A., Beynaghi, A., Fritzen, B., Ulisses, A., Avila, L. V., . . . Mifsud, M. (2024). Digital transformation and sustainable development in higher education in a post-pandemic world. *International Journal of Sustainable Development & World Ecology, 31*(1), 108-123.

Liu, S., Chen, Y., Huang, H., Xiao, L., & Hei, X. (2018). *Towards smart educational recommendations with reinforcement learning in classroom.* Paper presented at the 2018 IEEE international conference on teaching, assessment, and learning for engineering (TALE).

Luan, H., Geczy, P., Lai, H., Gobert, J., Yang, S. J., Ogata, H., . . . Tsai, C.-C. (2020). Challenges and future directions of big data and artificial intelligence in education. *Frontiers in Psychology, 11*, 580820.

Luckin, R., Holmes, W., Griffiths, M., & Forcier, L. (2016). Intelligence Unbound: The Future of Uploaded and Machine Minds: Wiley.

Lytras, M. D., Serban, A. C., Alkhaldi, A., Aldosemani, T., & Malik, S. (2024). Transformative Learning for Future Higher Education: The Artificial Intelligence-enabled Learning Revolution 2035 *Digital Transformation in Higher Education, Part B* (pp. 231-241): Emerald Publishing Limited.

Marengo, A., Pagano, A., Pange, J., & Soomro, K. A. (2024). The educational value of artificial intelligence in higher education: A 10-year systematic literature review. *Interactive Technology and Smart Education, 21*(4), 625-644.

Mongeon, P., & Paul-Hus, A. (2016). The journal coverage of Web of Science and Scopus: a comparative analysis. *Scientometrics, 106*, 213-228.

Nazari, N., Shabbir, M. S., & Setiawan, R. (2021). Application of Artificial Intelligence powered digital writing assistant in higher education: randomized controlled trial. *Heliyon, 7*(5).

O'Farrell, J., & Weaver, C. (2024). Technology and transformation: Redefining higher education for Generations Z and Alpha. *Available at SSRN 4833043*.

Pedro, F., Subosa, M., Rivas, A., & Valverde, P. (2019). Artificial intelligence in education: Challenges and opportunities for sustainable development.

Popenici, S. A., & Kerr, S. (2017). Exploring the impact of artificial intelligence on teaching and learning in higher education. *Research and practice in technology enhanced learning, 12*(1), 22.

Russell, S., & Norvig, P. (2010). Artificial intelligence: a modern approach. 3rd. *Upper Saddle River, EUA: Prentice-Hall*.

Sajja, R., Sermet, Y., Cikmaz, M., Cwiertny, D., & Demir, I. (2024). Artificial intelligence-enabled intelligent assistant for personalized and adaptive learning in higher education. *Information, 15*(10), 596.

Sánchez, E., & Lama, M. (2007). Monograph: Artificial intelligence techniques applied to education. *Iberoam. J. Artif. Intell, 11*, 7-12.

Sony, M., & Naik, S. (2020). Industry 4.0 integration with socio-technical systems theory: a systematic review and proposed theoretical model. *Technology in Society, 61*, 101248.

Wadhwani, P. (2023). AI in education market size—By component (solution, service), by deployment (on premise, cloud), by technology (machine learning, deep learning, natural

language processing), application, end-use & forecast, 2023–2032. *Global Market Insights Inc. https://www. gminsights. com/industry-analysis/artificial-intelligence-ai-in-education-market*.

Yu, X., Xu, S., & Ashton, M. (2023). Antecedents and outcomes of artificial intelligence adoption and application in the workplace: the socio-technical system theory perspective. *Information Technology & People, 36*(1), 454-474.

Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2019). Systematic review of research on artificial intelligence applications in higher education–where are the educators? *International journal of educational technology in higher education, 16*(1), 1-27.

Zouhaier, S. (2023). The impact of artificial intelligence on higher education: An empirical study. *European Journal of Educational Sciences, 10*(1), 17-33.

AN ASSESSMENT OF SOLAR ENERGY INSTALLED CAPACITY IN CHINA FROM THE PERSPECTIVE OF REGIONAL TOTAL FACTOR PRODUCTIVITY

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ABSTRACT

This study aims to examine the effect of the expansion of solar photovoltaic installed capacity on regional green total factor productivity in China, and to determine how this effect varies with the absorptive capability of the transmission network. For this purpose, a balanced panel data set covering 30 Chinese provinces over the 2010–2023 period, comprising 420 observations, has been formed. The dependent variable, green total factor productivity, is measured through the Global Malmquist–Luenberger (GML) index estimated by Data Envelopment Analysis, in which carbon dioxide emissions are incorporated into the technology as an undesirable output. Two-way fixed effects panel regression and the Hansen (1999) threshold regression model are employed jointly. The findings show that green productivity improved at an average annual rate of 1.34% at the national level, while the productivity gap between the Eastern and Western regions widened rather than narrowed. The interaction between solar installed capacity and the curtailment rate is negative and statistically significant ($\beta=-0.0285$; $p=0.007$). Threshold estimation identifies a significant breakpoint in interprovincial transmission line capacity at 23.71 GW (bootstrap $p=0.007$). The results reveal that capacity expansion alone is not sufficient in China, and that the productivity dividend of renewable investment is conditional upon the absorptive capacity of the transmission infrastructure.

Keywords: *Renewable Energy, Green Total Factor Productivity, Solar Energy, Panel Data Analysis, Regional Asymmetry, Threshold Regression, China.*

JEL Codes: *Q42, Q43, O47, R11, C23, O13.*

1. INTRODUCTION

The concept of productivity is generally measured as the output-to-input ratio. Although indices have their own specific areas of use, the most commonly utilized types are partial and total factor productivity indices. Partial productivity indices correspond to the average products of labor and capital, whereas total factor productivity (TFP) is expressed as the output per unit of labor and capital (Nadiri, 1970). Total factor productivity is one of the key concepts used in assessing economic performance. Increases in labor and capital inputs used in production can explain output growth only to a certain

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extent. The portion of growth that cannot be explained by increases in input quantities, also known as the "Solow Residual", corresponds to total factor productivity (Işık, 2016). Indeed, according to Domar (1961), total factor productivity constitutes the unexplained part of output change after accounting for changes in input utilization. If the production function is of the Cobb-Douglas type, if perfect competition conditions prevail in factor markets, and if the growth rates of inputs and outputs can be accurately measured, the Solow Residual can properly measure total factor productivity (Comin, 2010). Factor productivity plays a significant role in differences in per capita income across countries, in economic fluctuations, and in economic growth. According to Solow, in an economy with a neoclassical production function, long-term growth in per capita income is closely related to increases in total factor productivity (Solow, 1956).

Efficiency measurement primarily employs parametric and non-parametric methodological approaches. Among non-parametric methods, Data Envelopment Analysis (DEA) is the most widely utilized. Developed based on Farrell's 1957 proposal of the "Production Frontier Function," DEA was subsequently advanced by Charnes, Cooper, Banker, and Rhodes. This analysis makes it possible to compare input and output values with different measurement units by constructing the relative performance of decision-making units (DMUs), thereby identifying units with low efficiency and providing insights into how their efficiency can be improved (Dinçer, 2008; Cingi and Tarım, 2000). While DEA was initially used to assess the relative efficiency of different units, it has subsequently been employed to measure the total factor productivity of decision-making units (Rath et al., 2019).

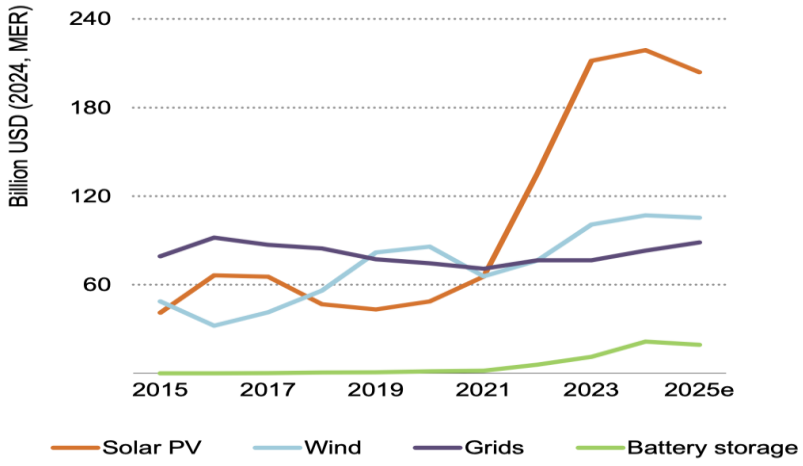
A decision-making unit identified as efficient by Data Envelopment Analysis may lose its efficiency over time. To capture the evolution of efficiency across periods, the Malmquist Total Factor Productivity (TFP) Index, which incorporates a temporal dimension, was developed (Dinçer, 2008). However, this index is insufficient in analyzing the adverse effects of undesirable outputs on productivity values. The Malmquist-Luenberger Total Factor Productivity Index, a modified version of the Malmquist TFP, was introduced by Chung, Färe, and Grosskopf in 1997, incorporating undesirable outputs into the analysis using linear distance functions (Bağrıaçık et al., 2022). In its revised form, the index enables the measurement of changes in total factor productivity by including undesirable or harmful outputs, such as environmental pollution or carbon emissions. Consequently, literature has increasingly featured analyses of green total factor productivity, which account for negative environmental externalities or energy consumption, rather than relying solely on traditional total factor productivity measures.

Studies on energy consumption occupy a significant place in the economics literature. Although the findings of research examining the relationship between energy consumption and economic growth are mixed, energy remains an indispensable component of the growth dynamics of any economy. As a fundamental input, energy is an integral part of production processes. Additionally, the sources from which consumed energy is derived are of great importance. Renewable energy sources are becoming

increasingly crucial for achieving environmental sustainability. Consequently, environmentally conscious energy investments, particularly in solar and wind power, are coming to the forefront.

When examining the distribution of renewable energy investments by country, China stands out prominently. China alone accounts for one-third of global energy investments. According to data from the International Energy Agency, China invested $625 billion in renewable energy in 2024 (IEA, 2025). This amount is twice the level of investments made in 2015. Moreover, China achieved its 2030 wind and solar energy capacity targets as early as 2024. While the installation of renewable energy systems in the country is expected to continue, investment growth is projected to slow in 2025, with a decline anticipated specifically in solar energy.

Graph 1. Investment in Selected Clean Energy Sectors in China (2105-2025e)



Source: IEA, 2025.

The primary determinant of China's energy investments has been the country's shifting macroeconomic priorities. It is also expected that renewable energy investments will be influenced by forthcoming changes in macroeconomic policies. Although China achieved 5% growth in 2024, negative factors such as weakening domestic consumption, deflation risks, and the ongoing real estate crisis have created various pressures on the economy. Following years of expansion in energy supply, China has recently prioritized the efficient utilization of energy capacity and the maintenance of industrial competitiveness. The energy sector, long dominated by state-owned enterprises and large-scale, state-financed projects, has begun to shift towards a structure that increasingly encourages private sector participation. Particularly in strategically important areas such as energy storage, nuclear energy, oil and gas exploration, and mining, policies are being implemented to promote private sector involvement. In 2024, private sector participation was facilitated in over 8,000 projects (IEA, 2025). In 2025, the National Energy Administration of China introduced additional measures to support the private sector in traditionally state-dominated fields such as renewable energy, storage, digitalization, hydropower, and transmission. The presence of the private sector is indispensable for the transformation

of the energy industry, and China has accelerated this transformation by gradually opening up its strategically important sectors to private enterprises. While the Chinese government maintains its leadership in energy investments, it is now designing a long-term transformation process to foster a dynamic investment environment under its newly assumed role.

In addition to these ongoing transformation efforts in the energy sector, the emergence of current problems also indicates a need for restructuring within the sector. It faces major challenges related to excess supply and the transmission of energy. These issues are particularly significant in the context of solar energy production.

China added 277 GW of installed solar power capacity in 2024 and 315 GW in 2025. In 2025, it accounted for more than half of global solar energy production. Significant investments in domestic solar energy production, along with national initiatives such as the Golden Sun Program, have established China as a leader in the solar energy sector. However, the rapidly growing capacity experienced a sharp decline, dropping by 79% to 10 GW in April 2026 (CarbonBrief, 2026). The Chinese government aims to increase installed solar capacity by 200 GW in 2026. The surplus in energy supply, falling panel prices since 2022, inadequate grid and infrastructure, the new financing model introduced in 2025, and stringent efficiency standards to be implemented in 2027 have all contributed to the slowdown in capacity growth. Inflationary pressures, particularly the rising prices of various grid materials such as cables and transformers since 2020, continue to pose threats and increase the costs of energy production and transmission.

In China, solar energy production primarily takes place in the inland and western regions—especially Xinjiang, Qinghai, Gansu, and Inner Mongolia—where population density is low. However, industrial zones with high electricity demand are located along the country's eastern coast. Insufficient transmission infrastructure leads to curtailment issues, where a portion of the generated electricity cannot be integrated into the grid; in some provinces, this curtailment rate reaches up to 30%. Moreover, excessive electricity generation during certain hours of the day imposes additional burdens on underdeveloped grid regions, necessitating production restrictions.

In light of these developments, the efficiency of solar-based electricity generation has become increasingly important. This study aims to investigate the effects of increases in installed solar power capacity on total factor productivity in 30 administrative regions in China, including provinces, autonomous regions, and directly administered cities. Additionally, the study seeks to determine how these effects vary with respect to grid integration capacity.

2. LITERATURE REVIEW

A review of the literature on energy efficiency reveals the frequent use of non-parametric methods, among which Data Envelopment Analysis (DEA) has gained increasing popularity. Hanoum et al. (2026) examined 461 academic studies published between 1994 and 2024 and found a substantial

increase in the use of DEA in studies after 2010. Their findings indicate a shift in research focus from traditional optimization to performance evaluations centered on undesirable outputs and sustainability. Xu et al. (2020), in their literature review on energy efficiency, noted that DEA models have evolved from simple static structures to more complex forms that incorporate undesirable outputs, network configurations, and dynamic models. The findings also emphasize that most studies are conducted at the national or provincial level, while firm-level research remains insufficient. Mardani et al. (2017) analyzed 144 academic studies published between 2006 and 2015 that utilized DEA, concluding that this method is a highly effective tool for analyzing energy efficiency issues. Moreover, the majority of these studies originate from China and have increasingly shifted toward topics such as environmental efficiency, sustainable energy, and eco-efficiency.

A large portion of the literature agrees that ensuring the sustainability of economic growth requires the inclusion of not only economic outputs but also certain undesirable environmental outputs, such as carbon dioxide emissions, in analytical models. Studies focusing on China have consistently demonstrated that the eastern coastal regions possess higher levels of efficiency and technological adoption compared to the central and western regions. Additionally, many studies highlight that technological advancement is the primary driving force behind increases in efficiency.

Wei, Ni, and Shen (2009) analyzed energy efficiency across 29 Chinese provinces for the period 1997–2006 using Data Envelopment Analysis and TOBIT/GLS econometric models. The results indicate that state ownership and the share of industry negatively affect efficiency, whereas technological level and the use of non-coal energy sources have a positive impact. The study also notes that eastern regions exhibit higher energy efficiency compared to central and western regions, and attributes regional disparities primarily to differences in industrial structure.

Wu, Cao, and Liu (2014) employed Data Envelopment Analysis and the Malmquist index to investigate energy use efficiency in 30 provinces, autonomous regions, and municipalities in China between 2006 and 2009. The results show that industrial enterprises with the highest average energy efficiency are located in the eastern region, followed by the central region. Beijing, Shanghai, Jiangsu, Zhejiang, Guangdong, and Hainan exhibit high energy efficiency, while the six regions with the lowest efficiency are Ningxia, Inner Mongolia, Shaanxi, Liaoning, Chongqing, and Jilin. The findings confirm that Eastern China is the clear leader in terms of efficiency, whereas the central and western regions lag significantly due to technological and infrastructure deficiencies.

Li and Lin (2015) examined the energy intensity gap in 30 Chinese provinces over the period 1996–2015 using Data Envelopment Analysis. Their findings reveal that energy intensity fluctuates around 21%, 7.5%, and 12% for Eastern, Central, and Western China, respectively, with Eastern China possessing the highest level of energy technology. The study also indicates that the energy intensities of China's provinces have not converged to an optimal level.

Wang and Feng (2015) applied Global Data Envelopment Analysis and the Global Malmquist Index in their study at the provincial level in China for the period 2002–2011. The findings indicate that China has exhibited strong performance in terms of economic efficiency; however, its energy and environmental performance remain less optimistic. Technological progress is identified as the most significant factor driving efficiency, while declines in scale and managerial efficiency are reported as key obstacles to further progress.

Feng and Wang (2017) examined the energy efficiency and conservation potential of the industrial sector in Chinese provinces from 2000 to 2014 using Data Envelopment Analysis and the Global Malmquist Index. The results indicate that technological progress is the most important driver of efficiency in all regions. However, the current investment-driven model has led to scale inefficiencies in many provinces.

Zhang et al. (2017) employed a three-stage Data Envelopment Analysis model to measure industrial eco-efficiency in 30 Chinese provinces from 2005 to 2016. The results demonstrate that regional industrial eco-efficiency in China is influenced by environmental regulations, technological innovations, the level of economic development, and industrial structure. After removing external environmental effects and statistical noise, the national average industrial eco-efficiency drops by 30%. The main cause of efficiency differences among provinces is identified as scale efficiency.

Zhan, Guo, and Zhao (2019) used a three-stage Data Envelopment Analysis model to evaluate provincial energy efficiency in China from 2008 to 2016, excluding external environmental factors. The findings reveal that provincial energy efficiency in China is significantly influenced by economic and energy consumption structure, the process of urbanization, and the level of technological innovation. The authors note that the rate of urbanization and R&D investments contribute to increased efficiency; however, provincial governments' energy-saving policies have not yet reached the desired level of effectiveness.

Wang and Wang (2022) calculated the energy efficiency of 30 provinces and municipalities in China for the period 2008–2020 using Data Envelopment Analysis. The results suggest a continuous improvement in national energy efficiency. However, the development of energy efficiency across regions remains highly uneven, with the highest levels in the east and the lowest in the west. Moreover, technological progress is reported to have a pronounced positive effect on energy efficiency in all three major regions of China.

Zhao et al. (2024) calculated the energy efficiency of 2052 county-level regions in China from 2006 to 2020 using Data Envelopment Analysis and examined regional disparities. The study shows that energy efficiency in Chinese counties has generally increased and maintained a relatively stable spatial pattern. Both overall and intra-regional differences in energy efficiency have significantly

decreased nationwide. As of 2020, the regional disparity in energy efficiency ranks from highest to lowest as eastern, western, and central regions.

3. METHODOLOGY AND DATA

The empirical strategy adopted in this study proceeds in three sequential and logically nested stages. In the first stage, a non-parametric frontier framework is employed to construct a province-level index of environmentally adjusted productivity, thereby generating the dependent variable of interest. In the second stage, the constructed index is regressed on solar photovoltaic installed capacity and a vector of structural covariates within a linear static panel framework, in which the conditioning role of grid curtailment is captured through a multiplicative interaction term. In the third stage, the implicit assumption of parameter constancy embedded in the linear specification is relaxed by estimating a fixed-effects threshold regression model in the tradition of Hansen (1999), which permits the marginal contribution of renewable capacity to green productivity to differ endogenously across latent infrastructural regimes. This progression from frontier estimation to conditional-mean estimation and finally to regime-dependent estimation is designed to address the central research question of the study, namely whether the productivity dividend of renewable capacity expansion is uniform across Chinese provinces or is instead contingent upon the absorptive capability of the regional transmission network.

The sequential design also serves an identification purpose. Because the green productivity index is itself an estimated quantity derived from a frontier technology, treating it directly as a regressand in a single-equation framework would confound frontier measurement error with structural parameters. By separating the measurement stage from the inference stage and by relying exclusively on within-province variation in the second and third stages, the design isolates the temporal covariation between capacity deployment and productivity dynamics from the substantial and persistent cross-sectional heterogeneity that characterises the Chinese provincial economy.

The analysis is conducted on a balanced annual panel comprising 30 Chinese provinces, autonomous regions, and centrally administered municipalities observed continuously over the period 2010–2023, which yields 420 province-year observations. Hong Kong, Macao, and Taiwan are excluded because of the absence of comparable provincial energy accounts, and Tibet is retained despite its small economic weight in order to preserve coverage of the extreme upper tail of the curtailment distribution. The 2010 starting point is dictated by the first year in which the National Energy Administration published province-disaggregated solar photovoltaic capacity statistics on a consistent definitional basis, while the 2023 terminal year reflects the most recent vintage for which finalised provincial carbon accounts were available at the time of estimation.

Provinces are allocated to four macro-regions—Eastern, Central, Western, and Northeastern—following the standard classification maintained by the National Bureau of Statistics of China. This partition assigns 10 provinces to the Eastern region, 6 to the Central region, 11 to the Western region,

and 3 to the Northeastern region, corresponding to 140, 84, 154, and 42 province-year observations, respectively. The classification is retained without modification because it coincides with the administrative units through which cross-provincial transmission planning and renewable consumption quotas are actually formulated, and it therefore possesses institutional as well as geographical content.

The data are assembled from four primary repositories. Provincial solar photovoltaic installed capacity and curtailment rates are obtained from the National Energy Administration (NEA); full-load utilisation hours and interprovincial transmission line capacity are drawn from successive editions of the *China Electric Power Yearbook* (CEPY); per capita gross domestic product, gross fixed capital formation, energy intensity, aggregate energy consumption, and population are taken from the *China Statistical Yearbook* and the *China Energy Statistical Yearbook* published by the National Bureau of Statistics (NBS); and province-level carbon dioxide emissions are sourced from the Carbon Emission Accounts and Datasets (CEADs) inventory. The pilot emissions trading scheme indicator is coded from National Development and Reform Commission designations. Monetary aggregates are reported at current prices in the source data and are entered in logarithmic form, so that province-specific price levels are absorbed by the fixed effects and common inflationary movements by the time effects. The panel is balanced by construction and contains no missing observations.

Conventional measures of total factor productivity treat the production process as though it generated only marketed output, and consequently attribute to productivity growth any expansion in output that is in fact purchased through an increase in environmental damage. Because the object of interest in the present study is the productivity consequence of a decarbonisation strategy, such a measure would be systematically biased in favour of provinces that have expanded emissions-intensive output. The dependent variable is therefore constructed as a Global Malmquist–Luenberger (GML) productivity index, which explicitly incorporates undesirable outputs into the technology set (Chung, Färe and Grosskopf, 1997; Oh, 2010).

Let each province be treated as a decision-making unit that employs a non-negative vector of N inputs, denoted x, to produce a non-negative vector of M desirable outputs, denoted y, jointly with a non-negative vector of J undesirable outputs, denoted b. The environmental technology is defined as the output set

$$P(x) = \{(y, b) : x \text{ can produce } (y, b)\}, \tag{1}$$

which is assumed to satisfy the standard axioms of closedness and boundedness, together with the two properties that distinguish environmental from conventional technologies. The first is null-jointness, which requires that the desirable output cannot be produced in the absence of the undesirable output, so that $(y, b) \in P(x)$ and $b = 0$ jointly imply $y = 0$. The second is weak disposability of outputs, which requires that $(y, b) \in P(x)$ implies $(\theta y, \theta b) \in P(x)$ for all $\theta \in [0, 1]$, thereby encoding the assumption that emissions can be reduced only at the cost of a proportional contraction in marketed output. Together

these two axioms ensure that abatement is treated as costly rather than free, which is precisely the feature absent from conventional Malmquist indices.

The distance from an observed input–output combination to the frontier of this technology is measured by the directional output distance function

$$D(x, y, b; g_y, g_e) = max \{\beta : (y + \beta g_y, b - \beta g_e) \in P(x)\}, \quad (2)$$

in which the directional vector is set to $g = (y, -b)$, so that the efficiency score is defined with reference to a path along which desirable output is expanded and undesirable output contracted in equal proportion. The scalar β therefore admits a direct interpretation as the proportion by which a province could simultaneously raise output and lower emissions were it to operate on the best-practice frontier.

Following Oh (2010), the index is constructed relative to a *global* technology, denoted $P^G(x)$, defined as the union of the annual technology sets over the entire sample period, that is, the union of $P_t(x)$ for t = 2010, 2011, …, 2023. The global formulation is preferred to the contemporaneous and sequential alternatives on two grounds. First, it guarantees circularity, so that productivity comparisons are transitive across any pair of years and cumulative growth over the full sample can be decomposed without ambiguity. Second, it eliminates the infeasibility problems that arise in contemporaneous mixed-period linear programmes when technical regress occurs, a situation that is common in provincial energy panels subject to abrupt regulatory shocks. The resulting index between periods t and $t + 1$ is

$$GML(t, t + 1) = [1 + D^G(x_t, y_t, b_t; g)] / [1 + D^G(x_{t+1}, y_{t+1}, b_{t+1}; g)], \quad (3)$$

which is multiplicatively decomposable into an efficiency change component, capturing movement of the province towards or away from the contemporaneous frontier, and a technical change component, capturing displacement of the frontier itself. Values above unity denote productivity improvement between the two periods.

The technology is estimated by data envelopment analysis under the assumption of constant returns to scale, using capital stock and labour as inputs, real gross domestic product as the desirable output, and carbon dioxide emissions as the undesirable output. The non-parametric approach is adopted in preference to stochastic frontier estimation because it imposes neither a functional form on the production technology nor a distributional assumption on the inefficiency term, both of which are difficult to defend across provinces whose industrial composition differs as sharply as those of Shanghai and Qinghai (Charnes, Cooper and Rhodes, 1978; Färe, Grosskopf, Norris and Zhang, 1994). Cumulative indices are chained from a base of unity in 2010, so that the reported series is directly interpretable as the level of green productivity relative to each province's own 2010 position.

Table 1 reports the definition, unit of measurement, and source of each variable entering the empirical models. The focal explanatory variable is provincial solar photovoltaic installed capacity, which is the policy instrument whose productivity consequences the study seeks to evaluate. The

curtailment rate—the proportion of technically generable renewable electricity that is not dispatched to the grid—enters both as a control in its own right and, more importantly, as the moderating variable through which the conditional structure of the capacity–productivity relationship is identified.

Table 1. Variable Definitions, Units, and Sources

Variable	Unit	Definition	Source
GML–TFP index	Index (2010 = 1)	Global Malmquist–Luenberger productivity index; inputs: capital, labour; desirable output: GDP; undesirable output: CO_2	Authors' DEA estimation
Solar installed capacity	GW	Cumulative province-level installed photovoltaic generating capacity	NEA
Full-load utilisation hours	Hours per year	Equivalent full-load operating hours of installed generating capacity	CEPY
Per capita GDP	CNY, current prices	Gross regional product divided by year-end resident population	NBS
Gross fixed capital formation	Billion CNY, current prices	Provincial gross fixed capital formation	NBS
Energy intensity	tce per 10,000 CNY of GDP	Total primary energy consumption per unit of gross regional product	NBS
Transmission line capacity	GW	Rated capacity of interprovincial transmission interconnections	CEPY
Curtailment rate	Proportion (0–1)	Share of generable renewable electricity not absorbed by the grid	NEA
CO_2 emissions	Million tonnes	Province-level territorial carbon dioxide emissions	CEADs
Total energy consumption	Mtce	Aggregate primary energy consumption	NBS
Population	Million	Year-end resident population	NBS
ETS pilot dummy	0/1	Equals 1 from 2013 onward for the seven pilot carbon-market jurisdictions	NDRC

Note: $N = 420$ province-year observations covering 30 provinces over 2010–2023. GW = gigawatt; tce = tonnes of coal equivalent; Mtce = million tonnes of coal equivalent; CNY = Chinese yuan renminbi; NEA = National Energy Administration; CEPY = *China Electric Power Yearbook*; NBS = National Bureau of Statistics; CEADs = Carbon Emission Accounts and Datasets; NDRC = National Development and Reform Commission. Pilot emissions trading jurisdictions are Beijing, Tianjin, Shanghai, Chongqing, Guangdong, Hubei, and Shenzhen.

The baseline econometric model relates the logarithm of the green productivity index to solar capacity and the vector of structural controls. Three nested specifications are estimated. The first is a pooled ordinary least squares model that exploits both cross-sectional and temporal variation:

$$\ln GML_{it} = \alpha + \beta_1 \ln Solar_{it} + \gamma' Z_{it} + \varepsilon_{it}. \tag{4}$$

The second specification augments equation (4) with province and year fixed effects, yielding the two-way within estimator

$$\ln GML_{it} = \beta_1 \ln Solar_{it} + \gamma' Z_{it} + \mu_i + \lambda_t + \varepsilon_{it}, \tag{5}$$

in which μ_i absorbs all time-invariant provincial heterogeneity—resource endowment, industrial legacy, geographical position relative to load centres, and the fixed component of institutional quality—while λ_t absorbs macroeconomic shocks, national policy discontinuities, and secular technological progress common to all provinces. The third specification introduces the multiplicative interaction that constitutes the analytical core of the study:

$$\ln GML_{it} = \beta_1 \ln Solar_{it} + \beta_2 Curt_{it} + \beta_3 (\ln Solar_{it} \times Curt_{it}) + \gamma' Z_{it} + \mu_i + \lambda_t + \varepsilon_{it}. \tag{6}$$

In equation (6) the marginal effect of capacity expansion is no longer a constant but a function of the prevailing curtailment environment,

$$\partial \ln GML_{it} / \partial \ln Solar_{it} = \beta_1 + \beta_3 Curt_{it}, \tag{7}$$

so that β_1 measures the productivity elasticity of capacity in the counterfactual absence of curtailment and β_3 measures the rate at which that elasticity is attenuated as grid absorption deteriorates. The central hypothesis of the study is that $\beta_3 < 0$. The conditioning vector Z_{it} comprises the logarithms of full-load utilisation hours, per capita GDP, gross fixed capital formation, and transmission line capacity, together with energy intensity in levels, the curtailment rate, and the emissions trading pilot indicator.

Equation (6) imposes the restriction that the attenuation of the capacity elasticity proceeds smoothly and linearly in the curtailment rate. Engineering considerations suggest a more discontinuous relationship, since grid absorption failures tend to become binding abruptly once local demand and export capability are exhausted. To relax the linearity restriction, a single-threshold fixed-effects panel model is specified following Hansen (1999):

$$\ln GML_{it} = \theta_1 \ln Solar_{it} \cdot I(q_{it} \le \gamma) + \theta_2 \ln Solar_{it} \cdot I(q_{it} > \gamma) + \delta' Z_{it} + \mu_i + \lambda_t + \varepsilon_{it}, \tag{8}$$

where $I(\cdot)$ denotes the indicator function, q_{it} is the threshold variable, and γ is the unknown threshold parameter. Two candidate threshold variables are examined: the curtailment rate, which proxies the intensity of the grid integration constraint, and interprovincial transmission line capacity, which proxies the physical capability to relieve it.

Estimation proceeds by concentrating the likelihood. For each candidate value of γ drawn from the empirical support of the threshold variable, the model is estimated by least squares after the two-way within transformation, and the estimate $\hat{\gamma}$ is selected as the value minimising the concentrated sum of squared residuals. Following standard practice, the search grid is trimmed to the interval between the 15th and 85th percentiles of the threshold variable so that each regime retains a sufficient number of observations for reliable inference. The null hypothesis of no threshold effect, $H_0: \theta_1 = \theta_2$, is tested using the likelihood-ratio statistic

$$F_1 = (S_0 - S_1(\hat{\gamma})) / \hat{\sigma}^2, \tag{9}$$

in which S_0 and $S_1(\hat{\gamma})$ denote the residual sums of squares from the linear and threshold specifications, respectively. Because the threshold parameter is unidentified under the null, the statistic possesses a non-standard asymptotic distribution, and *p* values are accordingly obtained through the fixed-regressor bootstrap procedure proposed by Hansen (1999) with 150 replications. Confidence intervals for γ are constructed as the no-rejection region of the likelihood-ratio statistic LR(γ), retaining all candidate values for which $LR(\gamma) \leq 7.35$, the asymptotic 95% critical value.

The choice among the estimators in equations (4) through (6) is not imposed a priori but is determined by a sequence of specification tests. The presence of unobserved provincial heterogeneity is assessed by an *F* test of the joint significance of the province effects and by the Breusch and Pagan (1980) Lagrange multiplier test. The choice between fixed and random effects is evaluated using the auxiliary-regression variant of the Hausman test proposed by Mundlak (1978), in which the group means of all time-varying regressors are added to a random-effects specification and their joint significance tested. This formulation is preferred to the classical Hausman (1978) statistic because it remains valid under heteroskedasticity and clustering, whereas the classical difference-in-covariance form is not guaranteed to be positive semi-definite in such settings and can return uninterpretable negative values.

Residual serial correlation is tested using the first-difference procedure of Wooldridge (2010) as implemented by Drukker (2003), and cross-sectional dependence is tested using the Pesaran (2004, 2015) CD statistic. The stationarity of the panel series is examined using the Im, Pesaran and Shin (2003) $\bar{W}$-$\bar{t}$ statistic, which permits heterogeneous autoregressive parameters across provinces and is therefore appropriate for a panel in which the speed of productivity adjustment plausibly differs by region. Multicollinearity is assessed by variance inflation factors.

In light of the diagnostic outcomes reported in next section, all reported standard errors are clustered at the provincial level, which accommodates arbitrary within-province serial correlation and heteroskedasticity (Cameron and Miller, 2015). Because the number of clusters (30) is moderate, the sensitivity of the principal inferences to the choice of variance estimator is additionally examined using the Driscoll and Kraay (1998) covariance matrix, which is consistent in the presence of spatial as well

as temporal dependence. All estimation was carried out at the 5% nominal significance level unless otherwise indicated.

4. ANALYSIS RESULTS

Table 2 summarises the distributional properties of the estimation sample. The mean value of the GML–TFP index across the 420 province-year observations is 0.941 (*SD* = 0.123), indicating that the representative province operated approximately 6% below the environmentally adjusted production frontier over the sample period. The dispersion of the index is substantial: the minimum of 0.691 and the maximum of 1.224 imply that the most productive province-year observation attained a green productivity level roughly 77% higher than the least productive, a spread that motivates the regional decomposition undertaken in next paragraphs.

Solar installed capacity displays pronounced right skewness, with a mean of 7.59 GW substantially exceeding the median of 3.51 GW and a maximum of 76.22 GW. This asymmetry, together with the strictly positive support of the series, justifies the logarithmic transformation adopted in the regression models. The curtailment rate averages 9.94% but ranges from 0.5% to 38.02%, a dispersion that is critical for the identification of the interaction and threshold effects, since the conditional structure of interest can only be detected if the moderating variable exhibits sufficient variation across the observed support. The emissions trading pilot indicator has a mean of 0.157, reflecting the fact that seven of the 30 provinces participated in the pilot schemes from 2013 onward.

Table 2. Descriptive Statistics of the Estimation Sample, 2010–2023

Variable	n	M	SD	Min	Mdn	Max
GML–TFP index	420	0.941	0.123	0.691	0.923	1.224
Solar installed capacity (GW)	420	7.593	10.749	0.306	3.509	76.221
Full-load utilisation hours	420	1,301.46	200.87	897.00	1,283.00	1,748.00
Per capita GDP (CNY)	420	95,382.09	59,578.83	18,216.00	79,674.50	392,044.00
Gross fixed capital formation (bn CNY)	420	570.66	304.99	79.20	504.65	1,793.70
Energy intensity (tce/10k CNY)	420	0.594	0.232	0.280	0.567	1.310
Transmission line capacity (GW)	420	39.08	18.82	6.20	35.40	115.30
Curtailment rate	420	0.099	0.073	0.005	0.077	0.380
CO_2 emissions (Mt)	420	23,134.59	15,631.84	1,565.30	18,907.90	97,892.60

Variable	n	M	SD	Min	Mdn	Max
Total energy consumption (Mtce)	420	2,321.51	737.45	741.00	2,363.35	4,197.10
Population (millions)	420	46.18	29.79	4.00	39.36	117.41
ETS pilot dummy	420	0.157	0.364	0.000	0.000	1.000

Note: The panel is balanced and comprises 30 provinces observed over 14 years. GML–TFP = Global Malmquist–Luenberger total factor productivity index, normalised to unity in 2010. All monetary variables are expressed at current prices.

Table 3 traces the evolution of the national mean GML–TFP index over the observation window. The series rises monotonically in every year of the sample, from 0.839 in 2010 to 1.003 in 2023, corresponding to a cumulative improvement of 19.58% and an average annual logarithmic growth rate of 1.34%. Regression of the national mean index on a linear time trend yields a slope coefficient of 0.0125 index points per annum ($SE = 0.0008$, $t = 14.85$, $p < .001$) with a coefficient of determination of $R^2 = .948$, confirming that the improvement is not merely a monotone drift but a highly regular linear progression.

The substantive significance of this finding lies in the fact that the index is environmentally adjusted. Because carbon dioxide emissions enter the technology as an undesirable output that cannot be freely disposed of, an increase in the index cannot be manufactured by expanding emissions-intensive output. The observed trajectory therefore constitutes direct evidence of a progressive decoupling of Chinese provincial economic activity from its carbon content over the fourteen-year window. It is nonetheless notable that the national mean crosses the unity threshold only in 2023, implying that the representative province required the entire period simply to recover the environmentally adjusted efficiency position it occupied at the base year of the index.

Table 3. Annual National Mean GML–TFP Index and Year-on-Year Change

Year	Mean index	Annual change	Cumulative change (%)	Period
2010	0.839	—	0.00	Sub-period I
2011	0.861	+0.023	2.70	Sub-period I
2012	0.882	+0.020	5.13	Sub-period I
2013	0.902	+0.020	7.53	Sub-period I
2014	0.918	+0.016	9.42	Sub-period I
2015	0.934	+0.016	11.38	Sub-period I
2016	0.949	+0.015	13.21	Sub-period II
2017	0.958	+0.008	14.22	Sub-period II

Year	Mean index	Annual change	Cumulative change (%)	Period
2018	0.971	+0.013	15.78	Sub-period II
2019	0.982	+0.011	17.09	Sub-period II
2020	0.989	+0.007	17.90	Sub-period III
2021	0.994	+0.006	18.58	Sub-period III
2022	0.996	+0.002	18.77	Sub-period III
2023	1.003	+0.007	19.58	Sub-period III

Note: Values are unweighted means across the 30 sample provinces. Fitted linear trend: $b = 0.0125$, $SE = 0.0008$, $t(12) = 14.85$, $p < .001$, $R^2 = .948$. Cumulative change is measured relative to 2010.

The aggregate trajectory documented above conceals a degree of interprovincial dispersion that is central to the argument of this study. Table 4 reports the period-mean GML–TFP index for each of the 30 sample provinces, together with mean solar capacity, mean curtailment, mean transmission capacity, and pilot carbon-market status. The ordering reveals a geographically systematic pattern rather than a random scatter.

The nine highest-ranked provinces are located without exception in the Eastern macro-region. Shanghai occupies the leading position with a mean index of 1.152, followed by Beijing (1.134), Guangdong (1.119), Jiangsu (1.101), and Zhejiang (1.079). These jurisdictions are characterised by moderate solar deployment—between 1.65 GW and 11.59 GW—combined with curtailment rates confined to a narrow band between 1.99% and 4.76%, and five of the nine participate in the pilot emissions trading schemes. At the opposite extreme, the six lowest-ranked provinces are all located in the Western macro-region: Tibet records the lowest mean index at 0.763, preceded by Gansu (0.786), Qinghai (0.804), Xinjiang (0.814), Ningxia (0.816), and Inner Mongolia (0.832).

The configuration of these lagging provinces is precisely the inverse of that observed at the top of the distribution. Xinjiang and Inner Mongolia host the two largest solar fleets in the sample, at 23.14 GW and 20.89 GW respectively—approximately five times the mean capacity of Shanghai and Beijing combined—yet they discard 21.88% and 17.96% of generable renewable electricity. Gansu and Tibet curtail 23.82% and 27.68%. None of the six participates in a pilot carbon market, and their mean transmission interconnection capacity ranges from 8.89 GW in Tibet to 32.84 GW in Inner Mongolia, against 82.43 GW in Shandong and 72.24 GW in Guangdong. The simple pairwise correlation between the logarithm of the productivity index and the curtailment rate across the pooled sample is −.806, whereas the correlation between the productivity index and log solar capacity is only .085. This descriptive contrast constitutes the first indication that installed capacity, considered in isolation, is a poor predictor of environmentally adjusted productivity.

Table 4. Provincial Mean GML–TFP Index and Associated Structural Characteristics, 2010–2023

Rank	Province	Macro-region	Mean GML	Solar (GW)	Curtailment (%)	ETS
1	Shanghai	Eastern	1.152	1.65	1.99	Yes
2	Beijing	Eastern	1.134	2.76	2.68	Yes
3	Guangdong	Eastern	1.119	4.41	3.10	Yes
4	Jiangsu	Eastern	1.101	6.64	3.69	No
5	Zhejiang	Eastern	1.079	3.86	3.00	No
6	Fujian	Eastern	1.069	2.75	3.07	No
7	Shandong	Eastern	1.061	11.59	4.76	No
8	Tianjin	Eastern	1.034	3.31	4.08	Yes
9	Hainan	Eastern	1.009	4.40	4.97	No
10	Henan	Central	0.992	9.93	5.89	No
11	Hubei	Central	0.974	3.31	5.18	Yes
12	Hebei	Eastern	0.964	15.46	13.41	No
13	Hunan	Central	0.958	2.76	5.65	No
14	Anhui	Central	0.946	6.07	6.98	No
15	Jiangxi	Central	0.932	4.97	5.79	No
16	Liaoning	Northeast	0.918	7.72	10.00	No
17	Jilin	Northeast	0.899	6.65	11.68	No
18	Shanxi	Central	0.899	8.30	8.96	No
19	Chongqing	Western	0.887	2.20	7.17	Yes
20	Heilongjiang	Northeast	0.872	5.49	13.80	No
21	Sichuan	Western	0.865	4.97	8.06	No
22	Shaanxi	Western	0.864	9.96	10.71	No
23	Yunnan	Western	0.853	6.64	11.84	No
24	Guizhou	Western	0.839	3.86	9.98	No
25	Inner Mongolia	Western	0.832	20.89	17.96	No
26	Ningxia	Western	0.816	12.09	19.60	No
27	Xinjiang	Western	0.814	23.14	21.88	No

Rank	Province	Macro-region	Mean GML	Solar (GW)	Curtailment (%)	ETS
28	Qinghai	Western	0.804	14.33	20.74	No
29	Gansu	Western	0.786	16.04	23.82	No
30	Tibet	Western	0.763	1.65	27.68	No

Note: Values are province-specific means over the full 2010–2023 window (n = 14 per province). ETS indicates participation in a pilot emissions trading scheme at any point during the sample period. Macro-regions follow the four-region classification of the National Bureau of Statistics.

Table 5 aggregates the provincial evidence to the level of the four macro-regions and thereby renders the structural paradox explicit. The Eastern region attains a mean green productivity index of 1.072 while deploying an average of 5.68 GW of solar capacity and curtailing only 4.48% of generable renewable output. The Western region records a mean index of 0.829—29.3% below the Eastern figure—despite deploying 10.52 GW of solar capacity, some 85% more than the Eastern region, and it discards 16.31% of generable output, a curtailment rate 3.6 times the Eastern level. The Central and Northeastern regions occupy intermediate positions consistent with their intermediate curtailment rates of 6.41% and 11.83%.

The regional ordering of mean productivity is monotonically inverse to the regional ordering of curtailment and monotonically inverse to the regional ordering of installed capacity. It is, by contrast, monotonically aligned with transmission interconnection capacity, which falls from 50.41 GW in the East to 26.14 GW in the West, and with per capita income, which falls from CNY 148,946 to CNY 59,328. The pattern is thus not one in which renewable investment fails to occur where productivity is low; it is one in which renewable investment is concentrated precisely where the complementary infrastructure required to convert it into productive service is weakest.

Table 5. Regional Comparison of Green Productivity and Structural Conditions, 2010–2023

Macro-region	n	Mean GML	Solar (GW)	Curtailment (%)	Transmission (GW)	Energy intensity	ETS share
Eastern	140	1.072	5.68	4.48	50.41	0.389	0.314
Central	84	0.950	5.89	6.41	43.98	0.542	0.131
Northeastern	42	0.896	6.62	11.83	38.98	0.678	0.000
Western	154	0.829	10.52	16.31	26.14	0.785	0.071
National	**420**	**0.941**	**7.59**	**9.94**	**39.08**	**0.594**	**0.157**

Note: n denotes province-year observations. Energy intensity is measured in tonnes of coal equivalent per 10,000 CNY of gross regional product. ETS share is the proportion of province-year observations subject to a pilot emissions trading scheme.

Table 6 partitions the sample into three sub-periods in order to establish whether the regional gap has narrowed as the national transmission programme has matured. The evidence indicates that it has not. Every region records an absolute improvement in green productivity across the three sub-periods,

and the proportional gains are remarkably uniform, ranging from 11.65% in the Central region to 12.25% in the Western region. Because the Western region began from a substantially lower base, however, this near-identical proportional growth translates into a widening rather than a narrowing absolute gap: the Eastern–Western differential increases from 0.231 index points in 2010–2015 to 0.250 in 2016–2019 and to 0.255 in 2020–2023.

This result is analytically important because it distinguishes between two competing interpretations of the East–West disparity. Under a catch-up interpretation, the Western region would be expected to converge as its infrastructure matures, and the observed gap would represent a transitory adjustment cost. Under a structural interpretation, the gap reflects a persistent misallocation that is reproduced rather than eroded by continued investment. The sub-period evidence is consistent with the second interpretation. It is notable that Western curtailment did fall substantially over the same interval, from 18.57% to 12.55%, and that Western solar capacity rose more than eightfold from 2.99 GW to 25.64 GW. The improvement in grid absorption was therefore real, but it was outpaced by the deployment it was intended to accommodate.

Table 6. Sub-Period Means of Green Productivity, Curtailment, and Solar Capacity by Macro-Region

Macro-region	GML 2010–2015	GML 2016–2019	GML 2020–2023	Δ GML (%)	Curt. 2010–2015 (%)	Curt. 2020–2023 (%)	Solar 2020–2023 (GW)
Eastern	1.013	1.100	1.133	11.86	4.97	3.53	13.84
Central	0.899	0.973	1.004	11.65	7.34	5.01	14.34
Northeastern	0.847	0.918	0.949	12.06	13.38	9.33	16.09
Western	0.783	0.850	0.878	12.25	18.57	12.55	25.64
East–West gap	*0.231*	*0.250*	*0.255*	—	—	—	—

Note: Δ GML (%) denotes the proportional change in the regional mean index between the first and third sub-periods. The East–West gap is the arithmetic difference in mean index values between the Eastern and Western regions in each sub-period.

Table 7 reports the battery of specification tests governing the choice of estimator. The F test of the joint significance of the province effects yields $F(29, 382) = 37.06$, $p < .001$, decisively rejecting the poolability restriction, and the Breusch–Pagan Lagrange multiplier statistic of 692.75 ($p < .001$) confirms the presence of a substantial variance component at the provincial level. The Mundlak auxiliary-regression test of the random-effects orthogonality condition yields $\chi^2(8) = 284.55$, $p < .001$, rejecting the hypothesis that the province effects are uncorrelated with the regressors and establishing the fixed-effects estimator as the consistent choice. This conclusion is intuitive on substantive grounds, since resource endowment and geographical distance from load centres are precisely the sort of

persistent provincial attributes that jointly determine both renewable siting decisions and productivity levels.

The Wooldridge test rejects the null of no first-order serial correlation, $F(1, 29) = 8.79$, $p = .006$, and the Pesaran CD statistic computed on one-way fixed-effects residuals equals 11.09 ($p < .001$) with a mean absolute pairwise correlation of .264, indicating pronounced cross-sectional dependence. The latter is unsurprising in a setting in which provincial energy systems are linked by a national grid and subject to common central-government directives. The inclusion of year effects in equations (5), (6), and (8) reduces the CD statistic to −2.60, and the residual dependence that remains is addressed through the robustness analysis of next paragraph. The Im–Pesaran–Shin test rejects the panel unit-root null for the logarithm of the productivity index ($W\text{-}\bar{t} = -5.54$, $p < .001$), confirming that the dependent variable is integrated of order zero and that the regressions are not spurious.

Variance inflation factors for the focal regressors are moderate, with log solar capacity at 3.24 and log utilisation hours at 3.11, both comfortably below conventional thresholds. Two of the control variables, log gross fixed capital formation and log transmission capacity, exhibit elevated factors of 37.48 and 27.67, reflecting a pairwise correlation of .969 between them. Because both are theoretically motivated—the former as a general capital-deepening control and the latter as the specific infrastructural channel of interest—neither is dropped from the baseline specification, but it confirms that the principal coefficient of interest is unaffected when gross fixed capital formation is excluded.

Table 7. Panel Diagnostic Test Results

Test	Null hypothesis	Statistic	p	Decision
F test of individual effects	No province effects	F(29, 382) = 37.06	< .001	Reject
Breusch–Pagan LM	No random effects	$\chi^2(1) = 692.75$	< .001	Reject
Mundlak (robust Hausman)	RE is consistent	$\chi^2(8) = 284.55$	< .001	Reject; use FE
Wooldridge	No serial correlation	F(1, 29) = 8.79	.006	Reject
Pesaran CD (one-way FE)	Cross-sectional independence	CD = 11.09	< .001	Reject
Pesaran CD (two-way FE)	Cross-sectional independence	CD = −2.60	.009	Reject
Im–Pesaran–Shin (ln GML)	Unit root in all panels	$W\text{-}\bar{t} = -5.54$	< .001	Reject; I(0)
Maximum VIF (focal regressors)	—	3.24	—	No collinearity concern

Note: FE = fixed effects; RE = random effects; LM = Lagrange multiplier; VIF = variance inflation factor. The Pesaran CD statistic is reported for residuals from the one-way (province effects only) and two-way (province and year effects) specifications. The mean absolute pairwise residual correlation is .264 in the one-way case and .226 in the two-way case.

Table 8 presents the three nested specifications. The pooled model in column 1 reproduces the pattern already visible in the descriptive evidence: per capita income and utilisation hours enter positively and significantly, energy intensity enters with a large negative coefficient of −0.302 ($p < .001$), and transmission capacity enters positively at 0.109 ($p = .006$). Log solar capacity, however, carries a negative and highly significant coefficient of −0.025 ($p < .001$), and the curtailment rate carries a *positive* coefficient of 0.252 ($p = .023$).

These two signs are economically implausible and expose the identification failure inherent in the pooled estimator. The apparent negative association between capacity and productivity, and the apparent positive association between curtailment and productivity, are artefacts of the omitted province effects: the provinces that have installed the most solar capacity and that curtail the most are the resource-rich, low-income, industrially specialised western jurisdictions whose green productivity is low for reasons entirely unrelated to their renewable programmes. The pooled specification attributes the consequences of provincial endowment to the renewable variables themselves. Given the decisive rejection of poolability reported in Table 7, column 1 should be read as a diagnostic benchmark rather than as a candidate structural model.

Column 2 introduces province and year fixed effects. Once persistent provincial heterogeneity and common national shocks are absorbed, the anomalous signs disappear: log solar capacity turns positive at 0.024 and the curtailment rate turns negative at −0.057, although neither coefficient attains conventional significance individually ($p = .417$ and $p = .174$, respectively). The collapse in the significance of nearly all regressors relative to column 1 is itself informative. It indicates that the great majority of the explanatory power of the pooled model derived from between-province rather than within-province variation, and that the year effects absorb the strong common upward trend documented in Table 3. What remains is the comparatively modest year-to-year variation within provinces around a common national path, and it is on this considerably more demanding source of identification that the subsequent inference rests.

Column 3 augments the two-way specification with the interaction between log solar capacity and the curtailment rate. The interaction coefficient is negative and significant at 1%, $\beta_3 = -0.0285$, $SE = 0.0104$, $t = -2.73$, $p = .007$, while the constituent solar term is positive at 0.026 and the curtailment term negative at −0.048. A joint Wald test of the hypothesis that curtailment plays no role in either its direct or its interactive capacity is rejected, $\chi^2(2) = 7.72$, $p = .021$, and the within-sample explanatory power rises from .540 to .574. The evidence therefore supports the central hypothesis $\beta_3 < 0$: the productivity contribution of solar capacity is systematically attenuated as the grid integration environment deteriorates.

It merits emphasis that the identified quantity is a differential rather than a level. The interaction term establishes that the capacity–productivity relationship is significantly *steeper* in provinces with

favourable grid conditions than in provinces with unfavourable ones; it does not establish that the elasticity is significantly different from zero at any particular value of curtailment. This distinction is pursued in the following subsection.

Table 8. Panel Regression Estimates for Log Green Total Factor Productivity

Variable	(1) Pooled OLS	(2) Two-way FE	(3) Two-way FE + interaction	Expected sign
ln Solar capacity	−0.0251*** (0.0051)	0.0235 (0.0289)	0.0262 (0.0296)	+
Curtailment rate	0.2517** (0.1106)	−0.0573 (0.0421)	−0.0475 (0.0442)	−
ln Solar × Curtailment	—	—	−0.0285*** (0.0104)	−
ln Utilisation hours	0.0932** (0.0425)	0.0388 (0.0329)	0.0393 (0.0330)	+
ln Per capita GDP	0.1201*** (0.0158)	0.0424 (0.0488)	0.0398 (0.0483)	+
ln Gross fixed capital formation	−0.0431 (0.0446)	−0.0151 (0.0354)	−0.0162 (0.0352)	+
Energy intensity	−0.3017*** (0.0539)	0.0023 (0.0123)	−0.0192 (0.0140)	−
ln Transmission capacity	0.1092*** (0.0394)	−0.0283 (0.0262)	−0.0286 (0.0267)	+
ETS pilot dummy	−0.0021 (0.0100)	0.0036 (0.0046)	0.0035 (0.0047)	+
Constant	−2.0261*** (0.4564)	—	—	
Province fixed effects	No	Yes	Yes	
Year fixed effects	No	Yes	Yes	
R^2 (within)	.891	.540	.574	
Observations	420	420	420	
Provinces	30	30	30	

Note: Standard errors clustered at the provincial level are reported in parentheses. The dependent variable is the natural logarithm of the GML–TFP index. Column 1 reports R^2 rather than within-R^2. Joint Wald test of curtailment and its interaction in column 3: $\chi^2(2) = 7.72$, $p = .021$. *$p < .10$. **$p < .05$. ***$p < .01$.

Because the interaction specification renders the capacity elasticity a function of curtailment, the coefficients in column 3 of Table 8 cannot be interpreted in isolation. Table 9 accordingly evaluates equation (7) at the mean curtailment rate of each macro-region and at the sample maximum. The point estimate declines monotonically from 0.0249 at the Eastern mean curtailment rate of 4.48% to 0.0183 at the Tibetan mean of 27.68%, a proportional attenuation of 26.5% across the observed range. Evaluated at the Western regional mean of 16.31%, the elasticity of 0.0215 is 13.7% below its Eastern counterpart.

Two features of Table 9 require careful statement. First, the direction and magnitude of the attenuation are exactly as hypothesised, and the *difference* between the elasticities across the curtailment distribution is statistically significant, as established by the interaction coefficient. Second, none of the conditional point estimates is individually distinguishable from zero at conventional levels, with p values ranging from .401 to .538. The correct inference is therefore that the data identify the moderating role of curtailment with reasonable precision but do not identify the unconditional level of the capacity elasticity, which is estimated with a standard error roughly comparable in magnitude to the coefficient itself.

This imprecision has an identifiable source. After the removal of province and year effects, the residual within-province variation in solar capacity is dominated by a near-common exponential deployment path—capacity rose by roughly an order of magnitude in every region between the first and third sub-periods, as Table 6 shows—leaving limited idiosyncratic variation from which to recover a level effect. The interaction, by contrast, is identified from the substantial cross-provincial dispersion in curtailment interacted with that common path, and is correspondingly better determined. Rather than being a defect, this pattern reinforces the substantive argument of the study: what the Chinese data identify robustly is not that capacity as such raises productivity, but that the grid environment governs whether it can.

Table 9. Conditional Marginal Effect of Log Solar Capacity at Selected Curtailment Rates

Evaluation point	Curtailment (%)	∂ ln GML / ∂ ln Solar	SE	t	p
Eastern regional mean	4.48	0.0249	0.0296	0.84	.401
Central regional mean	6.41	0.0243	0.0296	0.82	.411
Northeastern regional mean	11.83	0.0228	0.0296	0.77	.442
Western regional mean	16.31	0.0215	0.0296	0.73	.468
Tibet (sample maximum region)	27.68	0.0183	0.0297	0.62	.538

Note: Marginal effects are computed from column 3 of Table 8 as $\beta_1 + \beta_3 \times$ Curtailment, with standard errors obtained from the delta method using the province-clustered covariance matrix. The attenuation of the elasticity between zero curtailment and the Western regional mean is 13.7%, and between zero curtailment and the Tibetan mean is 26.5%.

Table 10 reports the Hansen (1999) threshold estimates. In specification A, in which log solar capacity is permitted to exert regime-dependent effects and the curtailment rate serves as the threshold variable, the concentrated sum of squares is minimised at $\hat{\gamma} = 10.03\%$, with a 95% likelihood-ratio confidence interval of [3.81%, 12.52%]. The sample splits into 262 observations in the low-curtailment regime and 158 in the high-curtailment regime. The likelihood-ratio statistic of 11.21 yields a bootstrap p value of .073, so the existence of a threshold in the capacity coefficient is supported at the 10% level but not at the 5% level. The regime-specific slopes are 0.0266 below the threshold and 0.0221 above it; both are positive, and their difference is modest. Notably, the direct curtailment coefficient in this specification becomes statistically significant once the regime split is admitted, $\beta = -0.0913$, $p = .049$.

Specification C provides the strongest evidence of genuine regime dependence. Here the curtailment rate is the regime-dependent regressor and interprovincial transmission capacity is the threshold variable. The estimated threshold is $\hat{\gamma} = 23.71$ GW, with a confidence interval of [23.40, 47.65] GW, and the likelihood-ratio statistic of 12.01 attains a bootstrap p value of .007, rejecting the no-threshold null at the 1% level. Only 81 province-year observations fall below the 23.71 GW transmission threshold, and these are concentrated overwhelmingly in Tibet, Qinghai, Ningxia, Gansu, and Xinjiang.

The regime coefficients in specification C invite careful interpretation. The productivity penalty associated with curtailment is −0.0623 ($p = .143$) in the low-transmission regime and −0.1188 ($p = .016$) in the high-transmission regime. That the penalty is larger, not smaller, where interconnection capacity is greater may appear counterintuitive at first reading, but it follows directly from the within-transformation on which the estimate rests. In well-interconnected provinces, curtailment is low and stable, so an observed increase represents a genuine and economically costly failure of a system that is otherwise capable of absorbing its renewable output. In poorly interconnected provinces, curtailment is chronically high, and marginal fluctuations around an already elevated level convey comparatively little additional information about the efficiency of resource use, since the binding constraint is structural rather than operational. The threshold therefore identifies the transmission capacity below which curtailment ceases to function as a margin of adjustment and becomes instead a permanent feature of the provincial energy system.

Specification B, in which curtailment is both the regime-dependent regressor and the threshold variable, locates the same 10.03% breakpoint but does not reject the no-threshold null (bootstrap $p = .140$). The regime coefficients nonetheless display the anticipated pattern of a sign reversal, from 0.0172 below the threshold to −0.0660 above it, and the point estimates are consistent with the interaction evidence of Table 8 even though they are not individually significant.

Table 10. Hansen (1999) Fixed-Effects Threshold Regression Estimates

Model	Regime-dependent regressor	Threshold variable	$\hat{\gamma}$ [95% CI]	LR	Bootstrap p	n_1 / n_2
A	ln Solar capacity	Curtailment rate	10.03% [3.81, 12.52]	11.21	.073	262 / 158
B	Curtailment rate	Curtailment rate	10.03% [3.81, 14.59]	8.90	.140	262 / 158
C	Curtailment rate	Transmission capacity	23.71 GW [23.40, 47.65]	12.01	.007	81 / 339

Note: Regime-specific coefficients (province-clustered standard errors in parentheses). Model A: $\theta_1 = 0.0266$ (0.0291), $\theta_2 = 0.0221$ (0.0293); curtailment control = −0.0913 (0.0463), $p = .049$. Model B: $\theta_1 = 0.0172$ (0.0454), $\theta_2 = -0.0660$ (0.0415). Model C: $\theta_1 = -0.0623$ (0.0425), $\theta_2 = -0.1188$ (0.0491), $p = .016$. Regime 1 comprises observations at or below $\hat{\gamma}$. All models include province and year fixed effects and the full control vector. Bootstrap p values are based on 150 fixed-regressor replications. LR = likelihood-ratio statistic for the no-threshold null; the 95% confidence interval for γ is the set of candidate values satisfying $LR(\gamma) \leq 7.35$.

Estimation of the interaction specification separately by macro-region, reported in Table 11, indicates that the pooled result is not driven by a single region and that the mechanism operates with opposite sign in the two extremes of the distribution. In the Eastern subsample the interaction is positive at 0.0451 (p = .087), whereas in the Western subsample it is negative at −0.0232 (p = .129). This divergence is consistent with the threshold evidence: in a low-curtailment environment, marginal variation in grid absorption is associated with the flexible, demand-following deployment typical of eastern distributed generation, whereas in a high-curtailment environment additional capacity encounters a binding integration constraint. Neither regional coefficient is significant at 5%, which is unsurprising given subsample sizes of 140 and 154 observations and the loss of degrees of freedom to region-specific fixed effects. The Central subsample yields a significant negative coefficient on transmission capacity, and the Northeastern subsample, comprising only three provinces, is not estimable owing to rank deficiency.

Table 12 subjects the principal finding to five robustness exercises. The interaction coefficient retains its sign, magnitude, and significance under the Driscoll–Kraay covariance estimator (β_3 = −0.0285, p = .028), confirming that the inference is not an artefact of the clustered variance estimator or of the residual cross-sectional dependence documented in Table 7. Re-specifying solar capacity in levels rather than logarithms preserves both the positive direct effect (p = .014) and the negative interaction (p = .007), the latter at the 1% level. Excluding gross fixed capital formation, the variable responsible for the elevated variance inflation factors, leaves the interaction essentially unchanged at −0.0283 (p = .007).

Two exercises qualify the result and are reported in the interest of full disclosure. Excluding Tibet, the extreme observation in the curtailment distribution, attenuates the interaction to −0.0262 and raises its p value to .167; and restricting the sample to 2010–2019 reverses the sign to +0.0145 (p = .548). Taken together these two checks indicate that the identification of the interaction draws materially on the tail of the curtailment distribution and on the final four years of the sample, during which western

deployment accelerated most sharply. The finding should therefore be characterised as robust to the choice of estimator, variance estimator, and functional form, but as dependent on the inclusion of the high-curtailment observations and the recent period in which the integration constraint became binding. That dependence is substantively coherent—the mechanism can only be identified where and when the constraint actually operates—but it counsels against extrapolating the estimated attenuation to environments in which curtailment is uniformly low.

Table 11. Regional Subsample Estimates of the Interaction Specification

Variable	Eastern	Central	Western	Northeastern
ln Solar capacity	−0.0050 (0.0464)	−0.0533 (0.0874)	0.0498 (0.0517)	Not estimable
Curtailment rate	−0.1099 (0.1084)	0.1710 (0.3180)	−0.0268 (0.0783)	Not estimable
ln Solar × Curtailment	0.0451* (0.0261)	−0.0510 (0.1597)	−0.0232 (0.0152)	Not estimable
ln Transmission capacity	0.0300 (0.0416)	−0.0992*** (0.0255)	−0.0165 (0.0487)	Not estimable
ln Utilisation hours	−0.0015 (0.0431)	−0.0114 (0.1098)	0.1233*** (0.0417)	Not estimable
ETS pilot dummy	0.0061 (0.0064)	0.0118* (0.0066)	−0.0126** (0.0063)	Not estimable
R^2 (within)	.466	—	.775	—
Observations	140	84	154	42
Provinces	10	6	11	3

Note: All models include province and year fixed effects and the full control vector; province-clustered standard errors in parentheses. The Northeastern subsample contains only three provinces and the regressor matrix is of deficient rank once province and year effects are removed, so no coefficients are reported. The within-R^2 for the Central subsample is negative and is therefore suppressed. *$p < .10$. **$p < .05$. ***$p < .01$.

Table 12. Robustness of the Solar × Curtailment Interaction

Specification	β_3	SE	p	Observations
Baseline (Table 8, column 3)	−0.0285	0.0104	.007	420
Driscoll–Kraay standard errors	−0.0285	0.0129	.028	420
Solar capacity in levels	−0.0037	0.0013	.007	420
Gross fixed capital formation excluded	−0.0283	0.0105	.007	420
Solar capacity per capita	−0.0270	0.0202	.181	420
Tibet excluded	−0.0262	0.0189	.167	406
Restricted to 2010–2019	0.0145	0.0241	.548	300

Note: β_3 is the coefficient on the interaction between solar capacity and the curtailment rate. Standard errors are clustered at the provincial level except in row 2. In the levels specification the interaction is formed with capacity measured in gigawatts rather than in logarithms, so the coefficient magnitude is not directly comparable with the remaining rows.

5. CONCLUSION

This study examined whether the expansion of solar photovoltaic capacity in China has translated into gains in regional environmentally adjusted productivity, and whether that translation is conditional upon the capability of the transmission network to absorb the resulting generation. Using a balanced panel of 30 provinces observed annually from 2010 to 2023, green total factor productivity was measured through a Global Malmquist–Luenberger index estimated by data envelopment analysis with carbon dioxide emissions treated as an undesirable output, and the resulting series was analysed within static two-way fixed-effects and Hansen threshold regression frameworks.

Four principal findings emerge. First, Chinese provincial green productivity improved steadily and regularly throughout the observation window, rising from a national mean of 0.839 in 2010 to 1.003 in 2023, a cumulative gain of 19.58% achieved at an average annual rate of 1.34% and describing a near-linear trend (R^2 = .948). Because the underlying index penalises emissions as a jointly produced undesirable output, this trajectory constitutes evidence of genuine decoupling rather than of output expansion purchased through environmental degradation.

Second, this aggregate advance conceals a severe and geographically systematic dispersion. The Eastern macro-region attained a mean index of 1.072 against 0.829 in the Western macro-region, a differential of 29.3%, notwithstanding that the Western region deployed 85% more solar capacity per province. The provincial ordering is nearly the exact inverse of the ordering by curtailment: the pooled correlation between log green productivity and the curtailment rate is −.806, whereas the correlation with log installed capacity is only .085. Xinjiang and Inner Mongolia, which host the two largest provincial solar fleets in the sample, rank twenty-seventh and twenty-fifth in green productivity while discarding 21.88% and 17.96% of their generable renewable electricity.

Third, and centrally, econometric analysis confirms that installed capacity and grid absorption interact rather than operate additively. In the preferred two-way fixed-effects specification the interaction between log solar capacity and the curtailment rate is negative and significant at the 1% level ($\beta_3 = -0.0285$, $p = .007$), and curtailment enters jointly, in its direct and interactive capacities, at $\chi^2(2) = 7.72$, $p = .021$. The implied capacity elasticity falls by 13.7% between the Eastern and Western regional mean curtailment rates and by 26.5% at the sample extreme. The identified quantity is a differential: what the data establish with precision is that the productivity return to capacity is significantly steeper where the grid absorbs output than where it does not, rather than that the elasticity attains any particular level.

Fourth, threshold estimation indicates that the relationship is not merely attenuated but structurally regime-dependent. A transmission capacity threshold of 23.71 GW is identified with a bootstrap p value of .007, below which the operational relationship between curtailment and productivity changes character; 81 of the 420 province-year observations, concentrated in Tibet, Qinghai, Ningxia,

Gansu, and Xinjiang, fall in this regime. A curtailment threshold in the neighbourhood of 10% is also located, though it attains only marginal statistical support (bootstrap p = .073). Sub-period analysis further establishes that the Eastern–Western gap widened from 0.231 to 0.255 index points across the three sub-periods despite near-identical proportional growth in all four regions and a substantial absolute decline in Western curtailment from 18.57% to 12.55%, indicating that grid improvements have been consistently outpaced by the deployment they were intended to accommodate.

Taken together, these results support a qualified rather than an unconditional assessment of China's renewable programme. The programme has delivered measurable and sustained gains in environmentally adjusted productivity at the national level. It has done so, however, through a spatial allocation in which capacity is systematically sited where the complementary infrastructure required to make it productive is weakest, with the consequence that the interregional productivity gap has proved resistant to closure.

The study contributes to three connected literatures. To the literature on environmental productivity measurement it offers a province-level application of the global directional distance framework that isolates the infrastructural, as distinct from the technological, determinants of green productivity growth. Much of the existing work in this tradition decomposes productivity change into efficiency and technical components without asking what physical conditions govern whether a given technology can be brought into productive use; the present analysis suggests that for intermittent renewables this question is not secondary.

To the literature on the economics of renewable integration the study offers evidence that the relationship between generating capacity and economic outcomes is fundamentally non-separable from network capability. The prevailing analytical convention treats installed capacity as the policy variable and transmission as a technical constraint to be relaxed at the margin. The interaction and threshold results reported here suggest the inverse ordering: transmission capability determines the productivity content of capacity, and beyond an identifiable regime boundary capacity additions may cease to generate measurable productivity returns at all.

To the broader literature on regional convergence in China the study contributes the observation that the green transition has, at least over the period examined, operated as a divergence mechanism rather than a convergence mechanism. Because renewable resource endowment is concentrated in the western provinces while consumption is concentrated in the east, a policy that allocates capital to endowment rather than to absorptive capability reproduces the spatial inequality it was in part intended to remedy.

Three implications follow from the empirical findings, ordered by the strength of the evidence supporting them.

- Sequence transmission investment ahead of generation investment in resource-rich provinces. The transmission threshold identified in Model C of Table 10 (23.71 GW, bootstrap $p = .007$) is the most statistically secure non-linearity in the analysis, and the provinces falling below it are precisely those occupying the bottom of the productivity ranking. National planning that continues to subsidise capacity additions in western provinces without a prior or simultaneous expansion of ultra-high-voltage interconnection can be expected to reproduce the observed pattern in which the largest fleets deliver the smallest productivity returns. The policy instrument implied by the evidence is not a reduction in renewable ambition but a reordering of the investment sequence.
- Adopt curtailment as an operational planning criterion rather than an ex post reporting statistic. The evidence locates a curtailment breakpoint near 10%, although at only marginal significance (bootstrap $p = .073$), and the confidence interval of [3.81%, 12.52%] is wide. The appropriate policy inference is therefore directional rather than a precise numerical target: sustained curtailment in the upper part of this interval signals that further capacity additions are unlikely to yield productivity returns commensurate with their capital cost, and that resources are better directed towards local storage, demand-side flexibility, or interconnection. Given the width of the interval, treating any single figure as a hard regulatory limit would exceed what the estimates can support.
- Extend carbon market coverage to the lagging western and northeastern provinces. Descriptively, participation in the pilot emissions trading schemes coincides closely with high green productivity: five of the nine highest-ranked provinces participate, and none of the six lowest-ranked provinces does. The regression evidence for a causal interpretation is, however, weak—the pilot indicator is insignificant in all three specifications of Table 8 and carries a small negative and marginally significant coefficient in the Western subsample. The correlation is therefore best read as reflecting the joint determination of market participation and productivity by underlying regional development, and this recommendation should be regarded as suggested by the descriptive evidence rather than established by the estimates.

A common thread unites the three proposals. The binding constraint on the productivity contribution of China's renewable programme is not the rate of capacity accumulation, which has been extraordinary by any international comparison, but the spatial mismatch between the location of generation and the location of consumption, and the institutional and physical mechanisms available to bridge it.

REFERENCES

Bağrıaçık, et al. (2022). Reformların yükseköğretim sistemlerinin toplam fakötr verimliliği üzerindeki etkisi. *Mehmet Akif Ersoy Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi, 9*(1), 121–143.

Breusch, T. S., & Pagan, A. R. (1980). The Lagrange multiplier test and its applications to model specification in econometrics. *The Review of Economic Studies, 47*(1), 239–253.

Cameron, A. C., & Miller, D. L. (2015). A practitioner's guide to cluster-robust inference. *Journal of Human Resources, 50*(2), 317–372.

CarbonBrief. (2026). *Chart: Why China's solar boom is slowing down*. https://www.carbonbrief.org/chart-why-chinas-solar-boom-is-slowing-down

Caves, D. W., Christensen, L. R., & Diewert, W. E. (1982). The economic theory of index numbers and the measurement of input, output, and productivity. *Econometrica, 50*(6), 1393–1414.

Chambers, R. G., Chung, Y., & Färe, R. (1996). Benefit and distance functions. *Journal of Economic Theory, 70*(2), 407–419.

Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision making units. *European Journal of Operational Research, 2*(6), 429–444.

Chung, Y. H., Färe, R., & Grosskopf, S. (1997). Productivity and undesirable outputs: A directional distance function approach. *Journal of Environmental Management, 51*(3), 229–240.

Cingi, S., & Tarım, Ş. A. (2000). *Türk banka sisteminde performans ölçümü DEA-Malmquist TFP endeksi uygulaması*. Türkiye Bankalar Birliği Araştırma Tebliğleri Serisi, (01).

Comin. (2010). Total factor productivity. In S. N. Durlauf & L. E. Blume (Eds.), *Economic growth: The new Palgrave economics collection*. Palgrave Macmillan.

Dinçer, E. (2008). Veri zarflama analizinde Malmquist endeksiyle toplam faktör verimliliği değişiminin incelenmesi ve İMKB üzerine bir uygulama. *Marmara Üniversitesi İİBF Dergisi, 15*(2), 825–846.

Domar, E. (1961). On the measurement of technological change. *The Economic Journal, 71*(284), 709–729.

Driscoll, J. C., & Kraay, A. C. (1998). Consistent covariance matrix estimation with spatially dependent panel data. *Review of Economics and Statistics, 80*(4), 549–560.

Drukker, D. M. (2003). Testing for serial correlation in linear panel-data models. *The Stata Journal, 3*(2), 168–177.

Färe, R., Grosskopf, S., Norris, M., & Zhang, Z. (1994). Productivity growth, technical progress, and efficiency change in industrialized countries. *The American Economic Review, 84*(1), 66–83.

Feng, C., & Whang, M. (2017). Analysis of energy efficiency and energy savings potential in China's provincial industrial sectors. *Journal of Cleaner Production, 164*, 1531–1541.

Hanoum, S., et al. (2026). Data envelopment analysis applications for energy efficiency in power generation: A comprehensive review with bibliometric and content analysis. *Energy Conversion and Management, 30*.

Hansen, B. E. (1999). Threshold effects in non-dynamic panels: Estimation, testing, and inference. *Journal of Econometrics, 93*(2), 345–368.

Hausman, J. A. (1978). Specification tests in econometrics. *Econometrica, 46*(6), 1251–1271.

International Energy Agency. (2025). *World energy investment 2025*. IEA. https://www.iea.org/reports/world-energy-investment-2025

Im, K. S., Pesaran, M. H., & Shin, Y. (2003). Testing for unit roots in heterogeneous panels. *Journal of Econometrics, 115*(1), 53–74.

Işık, C. (2016). Türkiye'de toplam faktör verimliliği ve ekonomik büyüme ilişkisi. *Verimlilik Dergisi, 2*(19).

Li, K., & Lin, B. (2015). The improvement gap in energy intensity: Analysis of China's thirty provincial regions using the improved DEA (Data Envelopment Analysis) model. *Energy, 84*, 589–599.

Mardani, E., et al. (2017). A comprehensive review of Data Envelopment Analysis (DEA) approach in energy efficiency. *Renewable and Sustainable Energy Reviews, 70*, 1298–1322.

Mundlak, Y. (1978). On the pooling of time series and cross section data. *Econometrica, 46*(1), 69–85.

Nadiri, I. (1970). Some approaches to the theory and measurement of total factor productivity: A survey. *Journal of Economic Literature, 8*(4), 1137–1177.

National Bureau of Statistics of China. (2011–2024). *China statistical yearbook and China energy statistical yearbook*. China Statistics Press. https://www.stats.gov.cn/

Oh, D. (2010). A global Malmquist-Luenberger productivity index. *Journal of Productivity Analysis, 34*(3), 183–197.

Pesaran, M. H. (2004). *General diagnostic tests for cross section dependence in panels* (CESifo Working Paper No. 1229).

Pesaran, M. H. (2015). Testing weak cross-sectional dependence in large panels. *Econometric Reviews, 34*(6–10), 1089–1117.

Rath, et al. (2019). Do fossil fuel and renewable energy consumption affect total factor productivity growth? Evidence from cross-country data which policy insights. *Energy Policy, 127*, 186–199.

Shan, Y., Guan, D., Zheng, H., Ou, J., Li, Y., Meng, J., Mi, Z., Liu, Z., & Zhang, Q. (2018). China CO_2 emission accounts 1997–2015. *Scientific Data, 5*, 170201.

Solow, R. (1956). A contribution to the theory of economic growth. *The Quarterly Journal of Economics, 70*(1), 65–94.

Tone, K. (2001). A slacks-based measure of efficiency in Data Envelopment Analysis. *European Journal of Operational Research, 130*(3), 498–509.

Wang, Z., & Feng, C. (2015). A performance evaluation of the energy, environmental, and economic efficiency and productivity in China: An application of global Data Envelopment Analysis. *Applied Energy, 147*, 617–626.

Wang, Z., & Wang, X. (2022). Research on the impact of green finance on energy efficiency in different regions of China based on the DEA-Tobit model. *Resources Policy, 77*, 102695.

Wei, C., Ni, J., & Shen, M. (2009). Empirical analysis of provincial energy efficiency in China. *China & World Economy, 17*(5), 88–103.

Wooldridge, J. M. (2010). *Econometric analysis of cross section and panel data* (2nd ed.). MIT Press.

Wu, A., Ying, Y., & Liu, B. (2014). Energy efficiency evaluation for regions in China: An application of DEA and Malmquist indices. *Energy Efficiency, 7*, 429–439.

Xu, et al. (2020). Energy efficiency evaluation based on Data Envelopment Analysis: A literature review. *Energies, 13*.

Zhang, J., et al. (2017). Industrial eco-efficiency in China: A provincial quantification using three-stage Data Envelopment Analysis. *Journal of Cleaner Production, 143*, 238–249.

Zhao, H., Guo, Z., & Zhao, H. (2019). Provincial energy efficiency of China quantified by three-stage Data Envelopment Analysis. *Energy, 166*, 96–107.

Zhao, X., et al. (2024). Regional disparities and dynamic evolution of energy efficiency distribution: Evidence from 2052 Chinese counties. *Gondwana Research, 130*, 158–168.

BALANCING PUBLIC HEALTH AND ENVIRONMENTAL SUSTAINABILITY: THE ROLES OF BIOCAPACITY AND RENEWABLE ENERGY IN G20 ECONOMIES

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ABSTRACT

This study examines the long-term determinants of ecological footprint in 18 G-20 economies between 2000 and 2021, focusing on the roles of government health expenditure, biocapacity, renewable energy, and economic growth within the framework of the Environmental Kuznets Curve (EKC). Given the strong cross-sectional dependence and slope heterogeneity among countries, the analysis employs second-generation panel techniques: the Pesaran CD test, the Pesaran-Yamagata slope homogeneity test, the CIPS/CADF panel unit root tests, a cointegration test based on error correction, and the Pooled Mean Group (PMG) and Mean Group (MG) estimators. Long-term estimates of PMG show that, over the observed period, the ecological footprint increases monotonically with income (no inverted-U-shaped EKC), increases with biocapacity, decreases with the renewable energy share, and shows no significant relationship with health expenditure when income is controlled for. The findings highlight that the primary mechanism for reducing the ecological footprint in large economies is the use of renewable energy, rather than income or healthcare spending.

Keywords: *Ecological Footprint, Health Expenditures, Renewable Energy, Panel ARDL.*

JEL Codes: *H51, Q20, C23.*

1. INTRODUCTION

Developed and developing countries face a variety of environmental problems, including CO2 emissions, climate change, global warming, overconsumption of natural resources, and biodiversity loss. All these problems together have negative impacts on the environment and cause significant losses in individuals' well-being and welfare (Ziaul & Shuwei, 2023). Climate change, in particular, is one of the biggest problems because human activities disrupt ecosystem dynamics, making environmental protection and sustainability even more important in this context (Nguyen et al., 2023). Global environmental degradation, characterized by rising CO2 emissions and a widening ecological footprint, poses a significant risk to the world and is driving global warming to more severe levels. This

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environmental degradation stems from countries' economic growth performance and their reliance on predominantly non-renewable energy sources to achieve that growth (Idroes et al., 2024).

The ecological footprint assesses the gap between the availability of renewable resources and the extent to which humans consume them (Eufrasio Espinosa & Lenny Koh, 2024). It is a technique used to measure how much biologically productive land and water an individual or activity needs to produce the resources it consumes and subsequently eliminate the resulting waste. Because the ecological footprint takes into account various resource supplies, it is more advantageous for policymaking than basing policymaking on a single ecological indicator (Sarwar et al., 2024). Therefore, the ecological footprint is an important tool for monitoring trends in environmental degradation and evaluating the effectiveness of measures to prevent, mitigate, and adapt to its negative impacts (Karimli et al., 2024). Ecological footprint is becoming a preferred indicator in assessing environmental sustainability as a comprehensive measure of environmental pressure (Li & Hassan, 2026), as an indicator of a more comprehensive presentation of environmental degradation (Karabetyan & Sart, 2024; Saleem et al., 2019; Majeed & Mazhar, 2020), and as a representative of environmental pollution (Ucan et al., 2024). Considering the growth performance of world economies, the relationship between economic growth and environmental degradation, particularly the inverted U-shaped link between income and environmental pollution, is being questioned for both developed and developing countries under the environmental Kuznets curve hypothesis (Lau et al., 2025). The environmental Kuznets curve hypothesis posits an inverted U-shaped relationship between per capita income and various pollutants, meaning that as income rises, environmental pressure increases up to a certain level and then declines. This shows how environmental quality changes along with a country's prosperity (Dinda, 2004; Ostry, 2025).

G20 countries represent approximately 85% of global GDP and two-thirds of the world's population, making them a significant economic and regulatory force (WEF, 2025). Given that the biggest risks of the 21st century stem from climate change and increasing inequalities, they play a decisive role in managing these challenges and achieving environmental transformation (Anderson et al., 2025; Time Africa, 2025). The aim of this study is to identify the macroeconomic and environmental determinants of ecological footprint for 18 of the world's largest economies within the G20 and to test whether the Environmental Kuznets Curve (EKC) hypothesis is a comprehensive measure of environmental pressure. Unlike the commonly used CO2 emissions indicator, the ecological footprint captures all the impacts of human consumption on biologically productive land and sea and is therefore considered a more important and inclusive variable for assessing sustainability. In this context, the long-term relationship among four variables expected to affect the ecological footprint is analyzed for these selected countries: economic growth (for the EKC), government health expenditure (the longevity-consumption mechanism), biocapacity, and renewable energy share.

The study consists of five sections. The introduction is the first section of the study. Thereafter, the second section is devoted to literature review. In the next two sections, the data set of the study, the definition of the variables, and the methodology are stated. And finally, in the fifth section, the result of the study is explained.

2.LITERATURE REVIEW

The literature reveals that various factors influencing the ecological footprint are included, which can be grouped as economic, social, and political (Behera et al, 2024), such as income, education, and entrepreneurship (Karabetyan & Sart, 2024; Li & Hassan, 2026), and institutional quality (Raza et al., 2023).

In the literature, income is predominantly highlighted as one of the most influential variables on the ecological footprint, and this is interpreted in terms of the validity of the EKC hypothesis (Georgescu & Kinnunen, 2024; Güleç et al., 2026; Nica et al., 2026). According to a study analyzing the long-term and short-term causality between ecological footprint and GDP, FDI, and energy use in Finland for the period 1990-2021 (Georgescu & Kinnunen, 2024), long-term increases in GDP and FDI increase the ecological footprint, while energy use positively affects it. Furthermore, the existence of a U-shaped Environmental Kuznets Curve between GDP and ecological footprint is confirmed. Similarly, Güleç et al. (2026) empirically test the determinants of ecological footprint in E-7 countries during the period 1992-2022 using variables such as real GDP per capita, renewable and non-renewable energy consumption, trade openness ratio, gross fixed capital formation, and labor force participation rate. The coefficients related to economic growth confirm the Environmental Kuznets Curve hypothesis regarding the relationship between ecological footprint and these variables. Non-renewable energy consumption increases environmental pressure, while renewable energy has a mitigating effect. The trade openness ratio was not statistically significant. In addition to studies that conclude that improvements in institutional quality indicators positively affect countries' economic growth, there are studies that reach different conclusions.

Raza et al. (2023) evaluate the long-term impact of technological innovation, renewable energy, foreign direct investment, urbanization, GDP, and institutional quality on the ecological footprint in G20 countries between 1990 and 2021. The study's long-term predictions show that technological innovation, renewable energy consumption (alone), and institutional quality, when considered together, negatively impact the ecological footprint. A positive relationship exists between ecological footprint and foreign direct investment, economic growth (GDP), and urbanization in G20 countries. Kumar & Datta (2023) examine the impact of economic growth, foreign direct investment, urban population growth, and energy consumption on both ecological footprint and CO2 emissions for G20 countries (excluding the EU group) between 1990 and 2018 using PMG/ARDL and Granger causality tests. The results show a long-term cointegration relationship between the variables. In the long term, economic growth and

conventional energy use reduce environmental quality, whereas urbanization and foreign investment improve it. In the short term, there is a bidirectional causal relationship between ecological footprint, economic growth, and non-renewable energy consumption.

Uddin et al. (2017), examining the effects of real income, financial development, and trade openness on the ecological footprint (per capita) of consumption in developed and developing countries with significant ecological footprint scores in the world during the period 1991-2012, found a positive and significant relationship between ecological footprint and real income, while trade openness had a negative and insignificant effect on the ecological footprint. Financial development was also observed to reduce the ecological footprint. Similarly, Shahbaz et al. (2023), focusing on the effect of economic growth and financial development on the ecological footprint in the 10 countries with the highest ecological footprints (China, USA, India, Japan, Brazil, Indonesia, Mexico, Korea, Turkey, and the UK) for the period 1992-2017, included non-renewable energy consumption and trade openness as explanatory variables in the model. Financial development, economic growth, and non-renewable energy use increase the ecological footprint and decrease environmental quality. The effect of trade openness on environmental quality was not statistically significant. Furthermore, a bidirectional causality between economic growth and ecological footprint has been found. A 2019 study by Saleem et al., focusing on BRICS countries during the 1991-2014 period, tests the EKC hypothesis by investigating the impact of human capital and biocapacity on environmental degradation (ecological footprint, carbon emissions, nitrous oxide and methane emissions). Energy consumption significantly increases the ecological footprint and greenhouse gas emissions. The study finds bidirectional causality between economic growth, biocapacity, human capital, and environmental degradation. China is the only country in which the EKC hypothesis is confirmed across all models used. It shows that the environmental impact varies by indicator across BRICS countries; increasing biocapacity increases the ecological footprint and methane emissions. The study by Ullah et al. (2023) investigates the impact of economic growth, natural resources, urbanization, and biocapacity on Türkiye's ecological footprint between 1970 and 2018. The analysis results confirm that biocapacity has a positive effect on the ecological footprint. While economic growth has a significant enhancing effect on the ecological footprint in Türkiye, this effect decreases after a certain threshold in the long term. These results demonstrate that the EKC hypothesis is also valid for Turkey.

Among the factors affecting the ecological footprint, biocapacity is also mentioned in the literature (Saleem et al. 2019; Majeed & Mazhar, 2020; Danish et al. 2019; Ullah et al., 2023). Sarkodie's (2021) study examines 188 countries and regions between 1970 and 2017, considering dependent variables such as carbon footprint, ecological footprint, and ecological status, as well as biocapacity, population density, income, and trade. The study's findings do not support the inverted-U shape predicted by the EKC hypothesis in the relationship between economic growth and ecological footprint. This result indicates that as biocapacity increases, it positively affects environmental quality. The

relationship between ecological footprint and trade, income, human capital, and biocapacity is measured for selected countries grouped into high-, middle-, and low-income categories during the period 1961-2018. Human capital has a negative effect on the ecological footprint across all income levels. Biocapacity has a positive and significant effect for high- and middle-income countries, meaning that an increase in biocapacity increases the ecological footprint. An inverted U-shaped relationship exists between per capita income and ecological footprint in high-income and OECD countries (Majeed & Mazhar, 2020). This study examines the relationship between economic growth and ecological footprint in Pakistan using data from 1971-2014 and the ARDL approach. GDP, human capital, and biocapacity are included in the model. Both economic growth and biocapacity increase the ecological footprint. The results show no causality between economic growth and ecological footprint (Danish et al, 2019).

Ali et al. (2025) empirically test the relationship between green finance, renewable energy consumption, economic growth, health expenditures, and ecological footprint for Pakistan during the period 2000-2020. Health expenditures have a positive and statistically significant effect on the ecological footprint. In addition, renewable energy consumption has a negative and statistically significant effect on the ecological footprint. Furthermore, economic growth has a significant negative effect on the ecological footprint.

Using a panel dataset covering the period 1991-2023 for G7 countries, they examined the causal relationship between carbon footprint (dependent variable) and macroeconomic variables (economic growth, population change, renewable energy consumption, and technological innovation) using a Panel VAR model and Granger causality test. Renewable energy consumption and technological innovation reduce the carbon footprint, while economic growth and population change increase it. The results show bidirectional Granger causality between the carbon footprint and renewable energy consumption (Aslan & Topçuoğlu, 2026).

Sun & Stephen (2026) analyze the impact of fiscal policy, natural resource rent, environmental governance, and green innovation on ecological footprint in G-20 economies during the period 1990-2023 using the CS-ARDL framework. Fiscal expansion and resource dependence increase ecological pressures, while effective governance and green innovation mitigate them. Li & Hassan (2026) examine the impact of natural resources, education, trade, urban population, and financial resources on environmental sustainability in G-20 countries for the period 2000-2022 using the Driscoll-Kraay and CS-ARDL models. Increased natural resources and urban population reduce ecological pressure, while trade, financial resources, and education increase the ecological footprint. The study by Karabetyan & Hassan (2026) tests the relationship between entrepreneurial activity, education, and renewable energy use (the explanatory variable) and ecological footprints in selected G-20 countries between 2002 and 2020. A unidirectional causal relationship is found between entrepreneurial activity, education, and ecological footprint. Education, the use of renewable energy, and entrepreneurial activities have generally reduced the ecological footprint in the long term in most of the countries studied.

3. DATA SET

This study covers 18 G20 economies (Argentina, Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Mexico, Russia, South Africa, South Korea, Turkey, the United Kingdom, and the United States) observed annually between 2000 and 2021, representing a balanced panel of 396 observations. The dataset includes all G20 countries except the European Union and Saudi Arabia. The dataset ends in 2021, as the renewable energy series is not yet available.

Table 1. Variable Definitions and Transformations

Variable	Definition	Source	Form
ef_con	Ecological footprint of consumption per capita (gha)	Global Footprint Network	log (dependent)
Gdppc	GDP per capita (constant 2015 US$)	World Bank WDI	log + squared
Biocap	Biocapacity per capita (gha)	Global Footprint Network	log
Hexp	Current health expenditure (% of GDP)	World Bank WDI	level
Rec	Renewable energy consumption (% of final energy)	World Bank WDI	level

Note: Quantity and monetary variables enter in logs (elasticity interpretation and scale control); shares enter in levels (semi-elasticity).

Table 1 shows the model variables, where they were obtained from, and how they were used. During data validation, South Korea's ecological-footprint and biocapacity values were found to correspond to the "Grazing Land" sub-component rather than the "Total" column of the Global Footprint Network dataset (e.g. footprint of 0.18 instead of 5.26 gha in 2000). These two series were corrected to the Total column for all years; all other countries were unaffected. The correction materially improved the analysis (e.g. the footprint–income correlation rose from 0.48 to 0.91). Descriptive statistics are presented in Table 2.

Table 2. Descriptive Statistics (levels, 2000–2021)

Variable	Mean	Std.Dev.	Min	Max
Ecological footprint (gha)	4.619	2.264	0.715	10.978
Biocapacity (gha)	3.932	4.614	0.297	17.764
Health exp. (% of GDP)	7.831	3.246	1.853	18.516
GDP per capita (2015 US$)	23,646.9	18,030.1	756.7	62,680.3
Renewable energy (%)	14.799	12.495	0.700	50.000

Note: Descriptive statistics (N = 396). Biocapacity shows the widest dispersion (std > mean), reflecting large differences between resource-rich (Canada, Brazil, Australia) and resource-scarce economies.

Since G20 economies are highly integrated, the estimation strategy was designed to account for cross-sectional dependence and parameter heterogeneity. First, the Pesaran (2004) CD test is applied to assess cross-sectional dependence and to validate second-generation methods. The presence of slope homogeneity is assessed using the Pesaran-Yamagata (2008) $\tilde{\Delta}$ test to select between pooled and heterogeneous estimators. The analysis process continues with the Pesaran (2007) CIPS/CADF tests, which are robust against cross-sectional dependence. Cointegration is tested using error-correction-based evidence (Westerlund 2007 framework), supported by a pooled error-correction term. Finally, the panel ARDL approach developed by Pesaran, Shin, and Smith (1999) is used to estimate long-term relationships; Pooled Mean Group (PMG) and Mean Group (MG) estimators are compared via the Hausman test to determine whether long-term coefficients are homogeneous among countries.

4.METHODOLOGY

4.1. Cross-Sectional Dependence

The Pesaran CD test rejects cross-sectional independence at the 1% level for each series, confirming widespread interdependence among G20 economies and rendering first-generation tests obsolete.

Table 3. Pesaran (2004) CD

Variable	CD-statistic	p-value	Decision
ln ecological footprint	9.06	0.000	Reject H0
ln biocapacity	16.76	0.000	Reject H0
ln GDP per capita	40.84	0.000	Reject H0
Health expenditure	28.40	0.000	Reject H0
Renewable energy	5.57	0.000	Reject H0

4.2 Slope Homogeneity

The Pesaran-Yamagata test strongly rejects slope homogeneity for both the full EKC specification and the specification without a quadratic term, indicating that the marginal effects of the determinants differ between countries. This supports heterogeneous estimation (MG), while allowing PMG to remain acceptable under long-term homogeneity.

Table 4. Pesaran–Yamagata (2008) Slope Homogeneity Test

Specification	$\tilde{\Delta}$	p-value	$\tilde{\Delta}$ (adj.)	p-value
Full model (EKC, k = 5)	9.64	0.000	11.56	0.000
Without squared term (k = 4)	12.52	0.000	14.56	0.000

4.3 Panel Unit-Root Tests

CIPS/CADF tests show that none of the series are stationary in levels (constant + trend) but are stationary in first differences; therefore, each variable is first-order integrated, I(1). No variable is I(2), which satisfies the requirement of the panel ARDL framework. (First difference statistics for income are quite meaningful at low latency levels; attenuation at higher latencies reflects limited time dimension rather than I(2) behavior.)

Table 5. Pesaran (2007) CIPS Panel Unit-Root Test

Variable	CIPS (level)	CIPS (Δ)	Order
ln ecological footprint	−2.04	−3.00***	I(1)
ln biocapacity	−2.71	−3.55***	I(1)
ln GDP per capita	−2.11	−2.21*	I(1)
(ln GDP per capita)²	−2.02	−2.15*	I(1)
Health expenditure	−2.13	−2.59**	I(1)
Renewable energy	−2.33	−3.34***	I(1)

Note: Levels: constant + trend; differences: constant. *, **, *** denote stationarity at 10%, 5%, 1%. Critical values from Pesaran (2007) for N,T in this range.

4.4. Cointegration

Evidence based on error correction supports a long-term (cointegration) relationship. In country-by-country conditional error-correction regressions, the correction rate is negative for all 18 countries and statistically significant for 13 (10%), with an average correction of -1.11. Specifically, the combined error correction term from the PMG model (Section 4.5) is negative and significant at the 1% level, confirming cointegration within the ARDL framework.

4.5.Long-run Estimates: PMG and MG

The PMG estimator (common long-run coefficients, heterogeneous short-run dynamics) was estimated using the Pesaran-Shin-Smith condensed maximum likelihood algorithm and converged to stable, theory-consistent estimates. For comparison, the MG estimator (averaged unrestricted country regressions) has also been reported, but it is less sensitive due to its short time dimension (T = 22).

Table 6. PMG Long-Run Estimates

Regressor (long-run)	PMG coef.	Std.Err.	t	Sig.
ln GDP per capita	−0.990	0.212	−4.66	***
(ln GDP per capita)²	0.077	0.013	5.86	***
ln biocapacity	0.783	0.102	7.68	***
Health expenditure	−0.009	0.007	−1.34	n.s.
Renewable energy	−0.016	0.002	−9.16	***
Error-correction term (φ)	−0.409	0.048	−8.61	***

Note: Dependent variable: ln ecological footprint of consumption. *** p<0.01; n.s. = not significant.

Hausman test (MG vs PMG): $\chi^2(5) = 11.22$, $p = 0.047$. The test supports MG to some extent; however, MG's long-term coefficients are economically unreasonable and insensitive at T = 22 (e.g., an income coefficient of -10.6), so the rejection is due to MG noise rather than actual long-term heterogeneity. Therefore, PMG has been adopted as the preferred estimator.

4.6. Model Diagnostics

Two post-estimation checks were run on the PMG residuals. The Pesaran CD test indicates residual cross-sectional dependence (CD = 9.43, $p < 0.001$; mean pairwise |correlation| = 0.24), so the assumption of cross-sectionally independent errors does not hold. Serial correlation, by contrast, is negligible (mean residual AR(1) = −0.02; only 2 of 18 countries exceed |AR(1)| = 0.3), confirming that the ARDL(1,1) dynamics are adequate.

Table 7. PMG Post-Estimation Diagnostics

Diagnostic	Value	Verdict
Residual CD (Pesaran)	9.43 (p<0.001)	cross-sectional dependence present
Mean pairwise |corr| (residuals)	0.24	moderate
Mean residual AR(1)	−0.02	negligible serial correlation
Countries with |AR(1)| > 0.3	2 / 18	no concern

PMG point estimates remain consistent, but residual cross-sectional dependence affects the sensitivity of the inference. This provides empirical justification for the next planned phase of the project, which involves re-estimating the model with cross-sectionally enhanced estimators (CS-ARDL or CCEMG) that are robust against cross-sectional dependence. The absence of residual series correlation confirms that the dynamic specification itself is robust.

5. CONCLUSION

In the era of climate change, countries face numerous risks and challenges in achieving environmental sustainability. Economic growth-oriented economies achieve higher social welfare through growth, but increased production and consumption lead to greater environmental pressure from the use of natural resources. Improving environmental quality supports sustainability and development.

This study examines the long-term determinants of ecological footprint in 18 G-20 economies between 2000 and 2021, focusing on the roles of government health expenditure, biocapacity, renewable energy, and economic growth within the framework of the EKC. The negative, significant error correction term (-0.41) in the analysis results confirms a stable long-term relationship. Income terms form a U-shaped (negative linear, positive squared) curve with a turning point at ln GDP ≈ 6.46, below the sample minimum (6.63). Ecological footprint increases with income across the entire observed income range, and income elasticity rises from approximately 0.4 at low incomes to approximately 0.7 at high incomes. The inverted U-shaped Environmental Kuznets Curve is not supported by the ecological footprint across 18 G20 countries. Of the variables, biocapacity shows a positive and highly significant long-term elasticity (0.78). A 1% increase in biocapacity is associated with a 0.78% increase in the carbon footprint. When income is controlled, health expenditure is not significant in the long term. Although strongly correlated with the carbon footprint (0.68), this relationship appears to operate through income (the two are correlated at 0.76); the proposed long-life-consumption channel does not exist as an independent long-term effect. Renewable energy has a strong negative impact on the ecological footprint. A one-point increase in the share of renewable energy reduces the carbon footprint by approximately 1.6%. This emerges as the clearest finding in terms of policy and the study's hypotheses.

The study results show that in 18 G20 economies between 2000 and 2021, the ecological footprint of consumption is cointegrated with income, biocapacity, health expenditures, and renewable energy. Long-term evidence demonstrates that: (i) the ecological footprint increases with income throughout the observed period, and there is no inverted U-shaped Environmental Deficiency Curve (EDC); (ii) biocapacity increases the ecological footprint; (iii) health expenditures have no independent long-term effect; and (iv) renewable energy significantly reduces the ecological footprint.

From a policy perspective, the results show that economic growth alone does not automatically yield environmental gains for large, developed economies, and that expanding the share of renewable energy is the most effective means of reducing the ecological footprint. Therefore, economies need to focus on policies that prioritize a green economic transition by shifting away from non-renewable energy sources. However, the study also has some limitations. In this context, the MG estimates are imprecise due to the short time dimension (T = 22) for country-specific estimation, whereas PMG is a reliable estimator. Expanding the sample to include renewable energy data from 2021 onwards and examining

health expenditures by disaggregating them from other alternative indicators will further develop the analysis in future studies.

REFERENCES

Ali, A., Faisal, F., Isiksal, A. Z., & Maktoumi, I. S. A. (2025). Do green finance and health expenditures lessen the ecological footprint to ensure sustainable development? *Innovation and Green Development, 4*(2), 100223. https://doi.org/10.1016/j.igd.2025.100223

Anderson, S., Balata, F., Campos, I. M., de Conti, B., et al. (2025). *The G20 at a crossroads: An independent assessment of the G20's impact, and lessons for an equitable economic future*. New Economics Foundation, IEJ, IPS, Transforma, & CESR. https://new-economicsf.files.svdcdn.com/production/files/The-G20-at-a-crossroads-D.pdf?dm=1762525746

Aslan, A., & Topçuoğlu, V. (2026). Panel data analysis of the impact of economic growth, population change, innovation, and renewable energy policies on the carbon footprint in G-7 countries. *International Journal of Contemporary Economics and Administrative Sciences, XVI*(1), 764–787.

Behera, B., Behera, P., Sucharita, S., & Sethi, N. (2024). Mitigating ecological footprint in BRICS countries: Unveiling the role of disaggregated clean energy, green technology innovation and political stability. *Discover Sustainability, 5*, 165. https://doi.org/10.1007/s43621-024-00378-0

Danish, Hassan, S. T., Baloch, M. A., Mahmood, N., & Zhang, J. W. (2019). Linking economic growth and ecological footprint through human capital and biocapacity. *Sustainable Cities and Society, 47*, 101516. https://doi.org/10.1016/j.scs.2019.101516

Dinda, S. (2004). Environmental Kuznets curve hypothesis: A survey. *Ecological Economics, 49*(4), 431–455. https://doi.org/10.1016/j.ecolecon.2004.02.011

Eufrasio Espinosa, R. M., & Lenny Koh, S. C. (2024). Forecasting the ecological footprint of G20 countries in the next 30 years. *Scentifici Reports, 14*, 8298. https://doi.org/10.1038/s41598-024-57994-z

Georgescu, I., & Kinnunen, J. (2024). Effects of FDI, GDP and energy use on ecological footprint in Finland: An ARDL approach. *World Development Sustainability, 4*, 100157. https://doi.org/10.1016/j.wds.2024.100157

Güleç, O., Utlu Koçdemir, S., & Özyıldız, T. (2026). Sustainability in E7 economies: Testing the EKC hypothesis within the framework of economic growth and ecological footprint dynamics. *Journal of Economics and Administrative Sciences, 27*(2), 699–726. https://doi.org/10.37880/cumuiibf.1820233

Idroes, G. M., Hardi, I., Rahman, M. H., et al. (2024). The dynamic impact of non-renewable and renewable energy on carbon dioxide emissions and ecological footprint in Indonesia. *Carbon Research, 3*, 35. https://doi.org/10.1007/s44246-024-00117-0

Karabetyan, L., & Sart, G. (2024). The impact of entrepreneurship and education on the ecological footprint: Insights from the G-20 states. *Sustainability, 16*(1), 97. https://doi.org/10.3390/su16010097

Karimli, T., Mirzaliyev, N., & Guliyev, H. (2024). The globalization and ecological footprint in European countries: Correlation or causation? *Research in Globalization, 8*, 100208. https://doi.org/10.1016/j.resglo.2024.100208

Kumar, P., & Datta, S. K. (2023). Investigating the causal relationship between environmental degradation and selected economic factors: Evidence from G20 countries. *SN Buiness and Economics, 3*, 199. https://doi.org/10.1007/s43546-023-00565-7

Lau, L. S., Yii, K. J., Ng, C. F., Tan, Y. L., & Yiew, T. H. (2025). Environmental Kuznets curve (EKC) hypothesis: A bibliometric review of the last three decades. *Energy & Environment, 36*(1), 93–131.

Li, T., & Hassan, A. (2026). Urbanization, education, and resource efficiency: Empirical insights into environmental sustainability in G20 nations. *Sustainable Development, 34*(S1), 364–378. https://doi.org/10.1002/sd.70182

Majeed, M. T., & Mazhar, M. (2020). Reexamination of environmental Kuznets curve for ecological footprint: The role of biocapacity, human capital, and trade. *Pakistan Journal of Commerce and Social Sciences, 14*(1), 202–254.

Nguyen, T. T. H., Tu, Y. T., Diep, G. L., Tran, T. K., Tien, N. H., & Chien, F. S. (2023). Impact of natural resources extraction and energy consumption on the environmental sustainability in ASEAN countries. *Resources Policy, 85*, Part A, 103713. https://doi.org/10.1016/j.resourpol.2023.103713

Nica, E., Kliestik, T., Szpilko, D., Szydło, J., & Mazumder, S. (2026). Energy, environment, and policy in G20 countries: Modeling the N-shaped EKC with renewable energy, fossil fuels, nuclear energy, and R&D investment. *Energies, 19*(6), 1422. https://doi.org/10.3390/en19061422

Ostry, J. D. (2025, September 8). *Yes, there is an environmental Kuznets curve: Economic development can be a pathway to lower per-capita emissions*. Bruegel. https://www.bruegel.org/first-glance/yes-there-environmental-kuznets-curve-economic-development-can-be-pathway-lower-capita

Pesaran, M. H. (2004). *General diagnostic tests for cross section dependence in panels*. Cambridge Working Papers in Economics.

Pesaran, M. H. (2007). A simple panel unit root test in the presence of cross-section dependence. *Journal of Applied Econometrics, 22*(2), 265–312.

Pesaran, M. H., Shin, Y., & Smith, R. P. (1999). Pooled mean group estimation of dynamic heterogeneous panels. *Journal of the American Statistical Association, 94*(446), 621–634.

Pesaran, M. H., & Yamagata, T. (2008). Testing slope homogeneity in large panels. *Journal of Econometrics, 142*(1), 50–93.

Raza, A., Habib, Y., & Hashmi, S. H. (2023). Impact of technological innovation and renewable energy on ecological footprint in G20 countries: The moderating role of institutional quality. *Environmental Science and Pollution Research, 30*, 95376–95393. https://doi.org/10.1007/s11356-023-29011-9

Saleem, N., Shujah-ur-Rahman, S., & Jun, Z. (2019). The impact of human capital and biocapacity on environment: Environmental quality measure through ecological footprint and greenhouse gases. *Journal of Pollution Effects & Control, 7*, 237. https://doi.org/10.35248/2375-4397.19.7.237

Sarkodie, S. A. (2021). Environmental performance, biocapacity, carbon & ecological footprint of nations: Drivers, trends and mitigation options. *Science of the Total Environment, 751*, 141912. https://doi.org/10.1016/j.scitotenv.2020.141912

Sarwar, N., Bibi, F. N., Junaid, A., & Alvi, S. (2024). Impact of urbanization and human development on ecological footprints in OECD and non-OECD countries. *10*(19), e38058.

Shahbaz, M., Dogan, M., Akkus, H. T., & Gursoy, T. (2023). The effect of financial development and economic growth on ecological footprint: Evidence from top 10 emitter countries. *Environmental Science and Pollution Research, 30*, 73518–73533. https://doi.org/10.1007/s11356-023-27573-2

Sun, Y., & Stephen, E. (2026). Sustainable development pathways: How fiscal policy, green innovation, and environmental governance shape ecological footprints in G-20 economies? *Sustainable Development, 34*(S2), 170–181. https://doi.org/10.1002/sd.70310

Time Africa. (2025, October 6). *What is the G20? Understanding the world's most powerful economic forum G20*. https://africa.time.com/g20/what-is-the-g20-understanding-the-worlds-most-powerful-economic-forum/

Ucan, O., Ozturk, I., & Turgut, E. (2024). Determinants of ecological footprint in BRICS countries: A panel data analysis. *Environment, Development and Sustainability, 26*, 26839–26852. https://doi.org/10.1007/s10668-023-03755-3

Uddin, G. A., Salahuddin, M., Alam, K., & Gow, J. (2017). Ecological footprint and real income: Panel data evidence from the 27 highest emitting countries. *Ecological Indicators, 77*, 166–175. https://doi.org/10.1016/j.ecolind.2017.01.003

Ullah, A., Tekbaş, M., & Doğan, M. (2023). The impact of economic growth, natural resources, urbanization and biocapacity on the ecological footprint: The case of Turkey. *Sustainability, 15*(17), 12855. https://doi.org/10.3390/su151712855

WEF. (2025, 19 Kasım). *What is the G20 and why does it matter?* World Economic Forum. https://www.weforum.org/stories/global-cooperation/g20-summit-what-you-need-to-know/

Westerlund, J. (2007). Testing for error correction in panel data. *Oxford Bulletin of Economics and Statistics, 69*(6), 709–748.

Ziaul, I. M., & Shuwei, W. (2023). Environmental sustainability: A major component of sustainable development. *International Journal of Environmental, Sustainability, and Social Science (IJESSS), 4*(3), 900–907. https://doi.org/10.38142/ijesss.v4i2.296

LEADERSHIP DURING MERGERS AND ACQUISITIONS: A MULTILEVEL FRAMEWORK FOR TRUST, IDENTITY, AND INTEGRATION

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ABSTRACT

Leadership is widely acknowledged as important in mergers and acquisitions, yet literature still treats it more as a background condition than as a clearly specified mechanism explaining why some integrations build commitment and coordination while others generate distrust, delay, and value erosion. This gap matters because post-merger integration is not only a structural exercise; it is a high-uncertainty social process in which early decisions about pace, governance, executive appointments, communication, and symbolic actions shape how employees interpret the new organization. This paper develops a phase-based conceptual framework of leadership during M&A by synthesizing classic change-leadership theory with M&A integration scholarship and practitioner evidence from merger cases. Methodologically, it adopts an integrative conceptual review, drawing on foundational change frameworks, merger-specific work on culture and trust, and case-based practitioner evidence. The central argument is that effective M&A leadership involves four linked functions performed differently across phases: establishing strategic meaning, designing credible integration architecture, signaling fairness and inclusion, and sustaining trust while protecting the base business. The paper argues that leadership choices are especially consequential when they communicate whether the deal is being run as a takeover, a merger of equals, or a selective "best-of-both" integration. It further proposes that transparent communication, role modeling, carefully designed co-leadership arrangements, and symbolic acts that reduce hierarchy can increase trust and readiness, while poorly sequenced leadership decisions amplify anxiety and slow execution. The contribution is twofold: it re-centers leadership as a multilevel explanatory mechanism in M&A research and offers testable propositions and practice implications for executives responsible for integration success.

Keywords: *Mergers and Acquisitions, Post-Merger Integration, Leadership, Organizational Trust, Change Management.*

JEL Codes: *G34, M12, M14.*

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1. INTRODUCTION

Mergers and acquisitions are happening at a record pace around the world, but there's a catch: a shocking number of these deals fail to deliver on their financial and strategic promise. Often, the problem isn't the numbers, it's the people. The human and cultural side of a deal gets mishandled, and the whole thing falls apart.

We know that strong leaders are critical for navigating these disruptions and blending different company cultures. And yet, while everyone in the business world stresses the importance of leadership, academic research has been surprisingly slow to catch up. As Junni and Sarala (2014) pointed out, leadership in M&A is a "largely neglected area" of study. They found only a handful of solid studies and noted that most of them completely ignore the crucial pre-merger work and managerial due diligence.

This review is designed to fill that gap. We're taking a close look at leadership across the entire M&A lifecycle, bringing together theories to answer a few key questions: What do effective leaders do to make integration successful? How do those actions need to change as a deal moves from the planning stage to the post-integration phase? And how do different countries and cultures shape what works?

We'll explore how leadership affects individuals and teams, considering the impact of trust, communication, and culture on everything from employee readiness and retention to innovation and the bottom line. By pulling together findings from recent global studies, we aim to build a clear framework that can be a practical guide for leaders in the trenches and spark new avenues for future research.

2. THEORETICAL FOUNDATIONS

2.1. Transformational vs. Transactional Leadership in M&A

When a company goes through a merger, transformational leadership with its focus on vision, charisma, and personal support, can make all the difference for employees. Leaders with this style build trust and give people a sense of purpose, which helps everyone navigate the uncertainty of change. They build commitment by connecting with people on an emotional level and being someone employees can look up to. Burns (1978) and Bass (1985) describe transformational leaders as building commitment through idealized influence and emotional connection. It's no surprise, then, that this approach boosts morale and helps keep people from leaving. By creating a positive, supportive work environment, these leaders can dial down the anxiety and stress that mergers often cause. They help maintain a sense of who the company is, which can ease the feeling of loss that many employees experience.

On the other hand, there's transactional leadership, which is built on clear roles, rules, and a system of rewards and punishments. These leaders make expectations clear and offer specific incentives for following the rules. While that can keep operations stable, it often lacks the personal trust needed to get through a turbulent period of change. This style is more of an "order-based approach" that relies on

a reward-punishment system rather than charisma or mutual trust. Research suggests that focusing only on transactions isn't enough to meet employees' emotional needs during a merger.

Instead, many argue for a blended approach. The most effective leaders combine the vision of a transformational style with the structure of a transactional one. Ultimately, no leader is purely one or the other. In the wake of a merger, flexibility and balance are everything. As Szabó and Mishin (2023) conclude, the best results come when leaders combine both styles, tailoring their approach to context. No leader is purely transformational or transactional, flexibility and balance are essential in post-merger environments.

2.2. Authentic and Ethical Leadership

- Authentic Leadership

Avolio and Gardner (2005) define authentic leadership around four dimensions: self-awareness, relational transparency, balanced processing, and internalized moral perspective. In M&A, self-awareness means leaders recognize how the merger affects them and their biases. Relational transparency translates to being open about motives and feelings (e.g., "I am worried too, but here is our plan"). Balanced processing implies seeking and considering employee input on integration. An internalized moral perspective means basing decisions on values rather than short-term gain.

Empirical research on authentic leadership outside M&A suggests it builds trust and optimism (Walumbwa *et al.*, 2010). In the change literature, Posner and Kouzes (1993) found that being genuine was a key leadership hallmark. In an M&A context, anecdotal evidence from practice suggests that leaders who share their "personal story" of the merger (e.g., acknowledging sacrifices) help followers feel secure. A recent survey of HR professionals (The Merger & Acquisition Leadership Survey, 2020) reported that over 80% believed "authentic behaviour" (e.g. admitting mistakes, showing empathy) was critical for integration success.

For example, in a cross-border tech acquisition, the CEO of the acquirer held joint town halls with the target's staff, explicitly describing his own uncertainties and inviting questions. Follow-up interviews showed that employees found this approach reassuring and felt "we were in this together." This aligns with leadership theory: Avolio et al. (2004) note that authentic leaders tend to have high LMX because followers sense their genuineness.

Proposition 1: *Authentic leadership by top executives and integration managers will positively influence employee trust and identification with the merged company.* Proposition 2: *Perceived leader authenticity will moderate the negative effect of integration-related uncertainty on employee commitment.*

- Ethical Leadership

Brown and Trevino (2006) conceptualized ethical leadership as leaders who are "normative decision-makers" and "moral persons." They demonstrate ethics through fairness (justice) and role modelling (walking the talk). In M&A, ethical leadership can manifest in transparent decision processes (e.g., explaining how layoffs were decided) and equitable treatment across legacy groups. This matters because mergers are often viewed through a fairness lens: employees ask "Are we getting a raw deal compared to Company X's people?"

Studies outside M&A consistently find that ethical leadership builds trust and pro-organizational behaviour (Brown *et al.*, 2005). In M&A-specific research, one study of a cross-continental acquisition in the mining industry found that managers who maintained consistent promotion and pay policies across the merged firm avoided fueling resentment. In another example, a bank merger in Latin America was bolstered by the CEO's emphasis on corporate values; he personally visited branches to reiterate that "fairness will guide our decisions," which research participants later credited with reducing turnover.

Practically, ethical leadership during M&A involves: (a) transparent communication about changes (no hidden agendas), (b) procedural justice in restructuring (clear criteria for retention/layoffs), and (c) ethical role modeling (leaders refraining from self-serving behavior). For instance, if a CEO promises no meritocratic penalties before the deal and then cuts high-performers, trust collapses.

Proposition 3: *Ethical leadership practices (transparency, fairness) during integration will reduce employee cynicism and resistance.*
Proposition 4: *The positive effect of ethical leadership on employee cooperation will be mediated by perceived procedural justice.*

Authentic and ethical leadership form the moral bedrock of M&A leadership. While firm evidence in M&A is limited, the general leadership literature and practitioner accounts strongly suggest that leaders lacking authenticity/ethics exacerbate the "psychological contract breach" that often occurs in mergers. In contrast, virtues like trustworthiness and integrity become bridges across the institutional void of a new organization.

2.3. Strategic Leadership and LMX

Strategic leadership and the quality of leader–follower relationships are both central in understanding employee responses to mergers and acquisitions and, by extension, their readiness for change during post-merger integration. In the M&A context, strategic leadership refers primarily to the actions of the top management team in setting the overall direction of the merger, emphasising a clear vision for the combined organization, and aligning structures, systems, and culture with that vision (Cannella & Hambrick, 1993; Eisenhardt & Zbaracki, 1992). Senior executives are responsible for explaining why the merger is taking place, what strategic and operational synergies it seeks to realize, and how the integration process will unfold over time (Haleblian, Devers, McNamara, Carpenter, & Davison, 2009; Marks & Mirvis, 2011). By framing the merger as a purposeful, value-creating initiative

rather than a purely financial transaction, strategic leaders can provide employees with a sense of direction and reduce ambiguity about the future (Cartwright & Schoenberg, 2006; Haspeslagh & Jemison, 1991).

The way in which this vision is communicated is particularly salient. Research on change leadership emphasizes that frequent, transparent, and consistent communication from top management is associated with higher levels of trust, perceived fairness, and acceptance of change (Kotter, 1995; Schweiger & DeNisi, 1991). In merger situations, clear communication about integration goals, expected benefits, and potential risks can help employees make sense of the change and assess its implications for their own roles and careers (Buono & Bowditch, 2003; Seo & Hill, 2005). Conversely, a lack of communication or inconsistent messaging can exacerbate uncertainty and fuel rumors, thereby undermining employees' readiness to support integration efforts. Strategic leaders are therefore expected not only to design the integration strategy but also to serve as visible and credible champions of the merger, signaling commitment to the process and responsiveness to employee concerns (Cartwright & Cooper, 1993; Marks & Mirvis, 2011).

At a more proximal, relational level, Leader–Member Exchange (LMX) theory provides a useful lens for understanding how day-to-day interactions between supervisors and employees shape reactions to change. LMX theory posits that leaders form differentiated relationships with subordinates that vary in terms of trust, mutual respect, and obligation (Graen & Uhl-Bien, 1995). High-quality LMX relationships are characterized by open communication, socio-emotional support, and greater latitude for participation and influence, whereas low-quality exchanges tend to be more transactional and restricted to formal role requirements. In the context of organizational change, several studies have shown that high-quality LMX is associated with more positive attitudes toward change, stronger commitment to change initiatives, and reduced resistance (e.g., Van Dam, Oreg, & Schyns, 2008; Neves, 2009).

Although empirical work specifically examining LMX in merger and acquisition settings remains limited, the underlying mechanisms identified in the broader change literature are highly relevant to post-merger integration. High-quality LMX can provide employees with a trusted source of information about the change, help them interpret ambiguous signals from the broader organization, and offer emotional support during periods of uncertainty (Rafferty & Restubog, 2010). Supervisors who enjoy strong exchanges with their subordinates are also better positioned to involve them in problem solving, solicit feedback about integration challenges and tailor support to individual needs. All these can enhance perceptions of efficacy and control, key components of readiness for change (Armenakis & Harris, 2002; Holt, Armenakis, Feild, & Harris, 2007).

Leadership research in M&A further suggests that specific leadership styles may interact with LMX quality to shape integration outcomes. Reich (2011), for example, argues that transformational

leaders who articulate an appealing vision, demonstrate individualized consideration, and inspire followers, are particularly effective when they also cultivate high-quality leader–member exchanges. This combination enables leaders to build new cross-organizational social networks rapidly, bridge legacy group boundaries, and foster a shared identity in the merged organization. Similarly, work on authentic and ethical leadership indicates that when employees perceive their leaders as transparent, fair, and value-driven, they are more likely to trust managerial intentions. They can accept difficult integration decisions, and remain engaged despite short-term disruptions (Avolio & Gardner, 2005; Walumbwa, Avolio, Gardner, Wernsing, & Peterson, 2008).

Taken together, these perspectives indicate that strategic leadership and LMX operate at complementary levels in mergers and acquisitions. At the macro level, strategic leadership provides the overarching narrative, sets priorities, and aligns structures and cultures across.

3. LEADERSHIP ACROSS M&A PHASES

3.1. Pre-Merger Phase

Leadership starts before the deal closes. Pre-merger activities include strategic planning, cultural due diligence, and stakeholder communication. This phase is often under-researched, but practitioners stress its importance (Gebhardt, 2017). Effective pre-merger leadership involves behavioural due diligence: assessing the target's leadership team, cultural fit, and potential people issues. Leaders should begin aligning the vision and plans of both organizations in advance. For example, creating a unified vision and integration roadmap before announcement can reduce uncertainty. Although few academic studies address this stage, consultants advise transparent early communication. Leaders should inform key stakeholders of the upcoming change and involve managers in planning. (Junni & Sarala, 2014)

3.2. Integration Phase

The integration stage immediately after deal announcement and especially the first 100 days is where leadership actions critically affect employee reactions. Leaders must balance delivering strategic direction with managing human concerns. Key practices during integration include:

- Clear, frequent communication. Leaders should deliver consistent messages on the merger vision, goals, and expected changes. Day-1 announcements and regular updates reduce rumor and anxiety. For instance, a prominent senior leader serving as a "visible anchor" can comfort employees during this turbulent time.
- Trust and inclusion. Transformational behaviors are crucial here. By articulating an inspiring purpose and involving employees in integration teams, leaders build trust and buy-in. Mishra et al.'s study of Indian telecom M&A highlights trust: they found that preserving trust in the organization and its leaders post-merger was essential because employees often felt estranged.

Leaders who consistently demonstrate fairness, listen to employee concerns, and show empathy can counteract the inevitable uncertainty.

- Culture integration. Leaders must actively manage cultural differences. This can involve joint workshops, forming cross-company teams, or celebrating shared values. Research indicates that leadership behavior is a major factor in creating a cohesive culture. Able (2007) summarized Towers Perrin findings that effective M&A leaders inspire "coherence, community and trust" which align cultures. In practice, this might mean adopting a "best of both" approach or consciously retaining key cultural elements of each legacy firm.
- Middle management empowerment. Line managers on the ground play a pivotal role during integration. Javalquinto (2025) found that middle managers in the target company, together with senior leaders in the acquirer, have the greatest impact on integration outcomes. Empowering these managers to lead teams, address concerns, and implement local solutions can greatly aid integration. For example, Middle Manager A might know their team is worried about job security, so they proactively address this, thereby retaining talent.
- HR practices and support. Integrating HR systems (compensation, benefits, evaluations) falls partly on leadership. Empirical work shows that supportive HRM practices amplify leadership's effects. Canterino et al. (2024) demonstrate that HR practices which enhance employee participation mediate the positive effects of transformational leadership on job satisfaction and commitment. In other words, leaders should collaborate with HR to provide training, development opportunities, and voice mechanisms that help employees adjust to the merger.

3.3. Post-Integration Phase

Even after the initial integration rush, leadership remains important. In the post-integration period, leaders must monitor progress, reinforce change, and sustain momentum. For example, leaders should review integration metrics (e.g. retention, process synergies) and adjust plans as needed. They should continue to reinforce the newly formed culture and values so that new norms take root. Periodic surveys of employee sentiment and follow-up town halls can keep communication channels open. Finally, leaders ought to foster continuous innovation and improvement, recognizing teams that successfully bridge old and new ways of working.

4. CROSS-COUNTRY EVIDENCE AND CASE STUDIES

Research on M&A leadership spans many contexts, though coverage is uneven. Table 1 below summarizes key studies from different regions:

Table 1. Summary of Selected Studies on Leadership in M&A by Country/Method and Key Findings

Study (Authors)	Country/Context	Method/Sample	Key Findings
Reich (2011)	USA	Conceptual	Proposed that transformational leadership and high LMX facilitate post-merger work-group socialization and acceptance of change.
Canterino et al. (2024)	Italy	Mixed methods (survey + interviews)	Found that HR practices enhancing employee participation mediated the positive effect of transformational leadership on satisfaction and commitment. Emphasized importance of local managers' behaviours in integration.
Sari & Fauzi (2026)	Indonesia	Qualitative	Identified that post-merger transformational leaders acted as visionaries, role models, and emotional supporters. They helped employees cope with unclear structures and cultural differences by fostering acceptance and collaboration.
Mishra et al. (2018)	India (Telecom)	Case study	Emphasized *trust* dynamics: leaders' role in maintaining organizational and leader trust was crucial to retain employees and align disparate corporate cultures.
Mogale (2022)	South Africa (Telecom)	Qualitative	A leadership-driven change effort (new strategy, new leadership, culture overhaul) overcame strong resistance. Executives reported that "because of the new leadership… the organization started performing well," underlining leadership's pivotal role in success.
Javalquinto (2025)	International (ISCAE case studies)	Literature review and case analysis	Identified nine key leadership competencies for M&A success (problem-solving, communication, etc.) and found middle managers in targets and senior leaders in acquirers most critical. Recommended evaluating leadership capability in due diligence and retaining target's middle managers.

In addition to these studies, numerous anecdotal and industry sources reinforce similar themes. For example, case narratives from Europe and Asia stress that aligning corporate culture and demonstrating consistent leadership behavior are decisive factors in cross-border deals.

4.1. Multilevel Effects and Moderators

4.1.1. Leadership in M&A Exerts Effects at Multiple Levels:

- Individual level: Employees' attitudes and behaviors (job satisfaction, commitment, readiness for change) are directly shaped by leadership style and communication. Empirical evidence shows transformational leadership correlates with higher job satisfaction and affective commitment during integration. Similarly, high-quality LMX relationships increase employee engagement and reduce turnover intentions.
- Team level: Leadership fosters team learning and ambidexterity. Nemanich & Vera (2009) found that transformational leadership, together with a learning culture,

promoted *ambidexterity* (the ability to explore new ways while exploiting existing strengths) in acquisition teams. Employees reported adopting agile strategies (e.g. role flexibility, collaboration across units) under strong transformational leaders. Leadership also shapes social networks: good leaders integrate previously separate work groups through cross-functional teams and mentoring.

- Organizational level: Company-wide outcomes like integration success, financial performance, and innovation are influenced by leadership. For instance, Javalquinto (2025) reported that leadership capability in acquirers significantly predicted post-merger success, and poor leadership was a predictor of failed integrations. Leaders set priorities and create the "positive momentum" needed for the organization to maintain focus on value creation. They also influence organizational justice perceptions: fair treatment in promotions and compensation (as signaled by leaders) can shape organizational commitment.

4.1.2. Mediating Factors

The impact of leadership is often contingent on context.

Key mediators identified include:

A leader's impact doesn't happen in a vacuum—it all depends on the situation. Several factors can make or break their effectiveness during a merger:

- Culture, trust and open communication

When two companies with very different cultures merge, it can be a huge roadblock unless leaders step in to bridge the gap. Mishra et al. (2018) showed that in India's telecom deals when cultures clashed, leaders had to work hard to build trust and empathy. If they didn't, employees felt completely disconnected. This is especially true in international mergers, where cultural differences (e.g like how comfortable people are with uncertainty), can totally change how a leader's message is heard. Good, honest, two-way communication always makes a huge difference. Research shows that things like well-planned communication programs and giving people a "realistic preview" of the merger can really help calm everyone's nerves. When leaders keep the lines of communication open, they help people feel less uncertain and start to see themselves as part of the new company.

- Supportive HR and process fairness

A leader's efforts are much more powerful when backed by good HR policies. It's simple: leadership and HR have to be on the same page. A charismatic leader's promises don't mean much if they aren't supported by fair practices, like a clear and transparent promotion process. If employees believe that big decisions like layoffs or promotions are being handled unjustly, they'll lose trust in the merger, no matter

how inspiring the leader is. Even the most visionary leaders have to make sure their decisions are seen as legitimate, or they risk losing people's commitment.

Ultimately, leadership isn't a solo act. In a merger, a leader's success is magnified when they tackle cultural issues head-on, champion fairness, and have solid HR systems to back them up. On the flip side, even great leadership can backfire if communication is poor, or if people see their leaders as untrustworthy or simply bad at bringing two different cultures together.

Outcomes: Integration Success and Employee Impact

Leadership influences a broad range of outcomes in M&A:

- Integration success: Many studies use integration performance (financial/synergy targets) as an outcome. Strong leadership correlates with smoother integration and faster realization of deal rationale. For example, Javalquinto (2025) found that "leadership capabilities in acquiring companies" significantly predicted post-merger success. Leadership failures have been noted as reasons for collapse. Tierney (2007) summarizes Towers Perrin's findings that leaders who create "commitment, engagement, confidence and comfort" in employees directly boost integration success.
- Employee readiness and attitudes: Leadership markedly affects how ready employees are to embrace change. Transformational leaders tend to increase *readiness for change* by providing a convincing vision and emotional support. Canterino et al. (2024) linked transformational leadership (mediated by HR practices) to higher job satisfaction and commitment. When leaders communicate clearly and involve employees, staff are more likely to support the merger goals and less likely to seek alternative employment.
- Retention and turnover: Retaining key talent is crucial after a merger. Employees experiencing significant organizational disruption are 4.5 times as likely to be engaged when they strongly trust organizational leadership (Barrett & Kemp, 2024).
- In our review, retaining target-company managers was highlighted. Javalquinto (2025) reports that targeted retention of middle managers in the acquired firm *"may have a positive impact on integration results"*. This underscores that leaders' ability to convince and motivate critical employees can curb talent loss. In contrast, leadership missteps (e.g. ignoring employees' concerns) can accelerate exits.
- Performance and innovation: Effective leadership can spark innovation by encouraging knowledge sharing and adaptability. Nemanich & Vera's study suggests transformational leaders in M&A contexts help teams become ambidextrous, combining exploitation of existing strengths with exploration of new processes. While direct measures of innovation in M&A are rare, this implies better innovation outcomes under visionary leadership. Performance-wise,

Mogale's case study in South Africa showed that *"because of the new leadership… the organization started performing well"*. In other words, turnaround in post-merger performance was attributed to leadership-driven change.

4.2. Methodological Approaches and Measurement

The literature on M&A leadership employs a mix of qualitative and quantitative methods:

- Qualitative case studies and interviews: Many insights come from in-depth case research and interviews with executives or employees. For example, Sari and Fauzi (2026) used interviews to understand employee perceptions of leadership in an Indonesian public-sector merger. Mogale (2022) conducted interviews with South African telecom leaders to explore change management. These studies provide rich context, but often with small samples (e.g., n=3 or n=10).
- Surveys and longitudinal data: Other studies use surveys of employees during M&A or analyze archival data. Canterino et al. (2024) combined a survey of merged employees with follow-up interviews, exemplifying a "mixed methods" design. Large-scale analyses like Javalquinto (2025) review aggregated deal data to infer patterns across thousands of acquisitions. Experimental designs are rare; one notable exception (Matsui et al.) finds that realistic previews can causally reduce turnover intentions, but these are infrequent.
- Measurement issues: Leadership is usually measured by established scales like the MLQ for transformational/transactional style. Outcomes include survey measures of satisfaction, commitment, and self-reported trust, as well as objective indicators (turnover rates, financial targets). A challenge is isolating leadership's effect amid many changing variables in M&A. Researchers often control for deal size, type (friendly/hostile), and country. Multi-level modeling is increasingly common to capture individual vs. organizational effects.
- Limitations: Much of the research is cross-sectional or retrospective. There is a need for longitudinal panel data following the same employees over time. Self-reported leadership perception data can be biased. Finally, many studies focus on large corporations; SMEs or public-sector M&As might differ.

4.3. Managerial Implications

For executives leading an M&A, the literature suggests several practical actions:

1. Engage leaders early (due diligence phase)- Evaluate the management culture and plan leader roles in advance. Consider "behavioral due diligence" to assess leadership compatibility (Gebhardt, 2017). Identify who will stay or leave, and plan leadership communication strategies before closing.

2. Communicate vision and rationale- From announcement onward, leaders must deliver a clear, compelling message about the merger's purpose. As Able (2007) notes, good leaders *"imbue employees with…confidence and comfort to work through difficult transitions"*. Visible, credible leadership reduces anxiety. Senior leaders should appear together to show unity of command.

3. Build trust and inclusion- Demonstrate fairness and empathy. Involve employees in integration tasks where possible, listen to concerns, and provide frequent updates. Mishra et al. (2018) found that managing trust was critical in retaining employees post-merger. Leaders should be trained in communication skills and culturally sensitive behaviors.

4. Empower middle managers- Don't centralize all decisions at the top. Enable unit-level managers to adjust plans to local conditions. Canterino et al. (2024) highlight the influence of local leaders on employee attitudes. Retaining target firm's managers and giving them real responsibilities can accelerate integration and preserve key knowledge.

5. Use supportive HR practices- Complement leadership with enabling HR policies. Provide training on new systems, align compensation fairly, and recognize integration achievements. The evidence suggests that such HR support *mediates* leadership effects on satisfaction. For example, pairing a charismatic leader's message with a transparent promotion process signals consistency.

6. Monitor and adapt- Treat integration as an iterative process. Set up feedback loops (employee surveys, town halls) to detect emerging issues. Be prepared to adjust leadership approaches – for instance, shifting from inspirational (transformational) tactics in the early phase to more managerial (transactional) oversight once stability returns.

5. LIMITATIONS AND FUTURE RESEARCH

Despite growing interest, several gaps remain in the research on leadership in M&A:

- The pre-acquisition phase is understudied. Future research should examine how leadership decisions (selection of integration teams, communication planning, "behavioral due diligence") before deal closure affect outcomes. Investigating leaders' roles in due diligence and negotiation would help fill the noted void.
- Cross-cultural comparisons: Most empirical studies focus on Western contexts (US/Europe). How do leadership styles need to adapt in high power-distance or collectivist cultures? India's telecom case is a start, but similar studies in China, ASEAN, or Africa would broaden understanding. Likewise, country-specific expectations (e.g., paternalism in some Asian cultures) could moderate leadership impact.

- Shared leadership models: Co-CEO or joint leadership in M&A is an intriguing but under-explored phenomenon. Qualitative case studies of co-CEO structures (successes and failures) could yield insights. Hypotheses might examine conditions (mutual trust, founder oversight) under which shared leadership improves integration vs. when it causes conflict.
- Longitudinal and experimental designs: The field lacks longitudinal tracking of leadership effects over time. Panel surveys of employees at multiple integration stages could reveal causal patterns (e.g., does early transformational leadership predict retention 6 months later?). Field experiments on communication interventions (as in military or simulated settings) could also be fruitful.
- Multi-level modeling: Future studies should more explicitly model individual, team, and organizational levels. For example, nested data (employees within teams within firms) could disentangle how much variance in post-merger attitudes is due to team-level leadership vs. firm-level leadership cues.
- Digital and remote M&A leadership: With increasing virtual collaboration, how does virtual leadership compare? Research on remote mergers (e.g., tech consolidations) could explore how digital communication tools aid or hinder leadership.
- Measurement and new constructs: Validated measures of "M&A leadership effectiveness" would help, as opposed to borrowing general MLQ scales. Constructs like "cultural integration leadership" or "hybrid identity leadership" may need development.

Overall, advancing this field will require interdisciplinary work, combining organizational behavior, cross-cultural management, and strategic management approaches to fully capture leadership's role in M&A.

6. CONCLUSIONS

Leadership is a decisive but complex factor in M&A success. Transformational and inclusive leadership behaviors characterized by vision, trust-building, and support generally improve employee outcomes and integration performance. By contrast, solely transactional approaches often fail to address the human challenges of M&A. Our review across countries and industries shows that effective post-merger leaders communicate clearly, align cultures, involve middle managers, and sustain trust throughout the merger process. The proposed multilevel model synthesizes these findings, emphasizing that leadership must adapt across phases and interact with cultural and structural factors. Practically, organizations should involve leadership in due diligence, train leaders in change communication, and align HR practices with leadership strategies.

Going forward, scholars should broaden the empirical base (especially outside the West), investigate pre-merger leadership activities, and examine novel leadership forms (e.g., shared

leadership) in M&A. By deepening our understanding of "the human side" of mergers, future research can help ensure more M&A deals realize their potential.

REFERENCES

Able, R. M. (2007). *The importance of leadership and culture to M&A success*. Towers Perrin. https://www.towersperrin.com

Armenakis, A. A., & Harris, S. G. (2002). Crafting a change message to create transformational readiness. *Journal of Organizational Change Management, 15*(2), 169–183. https://doi.org/10.1108/09534810210423080

Avolio, B. J., & Gardner, W. L. (2005). Authentic leadership development: Getting to the root of positive forms of leadership. *The Leadership Quarterly, 16*(3), 315–338. https://doi.org/10.1016/j.leaqua.2005.03.001

Avolio, B. J., Gardner, W. L., Walumbwa, F. O., Luthans, F., & May, D. R. (2004). Unlocking the mask: A look at the process by which authentic leaders impact follower attitudes and behaviors. *The Leadership Quarterly, 15*(6), 801–823. https://doi.org/10.1016/j.leaqua.2004.09.003

Barrett, H., & Kemp, A. (2024, May 22). *Disruptive change is hitting leaders and managers hardest*. Gallup. https://www.gallup.com/workplace/645314/disruptive-change-hitting-leaders-managers-hardest.aspx

Bass, B. M. (1985). *Leadership and performance beyond expectations*. Free Press.

Brown, M. E., & Treviño, L. K. (2006). Ethical leadership: A review and future directions. *The Leadership Quarterly, 17*(6), 595–616. https://doi.org/10.1016/j.leaqua.2006.10.004

Brown, M. E., Treviño, L. K., & Harrison, D. A. (2005). Ethical leadership: A social learning perspective for construct development and testing. *Organizational Behavior and Human Decision Processes, 97*(2), 117–134. https://doi.org/10.1016/j.obhdp.2005.03.002

Buono, A. F., & Bowditch, J. L. (2003). *The human side of mergers and acquisitions: Managing collisions between people, cultures, and organizations*. Beard Books. (Original work published 1989)

Burns, J. M. (1978). *Leadership*. Harper & Row.

Cannella, A. A., Jr., & Hambrick, D. C. (1993). Effects of executive departures on the performance of acquired firms. *Strategic Management Journal, 14*(S1), 137–152. https://doi.org/10.1002/smj.4250140911

Canterino, F., Guerci, M., Cirella, S., & Shani, A. B. R. (2024). The intertwined effect of HRM practices and transformational leadership on employees' attitudes in an M&A context: Evidence from a

collaborative and mixed-methods study. *European Management Journal, 42*(1), 46–56. https://doi.org/10.1016/j.emj.2022.09.001

Cartwright, S., & Cooper, C. L. (1993). The role of culture compatibility in successful organizational marriage. *Academy of Management Executive, 7*(2), 57–70. https://doi.org/10.5465/ame.1993.9411302324

Cartwright, S., & Schoenberg, R. (2006). Thirty years of mergers and acquisitions research: Recent advances and future opportunities. *British Journal of Management, 17*(S1), S1–S5. https://doi.org/10.1111/j.1467-8551.2006.00475.x

Clapp-Smith, R., Vogelgesang, G. R., & Avey, J. B. (2009). Authentic leadership and positive psychological capital: The mediating role of trust at the group level of analysis. *Journal of Leadership & Organizational Studies, 15*(3), 227–240. https://doi.org/10.1177/1548051808326596

Eisenhardt, K. M., & Zbaracki, M. J. (1992). Strategic decision making. *Strategic Management Journal, 13*(S2), 17–37. https://doi.org/10.1002/smj.4250130904

Fauzi, A., & Sari, R. P. (2026). Transformational leadership in post-merger organizations: A qualitative study of an Indonesian state-owned company. *Journal of Contemporary Business Administration, 3*(2), 77–97. https://doi.org/10.12962/j30254256.v3i2.8792

Gebhardt, J. A. (2017). Pre-M&A "leadership"?: Might behavioral due diligence assessment be the answer? In S. Finkelstein & C. L. Cooper (Eds.), *Advances in mergers and acquisitions* (Vol. 16, pp. 21–36). Emerald Publishing. https://doi.org/10.1108/S1479-361X20170000016002

Graen, G. B., & Uhl-Bien, M. (1995). Relationship-based approach to leadership: Development of leader–member exchange theory of leadership over 25 years—Applying a multilevel, multidomain perspective. *The Leadership Quarterly, 6*(2), 219–247. https://doi.org/10.1016/1048-9843(95)90036-5

Haleblian, J., Devers, C. E., McNamara, G., Carpenter, M. A., & Davison, R. B. (2009). Taking stock of what we know about mergers and acquisitions: A review and research agenda. *Journal of Management, 35*(3), 469–502. https://doi.org/10.1177/0149206308330554

Haspeslagh, P. C., & Jemison, D. B. (1991). *Managing acquisitions: Creating value through corporate renewal*. Free Press.

Holt, D. T., Armenakis, A. A., Feild, H. S., & Harris, S. G. (2007). Readiness for organizational change: The systematic development of a scale. *The Journal of Applied Behavioral Science, 43*(2), 232–255. https://doi.org/10.1177/0021886306295295

Javalquinto, B. (2025). *The leadership role in mergers and acquisitions: A thorough examination of crucial elements for business success* [Working paper]. SSRN. https://doi.org/10.2139/ssrn.5337874

Junni, P., & Sarala, R. M. (2014). The role of leadership in mergers and acquisitions: A review of recent empirical studies. In C. L. Cooper & S. Finkelstein (Eds.), *Advances in mergers and acquisitions* (Vol. 13, pp. 181–200). Emerald Group Publishing. https://doi.org/10.1108/S1479-361X20140000013007

Kotter, J. P. (1995). Leading change: Why transformation efforts fail. *Harvard Business Review, 73*(2), 59–67.

Kouzes, J. M., & Posner, B. Z. (1993). *Credibility: How leaders gain and lose it, why people demand it*. Jossey-Bass.

Marks, M. L., & Mirvis, P. H. (2011). A framework for the human resources role in managing culture in mergers and acquisitions. *Human Resource Management, 50*(6), 859–877. https://doi.org/10.1002/hrm.20445

Mishra, A., Pradhan, A., & Bisht, O. (2018). The impact of trust on leadership during mergers and acquisitions: Case studies from the Indian telecom sector. *PEOPLE: International Journal of Social Sciences, 4*(2), 1035–1050. https://doi.org/10.20319/pijss.2018.42.10351050

Mogale, M. D. (2022). Leadership and change management: The case of a telecommunications company in South Africa. *Academy of Accounting and Financial Studies Journal, 26*(S3), 1–9.

Nemanich, L. A., & Vera, D. (2009). Transformational leadership and ambidexterity in the context of an acquisition. *The Leadership Quarterly, 20*(1), 19–33. https://doi.org/10.1016/j.leaqua.2008.11.002

Neves, P. (2009). Readiness for change: Contributions for employee's level of individual change and turnover intentions. *Journal of Change Management, 9*(2), 215–231. https://doi.org/10.1080/14697010902879178

Rafferty, A. E., & Restubog, S. L. D. (2010). The impact of change process and context on change reactions and turnover during a merger. *Journal of Management, 36*(5), 1309–1338. https://doi.org/10.1177/0149206309341480

Reich, R. W. (2011). The impact of transformational leadership and leader–member exchange on socialization in mergers and acquisitions. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.1967087

Schweiger, D. M., & DeNisi, A. S. (1991). Communication with employees following a merger: A longitudinal field experiment. *Academy of Management Journal, 34*(1), 110–135. https://doi.org/10.2307/256304

Seo, M.-G., & Hill, N. S. (2005). Understanding the human side of merger and acquisition: An integrative framework. *The Journal of Applied Behavioral Science, 41*(4), 422–443. https://doi.org/10.1177/0021886305281902

Szabó, L., & Mishin, A. (2023). *Leadership and employee satisfaction in cross-border mergers: A comparison of transformational and transactional styles* [Master's thesis, Jönköping University].

van Dam, K., Oreg, S., & Schyns, B. (2008). Daily work contexts and resistance to organisational change: The role of leader–member exchange, development climate, and change process characteristics. *Applied Psychology, 57*(2), 313–334. https://doi.org/10.1111/j.1464-0597.2007.00311.x

Walumbwa, F. O., Avolio, B. J., Gardner, W. L., Wernsing, T. S., & Peterson, S. J. (2008). Authentic leadership: Development and validation of a theory-based measure. *Journal of Management, 34*(1), 89–126. https://doi.org/10.1177/0149206307308913

BONUS ISSUE ANOMALY: SHORT-AND LONG-TERM PRICE EFFECTS IN BORSA ISTANBUL

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ABSTRACT

This study investigates how stock prices in Borsa Istanbul respond to bonus issue announcements over both short and longer horizons. The sample consists of 102 initial bonus issue announcements disclosed on the Public Disclosure Platform in 2024. Short-term effects are evaluated using market-adjusted abnormal returns and cumulative average abnormal returns, while six- and twelve-month buy-and-hold abnormal returns are used to assess longer-term performance. A clear positive price reaction emerges around the announcement date. The response is stronger for bonus issues financed from profits and profit reserves and for issues with higher ratios. Evidence over longer horizons is less conclusive, suggesting that the initial reaction does not necessarily persist. Overall, the results indicate that investors in Borsa Istanbul appear to treat bonus issue announcements as informative corporate signals.

Keywords: *Bonus Issue, Event Study, Abnormal Return, Borsa Istanbul*

JEL Codes*: G14, G11, G32.*

1. INTRODUCTION

A bonus issue allows a firm to convert its internal reserves into paid-in capital and allocate additional shares to existing shareholders. Although the number of shares outstanding increases, the share price is expected, in theory, to adjust downward in the same proportion. The transaction therefore does not by itself increase either the firm's market value or the aggregate wealth of its shareholders. For this reason, bonus issues are generally viewed as technical corporate actions rather than value-creating events. Even so, previous studies indicate that announcements of such issues may be associated with changes in stock prices and returns (Aslanoğlu et al., 2020; Çukur & Eryiğit, 2007).

Although a bonus issue does not create value in theoretical terms, investors may still attach meaning to its announcement. This makes the market response to bonus issues relevant to discussions of both market efficiency and market anomalies. Investors may regard such decisions as more than a technical accounting adjustment, interpreting them as signals about a firm's equity position, past profitability, growth prospects, or liquidity conditions (Işıker & Taş, 2021; Suidarma et al., 2026). The lower adjusted share price after the issue may also make the stock appear more affordable to some

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investors. Together with the increase in the number of shares outstanding, this perception may contribute to a stronger short-term market response.

Research on bonus issues in Borsa Istanbul has largely concentrated on short-term market reactions around the announcement or event date. For instance, some studies examine stock-return behavior within event windows covering the five trading days before and after the announcement (Erol & Aytekin, 2018; Küçüksille & Mizrahi, 2015). These studies provide evidence that bonus issue announcements can be reflected in stock prices, but they also show that the results are sensitive to the sample period, the choice of event date, the length of the event window, and the specific features of the capital increase.

At this point, two main gaps emerge. First, whether the short-term price reactions observed around bonus issue announcements persist in the long run remains insufficiently clarified in the context of Türkiye. Second, whether investor reactions differ according to transaction- and firm-specific characteristics, such as the source of the bonus issue, the issue ratio, and firms' sectoral characteristics, requires more detailed investigation. This distinction is important because the market may react not only to the bonus issue decision itself but also to the sources of financing and the magnitude of the issue.

This study aims to help fill these gaps in the literature by jointly examining the short- and long-term price effects of bonus issue announcements on Borsa Istanbul. For this purpose, the initial board of directors' decisions on bonus issues disclosed on the Public Disclosure Platform (KAP) in 2024 are analyzed using the event study methodology. Short-term price effects are measured using market-adjusted abnormal returns and cumulative average abnormal returns. In contrast, long-term effects are assessed using six- and twelve-month buy-and-hold abnormal returns. In addition, the study examines whether market reactions differ by the source of the bonus issue, the issue ratio, and sectoral classification. In this way, the study evaluates whether bonus issue announcements generate only a short-term price reaction or indicate stronger, more persistent pricing behavior under certain transaction characteristics. The remainder of the study is organized as follows: the next sections present the literature review, methodology, findings, and conclusion, respectively.

2. LITERATURE REVIEW

Theoretical approaches to bonus issues generally evaluate these transactions within the context of market efficiency, signaling theory, and investor behavior. Theoretically, bonus issues are technical corporate actions that do not directly increase the total market value of a company or the wealth of its shareholders. Nevertheless, market reactions to such announcements suggest that investors may interpret bonus issue decisions not merely as accounting transactions, but also as signals containing information about a firm's financial strength, past profitability, and prospects (Eriş, 2009; Işıker & Taş, 2021).

Bonus issues, stock dividends, stock splits, and similar corporate actions are often described as technical or even “cosmetic” transactions because they do not directly create firm value. Yet their

announcements can still be followed by abnormal stock returns, which makes them relevant to the literature on market anomalies. Several explanations have been proposed for this response, including signaling, increased investor attention, changes in liquidity or the trading range, and behavioral factors. Such reactions may be particularly visible in emerging markets, where investors can respond more strongly to corporate announcements. Examining performance beyond the immediate announcement period is therefore useful for determining whether these effects fade quickly or extend over a longer horizon (Kolari et al., 2021).

Evidence from international markets is far from uniform regarding the price effects of bonus issues, stock dividends, and stock splits. Some studies on the Indian market report positive abnormal returns around announcement periods. Mishra (2005), as cited in Küçüksille and Mizrahi (2015), found positive abnormal returns during the five days following bonus issue announcements. Lukose and Rao (2002), as cited by Erol and Aytekin (2018), documented notable abnormal returns from three days before to five days after the announcement and interpreted this pattern as evidence that bonus issues may convey information to investors. Other studies reach similar conclusions. Dhar and Chhaochharia (2008) reported significant positive effects on stock returns, while Suresha and Chandrashekara (2016) identified positive abnormal returns on the announcement day (Erol & Aytekin, 2018).

Results from other markets are less consistent. Masry (2015), as cited in Erol and Aytekin (2018), found no evidence that investors could earn abnormal returns from bonus issue announcements in the Egyptian market across the periods examined. Evidence from Indonesia is also mixed. Suidarma et al. (2026) reported a positive investor response before the effective date of stock split and reverse stock split announcements, while abnormal returns became more limited after the event. Taken together, these findings suggest that the market response to similar corporate actions can differ across countries, depending on market structure, prevailing conditions, and investor behavior.

Long-term evidence from developed markets provides another perspective on these corporate events. Kolari et al. (2021) found that positive long-run abnormal returns could emerge over certain periods following events such as stock splits. Their results, however, also show that these effects are not necessarily permanent and may vary with market conditions. Looking beyond the immediate announcement period is therefore important for assessing whether the initial market response fades over time or continues over a longer investment horizon.

Studies examining the price effects of bonus issue announcements in Türkiye have generally focused on short-term event windows. Küçüksille and Mizrahi (2015) investigated the effects of bonus-issue announcements on the market values of firms listed on Borsa Istanbul using the event-study methodology. They reported that cumulative abnormal returns could remain positive throughout the event window, although differences could emerge between average abnormal returns and cumulative

abnormal returns. This result shows why the market response to bonus issue announcements should be assessed over cumulative event windows rather than on the basis of individual trading days alone.

Erol and Aytekin (2018) analyzed how bonus issue announcements affected stock returns in the Borsa Istanbul equity market. They treated the Capital Markets Board approval date as the event date and focused on short-term event windows. Their results showed that cumulative abnormal returns did not move in a single direction throughout the event period; positive values on some days were followed by negative values on others. This pattern points to a changing short-term market response, with some of the initial price movement being corrected after the announcement.

Işıker and Taş (2021) looked more closely at the conditions that shape market reactions to bonus issue announcements. Their analysis considered the source of the issue, the issue ratio, and whether the disclosure was the initial announcement or a later one. The results indicate that both the financing source and the size of the issue matter for investor response. Higher issue ratios were associated with a more favorable market reaction, while initial announcements tended to produce stronger price effects than subsequent disclosures. The authors also drew attention to abnormal returns observed before the announcement, noting that these may reflect early pricing or possible information leakage.

Kaya (2023) examined the effects of rights issue and bonus issue announcements on stock returns in Borsa Istanbul during the pandemic period. The study found that the market response to capital increase announcements differed between the pre-pandemic and pandemic periods. This result suggests that reactions to bonus issue announcements are shaped not only by the characteristics of the announcement itself, but also by the broader macroeconomic and market environment.

Taken together, previous studies show that bonus issue announcements can affect stock prices, especially over short event windows. At the same time, the reported effects are not uniform and appear to depend on factors such as the event date, the length of the event window, market conditions, and the characteristics of the capital increase. Research on Türkiye has mainly concentrated on short-term reactions around announcement or approval dates, leaving the longer-term consequences relatively underexplored. There is also limited evidence on whether the source of the issue, the issue ratio, and sectoral differences shape both short- and long-term market responses. Against this background, the present study examines bonus issue announcements in Borsa Istanbul in 2024 using short-term CAAR (Cumulative Average Abnormal Return) and long-term BHAR (Buy-and-Hold Abnormal Return) measures, together with subgroup analyses based on the source of the issue, the issue ratio, and sector.

3. METHODOLOGY

This section describes the sample and data used in the analysis, outlines how short- and long-term price effects are measured, and explains the structure of the subgroup analyses.

3.1. Sample and data set

The sample includes Borsa Istanbul firms that announced bonus issues in 2024. The event date is taken as the first public disclosure of the relevant bonus issue decision on the Public Disclosure Platform (KAP), namely the date on which the board of directors' decision became publicly available. Defining the event date in this way allows the analysis to focus on the point at which investors first had access to the information.

A set of screening criteria was applied when forming the sample. For each bonus issue, only the first public disclosure of the board of directors' decision was retained. Later announcements concerning applications to the Capital Markets Board, regulatory approvals, general assembly decisions, registration, rights exercise dates, or similar follow-up stages were excluded. Announcements released after 6:00 p.m. were assigned to the next trading day, since information disclosed after Borsa Istanbul trading hours could only be incorporated into prices on the following session. Stock splits, dividend distributions, rights issues, and reverse stock splits were also left outside the sample.

These screening steps resulted in a final sample of 102 observations. The return on the Borsa Istanbul XU100 Index was used as the market return. Accordingly, each stock's return was evaluated after adjusting for general market movements over the same period.

3.2. Measurement of short-term price effects

Short-term price effects were measured using the market-adjusted abnormal return model. Under this approach, the actual return of each stock around the event date is compared with the market return on the same day, and the difference between the two is defined as the abnormal return. Accordingly, the abnormal return of stock i on day t is calculated as follows:

$$AR_{i,t} = R_{i,t} - R_{m,t} \quad (1)$$

where $AR_{i,t}$ denotes the abnormal return of stock i on day t; $R_{i,t}$ denotes the actual return of the corresponding stock on day t; and $R_{m,t}$ denotes the market return on the same day. The return on the Borsa Istanbul XU100 Index was used as the market return.

The event window was defined as the period from 10 trading days before to 10 trading days after the announcement date (−10,+10). This specification enables examination of both potential pre-announcement pricing effects and short-term market reactions following bonus issue announcements. To assess the cumulative price effect of the announcements, four different event windows were employed: (−1,+1), (0,+2), (−3,+3), and (−10,+10). Average abnormal returns (AARs) were calculated by taking the cross-sectional mean of daily abnormal returns (ARs), after which cumulative average abnormal returns were computed for the specified event windows. To limit the influence of extreme observations on the results, abnormal returns were winsorized at the 5th and 95th percentiles.

3.3. Measurement of long-term price effects

Long-term price performance was evaluated using the buy-and-hold abnormal return (BHAR) approach. BHAR compares the compounded return of an individual stock with the compounded return of the market index over the same post-announcement period. This makes it possible to see whether the market response observed after a bonus issue announcement remains only a short-term effect or continues over a longer investment horizon.

For stock i, BHAR over a t-day period is calculated, consistent with the literature, as the difference between the compounded returns of the stock and the market index as follows (Barbopoulos et al., 2016; Kolari et al., 2021):

$$BHAR_i = \prod(1 + R_{i,t}) - \prod(1 + R_{m,t}), t = 1, \dots, n \quad (2)$$

where $BHAR_i$ denotes the buy-and-hold abnormal return of stock i over the relevant period; $R_{i,t}$ denotes the return of stock i on day t; and $R_{m,t}$ denotes the market return on the same day.

Long-term performance was examined over two horizons: six months and twelve months after the announcement. The six-month BHAR (BHAR_6M) covers 126 trading days within the (0,+125) window, whereas the twelve-month BHAR (BHAR_12M) is calculated over 252 trading days within the (0,+251) window.

3.4. Subgroup analyses

To explore whether market reactions differ across bonus issue characteristics, the sample was divided into three sets of subgroups. First, the source of the bonus issue was considered. Accordingly, bonus issues were classified into three categories: those financed from profits and profit reserves, those financed from capital reserves, and hybrid issues that used both sources.

Second, the bonus issue ratio was considered. Based on the issue ratio, the sample was divided into three groups: 100% or below, between 100% and 300%, and above 300%. This classification was designed to evaluate whether the market responds differently to low-, medium-, and high-ratio bonus issue announcements.

Third, the firms' main sectors were taken into account. Accordingly, the sample was classified into broad sectoral groups—manufacturing, finance, and services—and short- and long-term abnormal returns were reported separately for these groups.

In the subgroup analyses, short-term price effects were compared using cumulative average abnormal returns. In contrast, long-term price effects were compared using six- and twelve-month buy-and-hold abnormal returns. The results were evaluated to determine whether market reactions to bonus-issue announcements differ by the source of the issue, the issue ratio, and sectoral characteristics.

4. FINDINGS

After applying the screening criteria, the final sample consists of 102 observations. In terms of the source of the bonus issue, the sample comprises 18 hybrid issues, 23 issues financed from profits and profit reserves, and 61 issues financed from capital reserves. With respect to the issue ratio, the sample includes 17 low-ratio (≤100%), 40 medium-ratio (100%–300%), and 45 high-ratio (>300%) bonus issues. Based on the broad sector classification, the sample consists of 31 observations from the financial sector, 24 from the services sector, and 47 from the manufacturing sector.

Short-term price effects were first evaluated using daily average abnormal returns and then cumulative average abnormal returns. Daily average abnormal returns for the (−10,+10) event window are presented in Table 1.

Table 1. Daily Average Abnormal Returns (%)

Day	AAR	Day	AAR	Day	AAR
-10	0.17	-3	-0.06	+4	0.10
-9	0.38	-2	0.72*	+5	-0.21
-8	0.02	-1	1.24*	+6	0.18
-7	0.02	0	2.44*	+7	0.18
-6	-0.54	+1	-0.18	+8	-0.39
-5	0.09	+2	-0.98*	+9	0.06
-4	-0.22	+3	-0.07	+10	-0.16

Note: * indicates statistical significance at the 10% level.

The positive reaction appears shortly before the announcement. Average abnormal return is 0.72% on day −2 and rises to 1.24% on day −1, before reaching 2.44% on the announcement day. Two trading days later, however, AAR turns negative at −0.98%, and this decline is statistically significant. The pattern therefore points to a favorable initial market response to bonus issue announcements, followed by some reversal after the event.

Table 2. Cumulative Average Abnormal Return Results

Event Window	CAAR (%)	p-value
(-1,+1)	3.49	<.001
(0,+2)	1.28	.078
(-3,+3)	3.11	.001
(-10,+10)	2.80	.019

Table 2 shows a positive cumulative market response to bonus issue announcements across all event windows. The largest CAAR, 3.49%, occurs in the (−1,+1) window, covering the trading day before and after the announcement. This result is statistically significant at the 1% level and points to a particularly strong response around the event date.

The broader event windows also produce positive and statistically significant CAAR values. CAAR reaches 3.11% for the (−3,+3) window and 2.80% for the (−10,+10) window. The (0,+2) window, however, yields a lower CAAR of 1.28%, with significance only at the 10% level. This pattern

suggests that most of the market reaction occurs before and around the announcement date, while the response becomes weaker in the days that follow.

Taken together, the CAAR results show that bonus issue announcements are associated with a positive short-term market response in Borsa Istanbul. However, the weaker result for the (0,+2) window, together with the negative AAR observed after the announcement, suggests that part of the initial reaction is reversed in the following days.

Table 3. Long-Term Abnormal Return Results

Event Window	BHAR (%)	p-value
BHAR_6M	2.09	.51
BHAR_12M	7.90	.08

The six-month results do not provide evidence of a persistent market effect. Average BHAR over this horizon is 2.09%, but the estimate is not statistically significant. Thus, the firms in the sample do not show significant market-adjusted outperformance during the first six months after the announcement.

The twelve-month picture is somewhat different. Average BHAR rises to 7.90% and is statistically significant at the 10% level. This points to some persistence in the positive price effect beyond the short run, although the evidence is not especially strong. The negative median BHAR also shows that this longer-term performance is not shared evenly across the firms in the sample.

Compared with the short-term CAAR results, the long-term evidence is clearly weaker. The announcements are followed by a pronounced price response over the short event windows, but the evidence that this effect continues over longer horizons is much less convincing.

Table 4. Abnormal Returns by Source of the Bonus Issue

Source	N	CAAR (-1,+1)	CAAR (0,+2)	CAAR (-3,+3)	CAAR (-10,+10)	BHAR_6M	BHAR_12M
Hybrid	18	3.32**	1.70	1.47	0.97	-18.56**	-0.82
Profits/Profit Reserves	23	5.90***	3.84**	6.78***	10.33***	9.60*	9.77
Capital Reserves	61	2.64**	0.19	2.21*	0.50	5.35	9.77

Note: *** indicates statistical significance at the 1% level; ** at the 5% level; and * at the 10% level.

The source of the bonus issue appears to matter for the short-term market response. The clearest reaction is observed for issues financed from profits and profit reserves. In this group, CAAR reaches

5.90% for the (−1,+1) window, 6.78% for (−3,+3), and 10.33% for (−10,+10), with all three estimates statistically significant. This pattern suggests that investors may attach greater informational value to bonus issues funded from profits.

Bonus issues financed from capital reserves show a more modest short-term response. In this group, statistically significant positive CAAR values appear only in the (−1,+1) and (−3,+3) windows. For hybrid issues, significance is confined to the (−1,+1) window. The longer-term results are less consistent across the three source groups. Six-month BHAR is positive and weakly significant for issues financed from profits and profit reserves, whereas it is negative and statistically significant for hybrid issues. Overall, the source-based comparison provides clearer evidence for short-term than for long-term effects.

Table 5. Abnormal Returns (%) by Bonus Issue Ratio

Issue Ratio	N	CAAR (-1,+1)	CAAR (0,+2)	CAAR (-3,+3)	CAAR (-10,+10)	BHAR_6M	BHAR_12M
Low (≤100%)	17	1.58	0.95	0.29	0.15	6.62	-0.56
Medium (100%–300%)	40	2.24**	-0.37	2.71**	3.81**	8.09	20.53***
High (>300%)	45	5.33***	2.87**	4.53**	2.91	-4.95	-0.13

Note: *** indicates statistical significance at the 1% level; ** at the 5% level; and * at the 10% level.

Short-term market reactions differ noticeably across issue-ratio groups. The low-ratio group does not produce statistically significant CAAR values in any of the event windows. By contrast, significant positive results appear in both the medium- and high-ratio groups. The strongest response is observed for high-ratio issues, where CAAR(-1,+1) reaches 5.33% and is significant at the 1% level. For the medium-ratio group, significant positive CAAR values are recorded in the (-1,+1), (-3,+3), and (-10,+10) windows.

Long-term performance does not follow the same pattern as the short-term results. Among the three issue-ratio groups, only the medium-ratio group records a statistically significant twelve-month BHAR, at 20.53%. Thus, although larger issue ratios are associated with stronger short-term reactions, this relationship does not extend consistently to longer-term returns.

Table 6. Abnormal Returns by Sector (%)

Sector	N	CAAR (-1,+1)	BHAR_12M
Finance	31	3.67***	26.07**
Services	24	1.72	18.77**
Manufacturing	47	4.29***	-9.64*

Note: *** indicates statistical significance at the 1% level; ** at the 5% level; and * at the 10% level.

The sectoral results in Table 6 point to differences in how the market responds to bonus issue announcements. Over the short event window, positive and statistically significant CAAR(-1,+1) values

are observed for firms in the finance and manufacturing sectors. In contrast, the short-term reaction in the services sector is positive but statistically insignificant.

Over the long run, twelve-month BHAR is positive and statistically significant in the finance and services sectors, whereas it is negative and statistically significant in the manufacturing sector. However, given the absence of a consistent sectoral pattern across the short- and long-term analyses and the limited number of observations within the subgroups, the sectoral results are more appropriately interpreted as preliminary evidence.

5. CONCLUSION

This study examines the short- and long-term price effects of bonus issue announcements for firms listed on Borsa Istanbul in 2024. The final sample comprises 102 observations based on the initial board of directors' decisions regarding bonus issues disclosed on the Public Disclosure Platform (KAP). Short-term price effects were measured using market-adjusted abnormal returns and cumulative average abnormal returns. In contrast, long-term effects were assessed using six- and twelve-month buy-and-hold abnormal returns. In addition, the study examined whether the price reaction differed according to the source of the bonus issue, the issue ratio, and sectoral classification.

The findings indicate that bonus issue announcements generate a positive and statistically significant short-term price reaction in Borsa Istanbul. Daily average abnormal returns become positive and significant beginning two days before the announcement, peaking on the event date. The event-day AAR is 2.44%, while the CAAR for the (−1,+1) window is 3.49%. The negative and statistically significant AAR observed on the second day following the announcement, however, indicates that a partial correction occurs after the initial short-term pricing response.

The subgroup results indicate that short-term market reactions are not uniform across different bonus issue characteristics. The strongest response is observed when the issue is financed from profits and profit reserves, while higher issue ratios are also associated with a stronger short-term price reaction. These patterns suggest that investors may look beyond the purely technical nature of a bonus issue and interpret its financing source and size as signals about the firm’s profitability, equity position, and growth prospects.

Long-term results provide a less clear picture than the short-term evidence. The six-month BHAR is not statistically significant, whereas the twelve-month BHAR is positive but only weakly significant. The negative median for the twelve-month BHAR further shows that the longer-term gains are not shared consistently across the sample. Accordingly, even though the results show that bonus issue announcements generate a pronounced short-term price anomaly, the persistence of this effect over the long run should be interpreted more cautiously.

Sector-based results reveal a mixed pattern. In the short run, finance and manufacturing firms record positive and statistically significant CAAR values, whereas the services sector does not show a

comparable short-term response. Over the longer horizon, BHAR is positive in finance and services but negative in manufacturing. Since these sectoral patterns are not consistent across short- and long-term measures and some subgroups contain relatively few observations, the sector results should be viewed as preliminary rather than definitive.

Taken together, the results indicate that investors treat bonus issue announcements as informative events and incorporate this information into stock prices. From a regulatory perspective, the significant positive abnormal returns observed before the announcement are particularly noteworthy, as they may reflect early market adjustment or possible information leakage. The partial reversal after the announcement also suggests that the initial price response is not fully sustained and that prices continue to adjust after the event.

Several limitations should be kept in mind when interpreting the results. The analysis covers only 2024, uses the market-adjusted abnormal return model, and includes relatively few observations in some of the subgroup comparisons. Future studies could extend the sample to a longer period and examine whether the results remain robust under risk-adjusted models such as the CAPM or Fama–French specifications. Further research could also focus more directly on the sources of pre-announcement price movements, the possibility of information leakage, and whether strategies based on bonus issue ratios remain profitable after transaction costs are taken into account.

REFERENCES

Aslanoğlu, S., Özkan, S., & Elçi, S. (2020). Examination of shareholders status who are unable to exercise their right of priority in capital increase in terms of equity and capital accounts. *Journal of Economics Finance and Accounting, 7(2)*, 134–154. https://doi.org/10.17261/Pressacademia.2020.1209

Barbopoulos, L. G., Molyneux, P., & Wilson, J. O. S. (2016). Earnout financing in the financial services industry. *International Review of Financial Analysis, 47*, 119–132. https://doi.org/10.1016/j.irfa.2016.07.001

Çukur, S., & Eryiğit, R. (2007). Yatırım ortaklıkları ve bedelsiz sermaye artırımları: İMKB'de ampirik bir analiz. *İktisat İşletme ve Finans, 22(254),* 73–85. https://doi.org/10.3848/iif.2007.254.2568

Eriş, N. (2009). *Bedelli ve bedelsiz sermaye artırımlarının yatırımcı davranışları üzerindeki etkisi: İMKB şirketleri üzerinde ampirik bir çalışma*, Master's thesis, Ankara University. Ankara University Social Sciences Institute.

Erol, A., & Aytekin, S. (2018). Borsa İstanbul pay piyasası şirketlerinin bedelsiz sermaye artırımı duyurularının hisse senedi getirileri üzerindeki etkisinin değerlendirilmesi. *Journal of Mehmet Akif Ersoy University Economics and Administrative Sciences Faculty, 5(3)*, 898–912. https://doi.org/10.30798/makuiibf.439219

Işıker, M., & Taş, O. (2021). Cracking the fault line in stock markets: The case of bonus issue announcements. *Journal of Capital Markets Studies, 5(1)*, 69–95. https://doi.org/10.1108/JCMS-03-2021-0008

Kaya, B. (2023). Küresel pandemi sırasında bedelli ve bedelsiz sermaye artırım duyurularının pay getirileri üzerindeki etkisi: Borsa İstanbul'dan kanıtlar. *İnsan ve Toplum Bilimleri Araştırmaları Dergisi, 12(2)*, 1122–1141. https://doi.org/10.15869/itobiad.1271390

Kolari, J. W., Pynnönen, S., & Tuncez, A. M. (2021). Further evidence on long-run abnormal returns after corporate events. *The Quarterly Review of Economics and Finance*, 81, 421–439. https://doi.org/10.1016/j.qref.2020.10.011

Küçüksille, E., & Mizrahi, R. (2015). Bedelsiz sermaye artırımı duyurularının şirketlerin piyasa değerlerine etkisi: Borsa İstanbul örneği. *Sosyal ve Beşeri Bilimler Araştırmaları Dergisi, 16(35)*, 129–149.

Suidarma, I. M., Putri, N. W. O. P., Dewi, P. A. S., Putra, I. K. K. A., Sara, I. M., & Marsudiana, I. D. N. (2026). The impact of stock splits and reverse stock splits on stock returns in the Indonesian market. International *Journal of Advanced and Applied Sciences, 13(2)*, 229–239. https://doi.org/10.21833/ijaas.2026.02.024