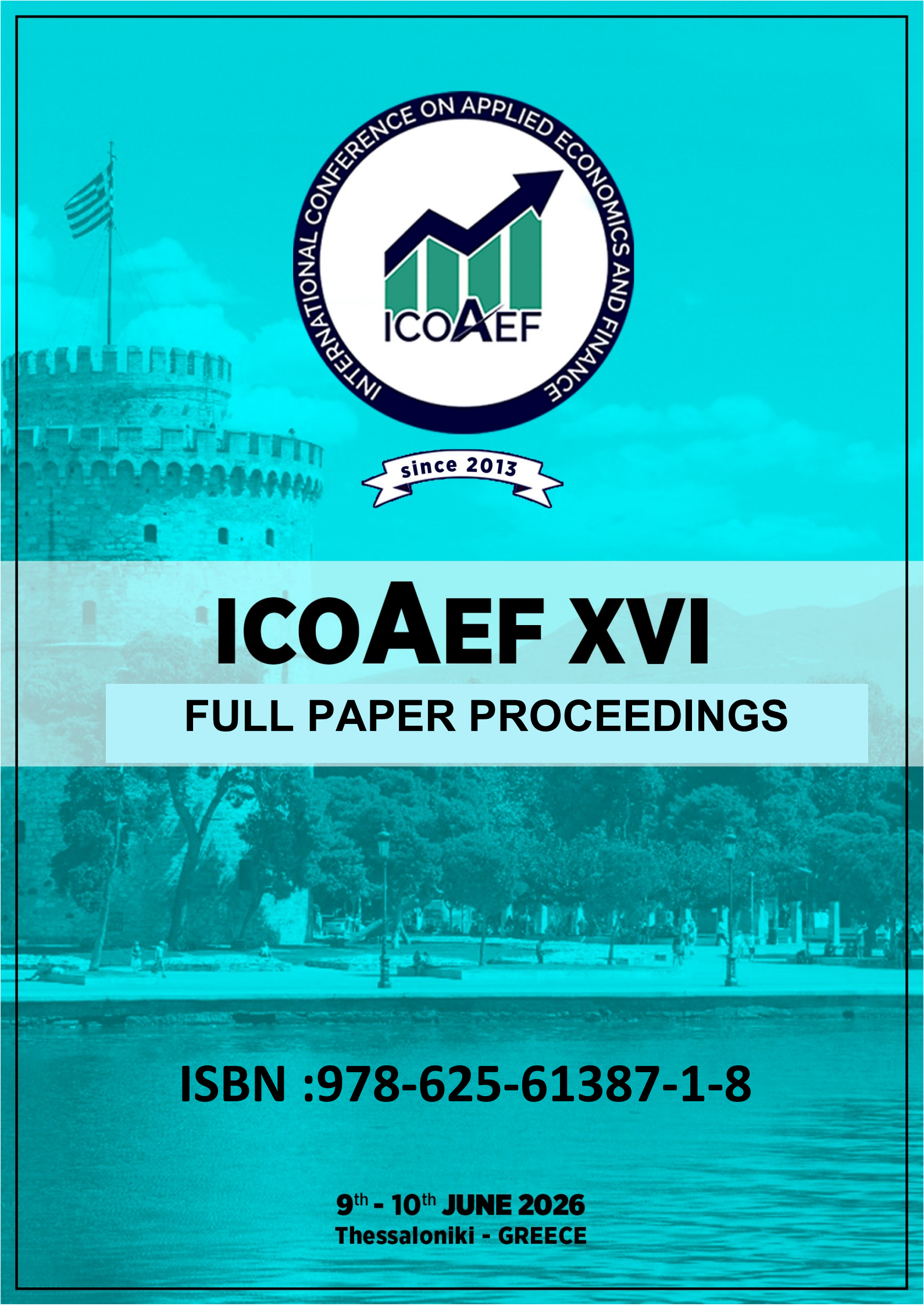

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ICOAEF XVI

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

Prof. H. Murat ERTUGRUL

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DETERMINANTS OF CARBON INTENSITY IN TÜRKIYE: ENERGY INTENSITY AND CAPITAL DEEPENING

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

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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.

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 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

[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).

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.

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

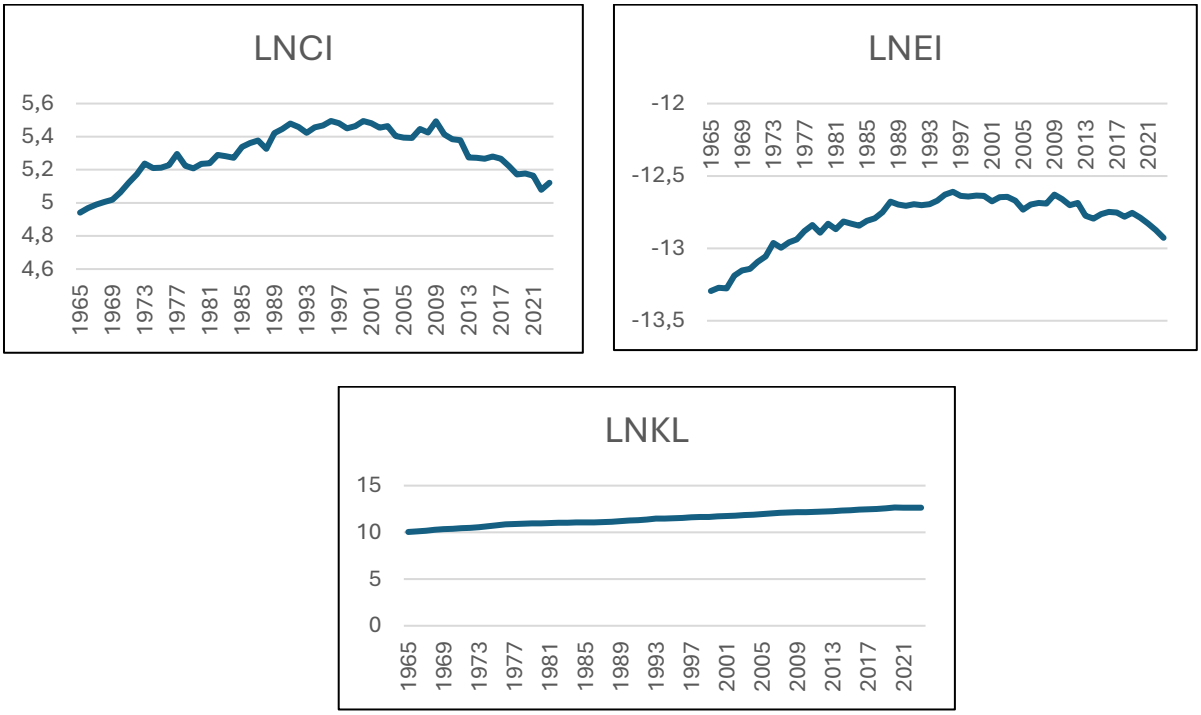
Variable	Definition	Explanation	Source
LNCI	Carbon intensity	CO_2/GDP	Carbon dioxide (CO_2) emissions were obtained from Our World in Data (OWID).
			Real GDP data at constant national prices was obtained from FRED (Federal Reserve Bank of St. Louis).
LNEI	Energy intensity	Total energy consumption/GDP	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

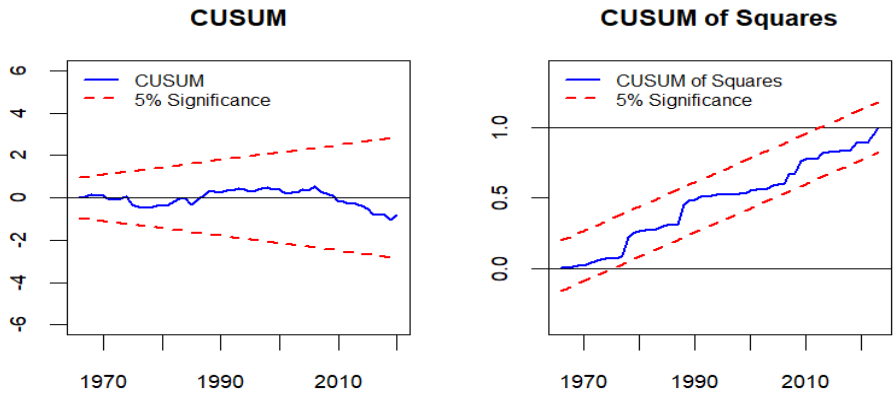
forces have been identified: The Capital-Labor Effect (KLE) leads capital-intensive countries to specialize in polluting production, while the Environmental Regulation Effect (ERE) enables countries with high environmental standards to specialize in clean production. In this framework, since pollution-intensive 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.

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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.

3.1. 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).

3.2. 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).

3.3. 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.

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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.

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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.

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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.

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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

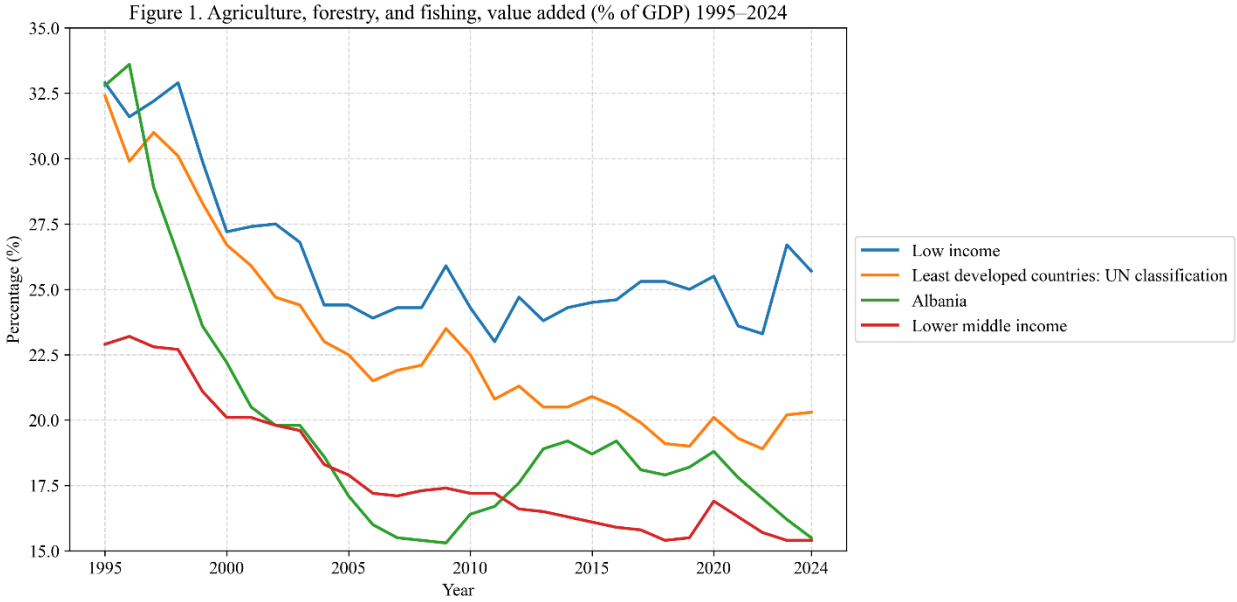
only perpetuate inequalities, preventing women from achieving full participation in rural development (Sulaj, Themelko, 2024). Export dynamics reflect rural producers' market positioning challenges. While exports increased 37% from 2020 to peak at 486,784 million ALL in 2022, they subsequently declined 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).

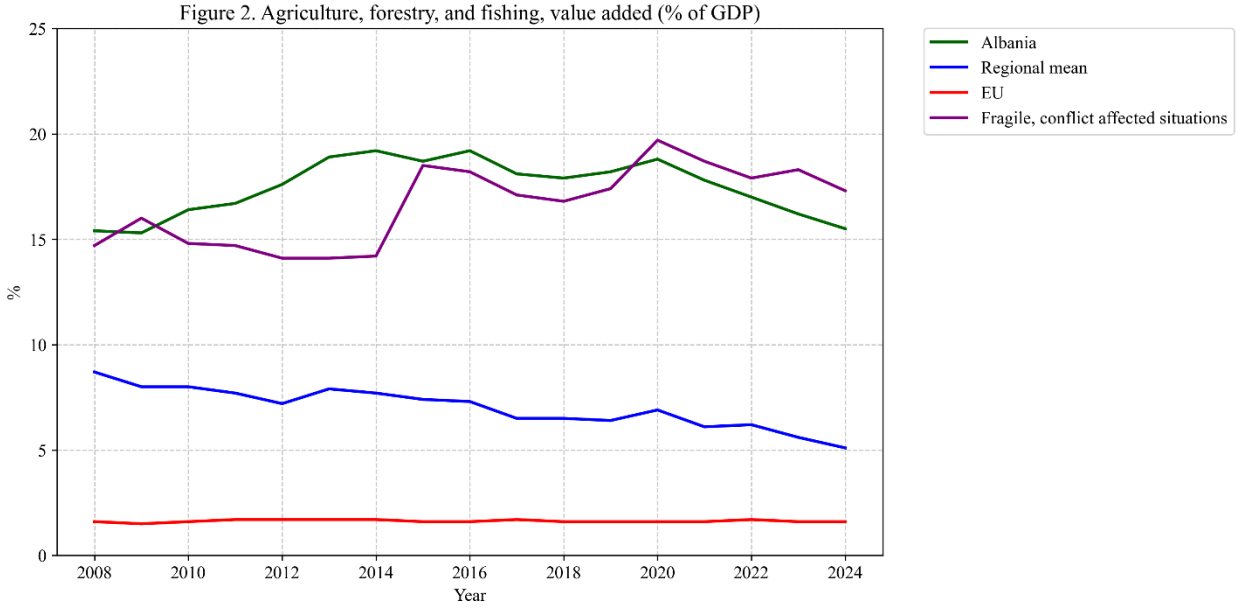
According to World Bank data, fragile and conflict-affected situations alongside low and lower-middle income countries exhibit similar agricultural GDP shares. The Western Balkans regional average (excluding Albania) demonstrates progressive economic transformation. Bosnia and Herzegovina reduced agriculture's 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.

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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.

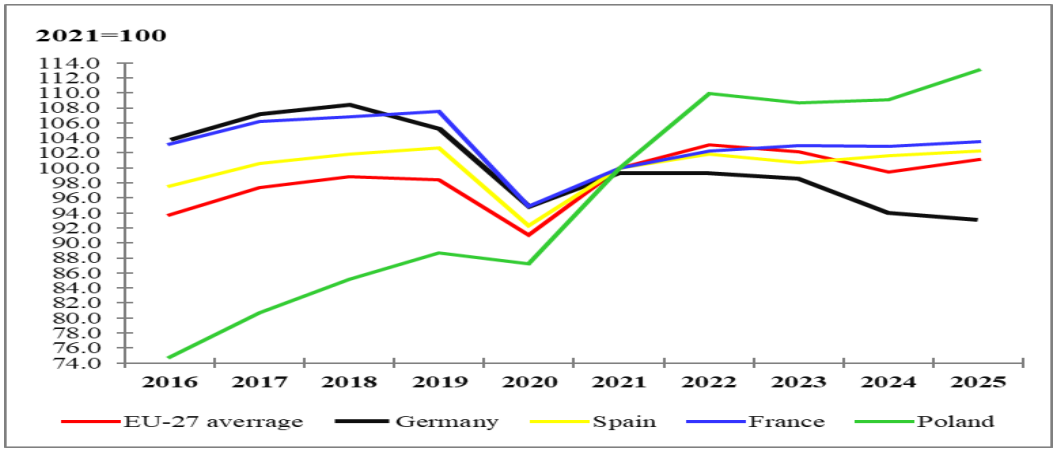
Against this background, the following discussion assesses whether recent policy measures should be understood primarily as temporary responses to successive crises or as part of a more durable reconfiguration of public intervention, increasingly shaped by resilience, technological capabilities, strategic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

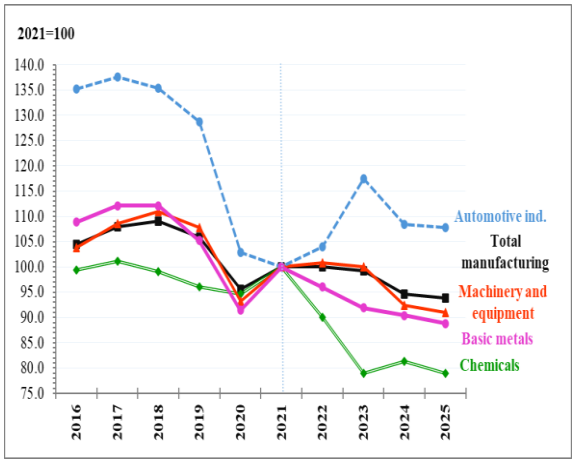
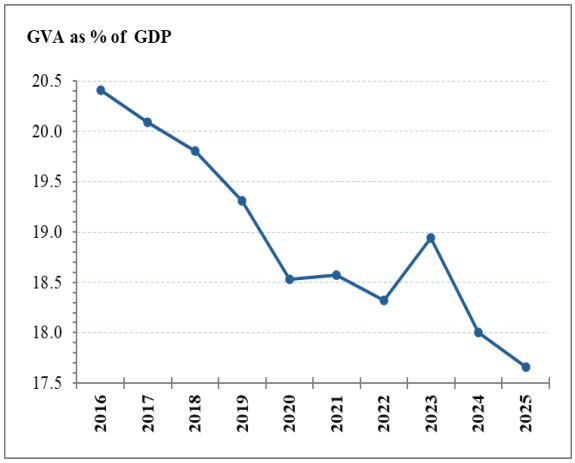


Figure 3. Manufacturing gross value added as share of GDP (%)**



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.

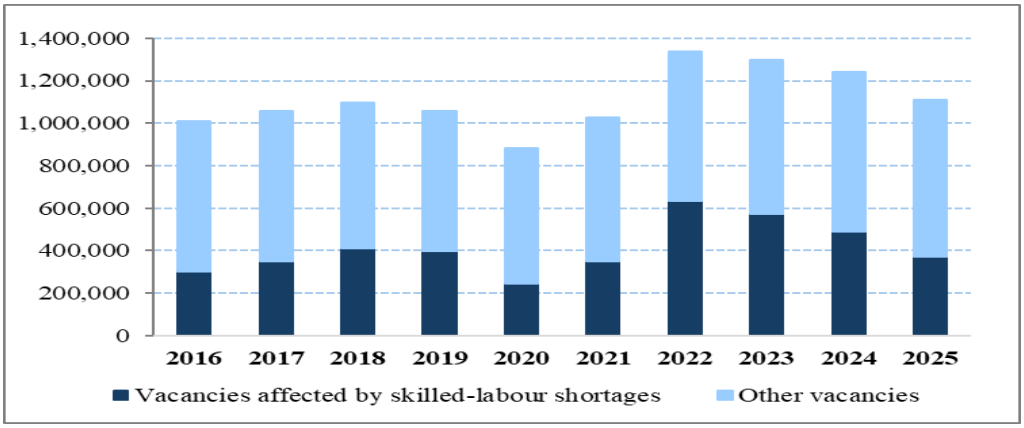
Beyond the sectoral patterns captured by the production indicators, Germany's industrial adjustment is also constrained by a deterioration in several key location conditions. Investment and infrastructure deficiencies, administrative complexity and slower implementation capacity increasingly affect firms' 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).

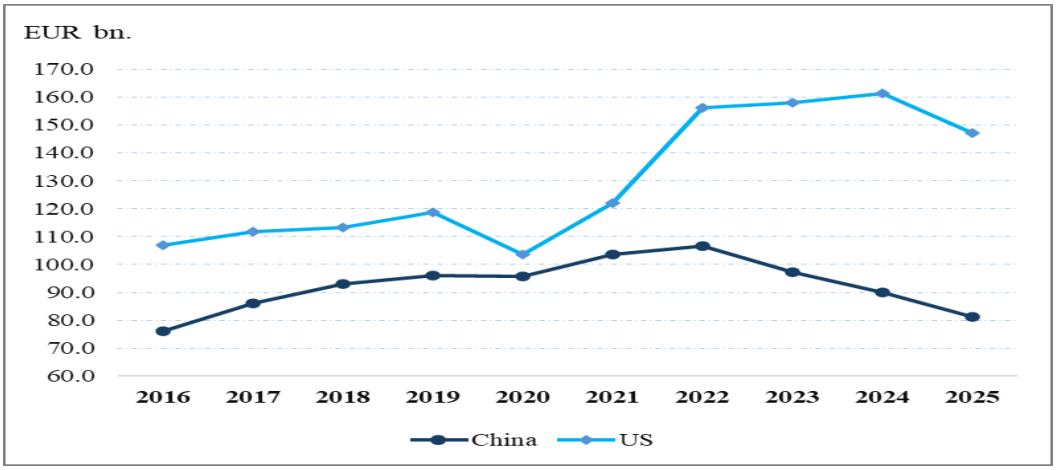
with only 57% of surveyed enterprises having invested during the preceding year despite 92% continuing to report investment needs. Among firms that refrained from investing, the main obstacles included macroeconomic uncertainty, elevated costs, limited internal funds, unfavourable financing conditions 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.

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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

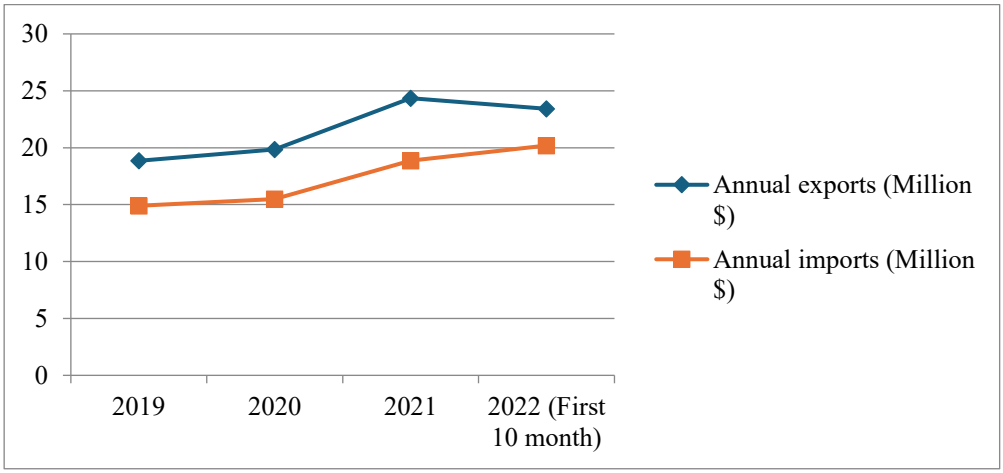
The neoliberal policies implemented after 1980 and the export-oriented growth models served as major drivers for the opening up of the Turkish economy and Turkish firms to foreign markets. With the liberalization of foreign trade, the country's economic capacity expanded significantly in terms of both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

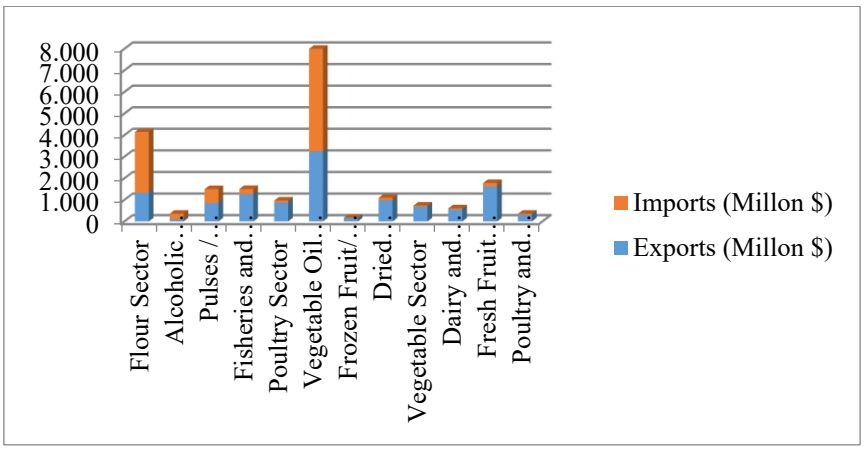
Figure 1. Comparison of Food Sector Export and Import Data by Years



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.

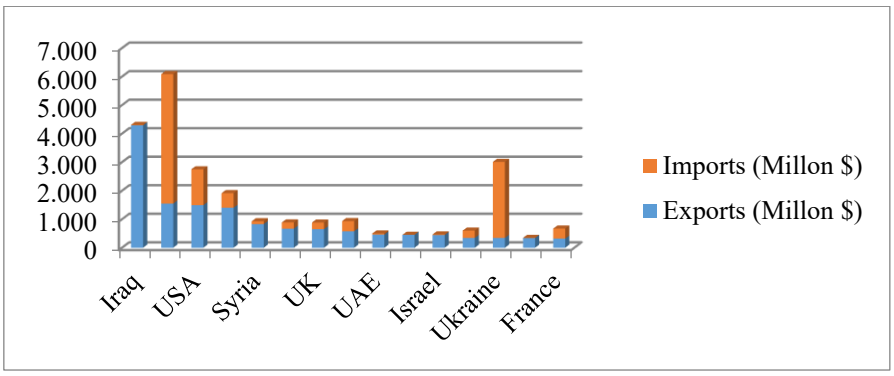
Figure 2. Foreign Trade Data of Selected Food Sector Commodities for the First 10 Months of 2022



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).

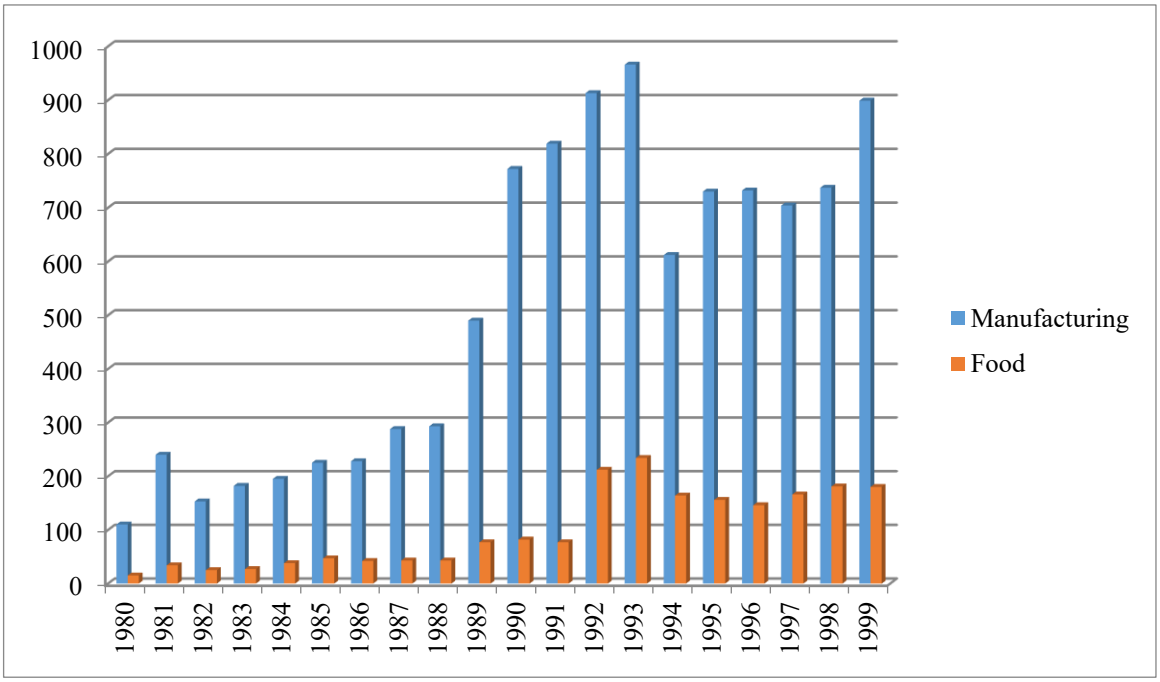
Looking at the distribution of investment permits granted by decrees issued after 1972 across production sectors, an investment of $11 million was made in the food sector (Şahin, 1975: 55).

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.

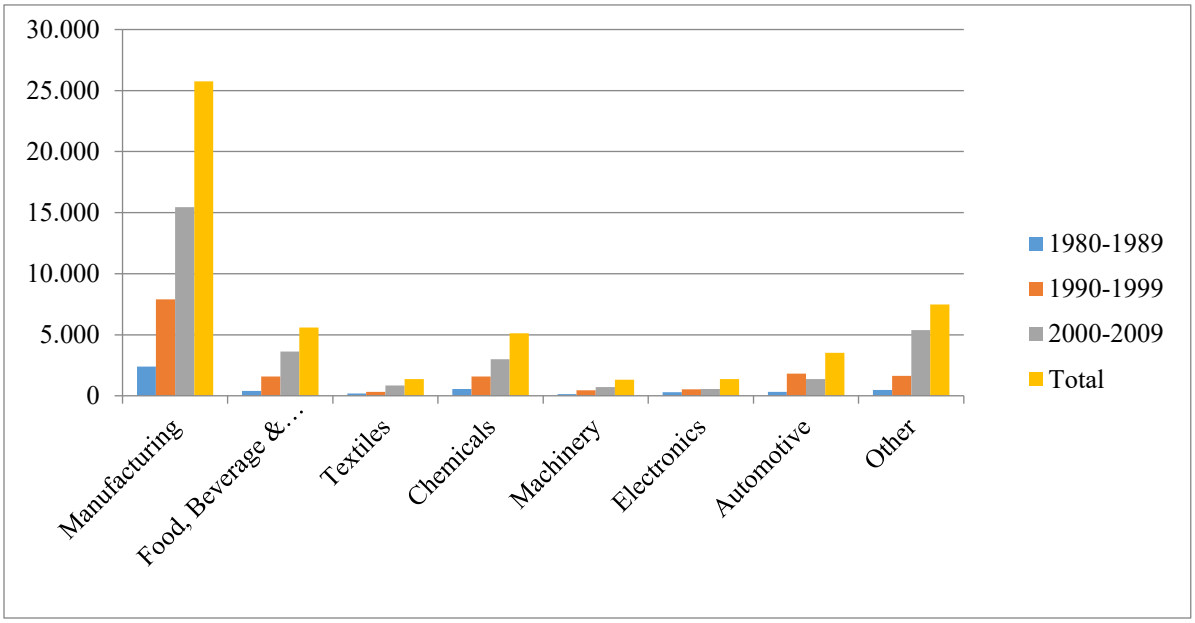
In 1989, a substantial increase in foreign capital was recorded across all sectors. The underlying cause was that the measures implemented in 1989 to encourage foreign currency inflows had a positive impact on foreign capital entry.

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.

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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.

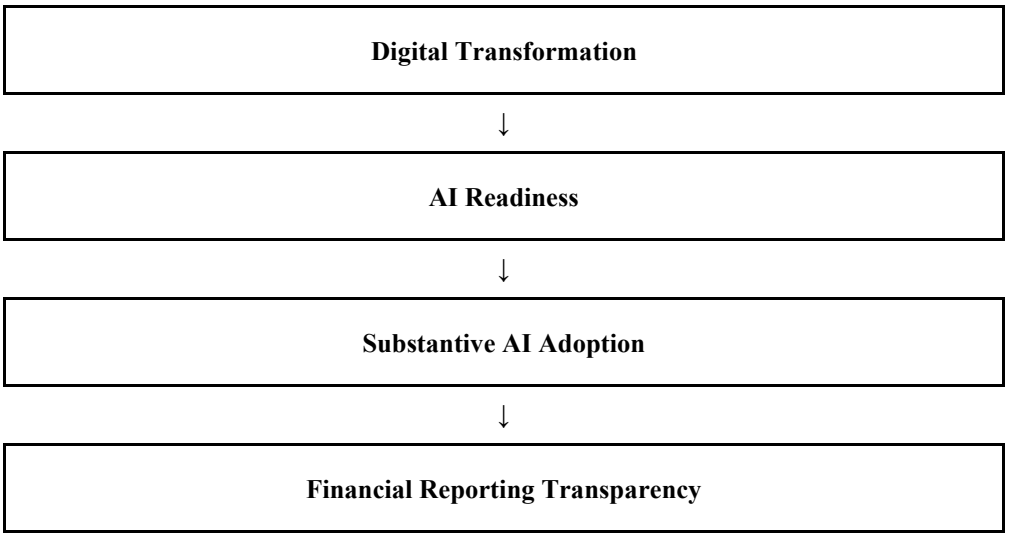
P2: AI readiness depends on technological infrastructure, organizational capabilities, human capital, and institutional and regulatory conditions.

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.

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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.

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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.

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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.

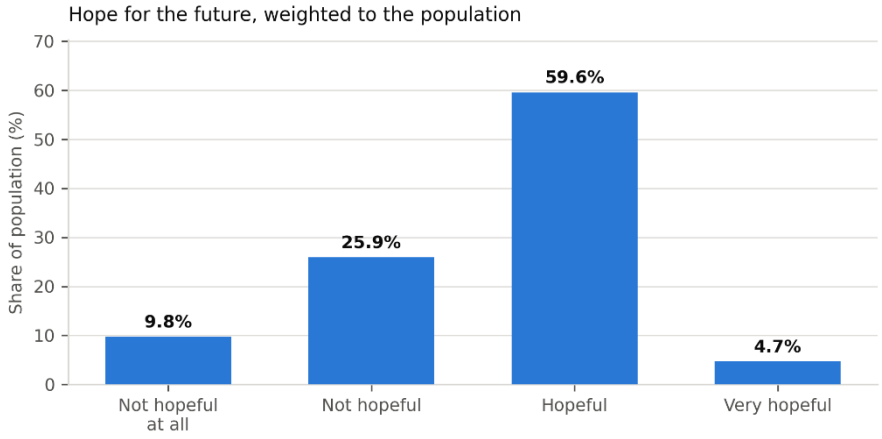
All estimates reported below are weighted by the individual sampling weight supplied with the release, and all standard errors are linearised (sandwich) estimators that account for the weighting. Weighting is not cosmetic here. The unweighted share of respondents expressing positive hope is 63.7 percent, 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.

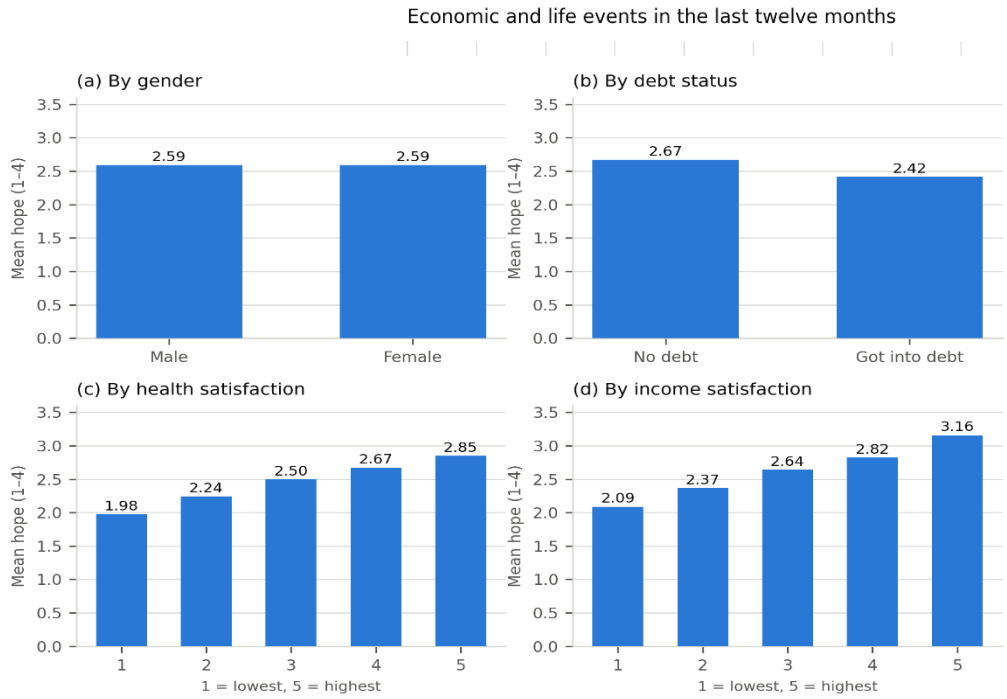
3.3. Independent Variables and Coding

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.

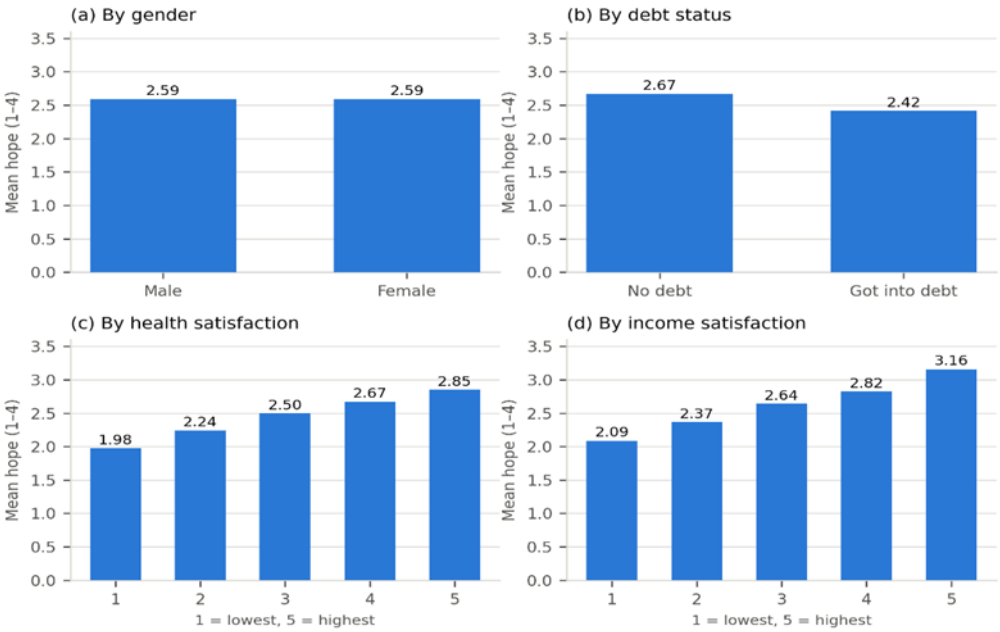
Figure 2. Weighted Prevalence of Economic and Life Events Reported in the Last Twelve Months



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.

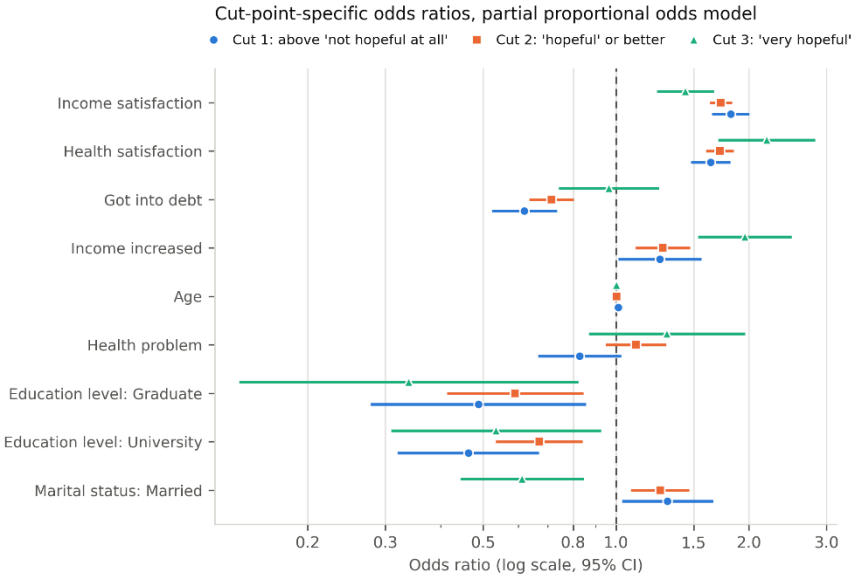
Table 4. Partial Proportional Odds Estimates: Cut-Point-Specific Effects (weighted)

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).

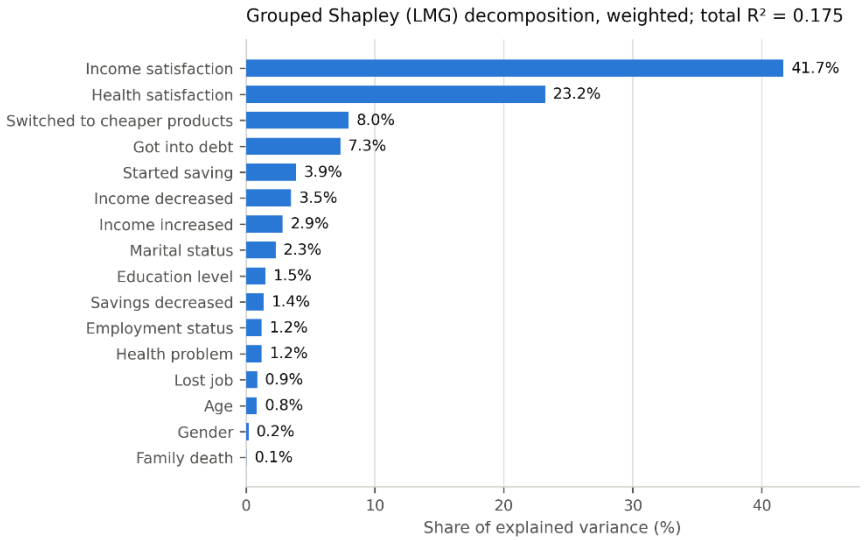
Table 5. Grouped Shapley (LMG) Decomposition of Hope (weighted)

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.

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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.

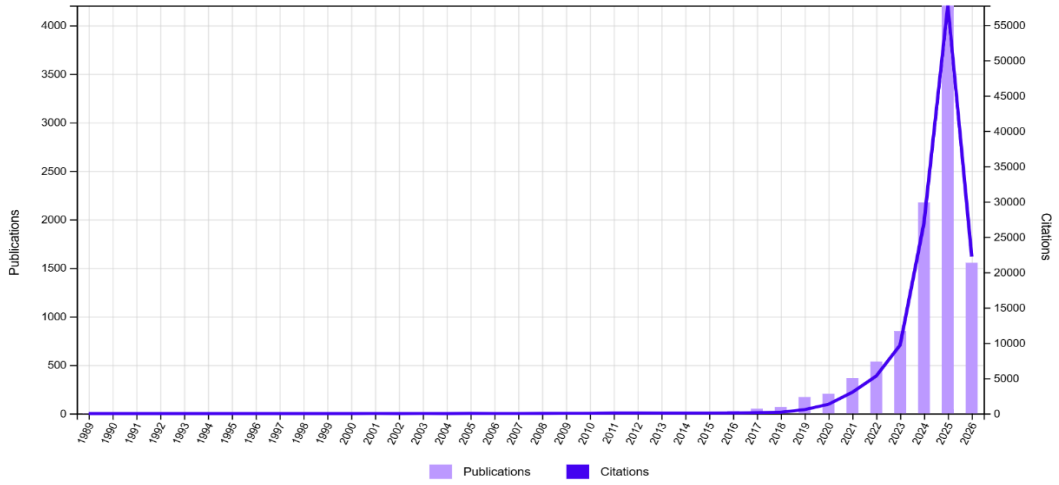
3. METHODOLOGY

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

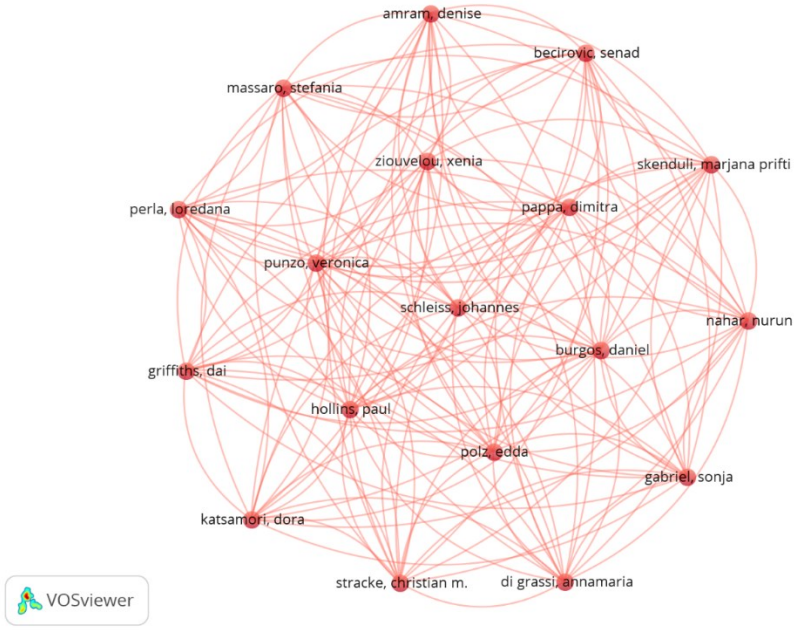


The Figure 1 represents a bibliometric trend analysis of research publications and citations over time. The bar chart (light purple) indicates the number of publications per year, while the line chart (dark blue) represents the number of citations received.

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

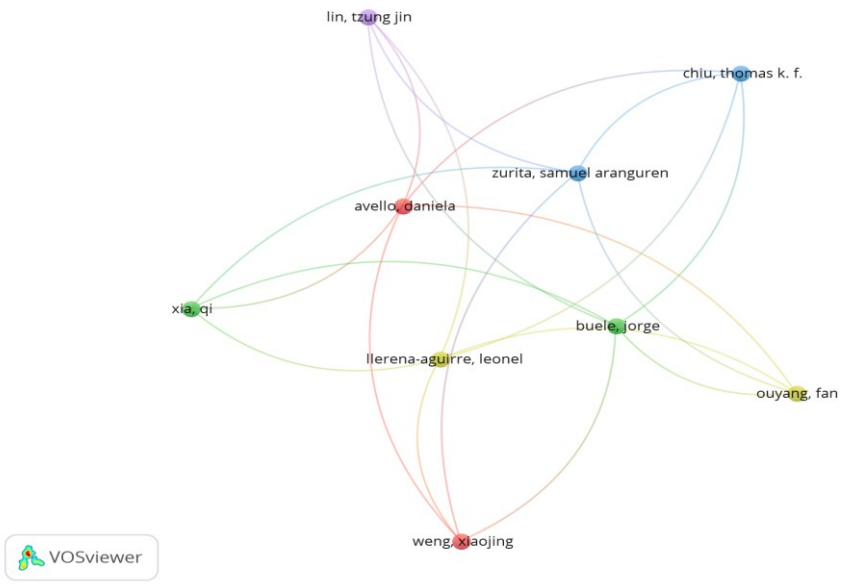


As shown in the Figure 2, the authors form a single, highly integrated cluster. This indicates that the collaboration network is not fragmented but rather concentrated around a closely connected research group. Authors such as Schleiss, Johannes; Pappa, Dimitra; Burgos, Daniel; Ziouvelou, Xenia; Polz, 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

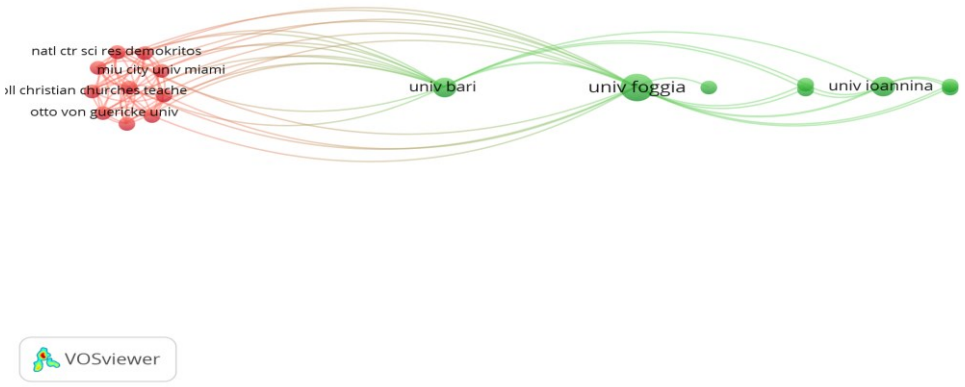


A network map was created to analyse citation relationships among authors based on the criteria that each author must have at least one publication and at least one citation. The analysis was conducted on the authors who met these thresholds and were interconnected within the citation network in Figure 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.

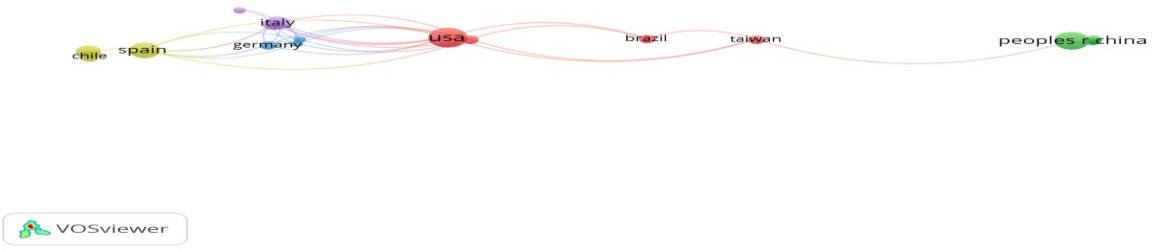
As illustrated in the Figure 4, institutions such as University of Foggia**,** University of Bari**,** and University of Ioannina occupy central positions within the network. These institutions appear to play a key role in bridging citation flows between different parts of the network. Their relatively 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.

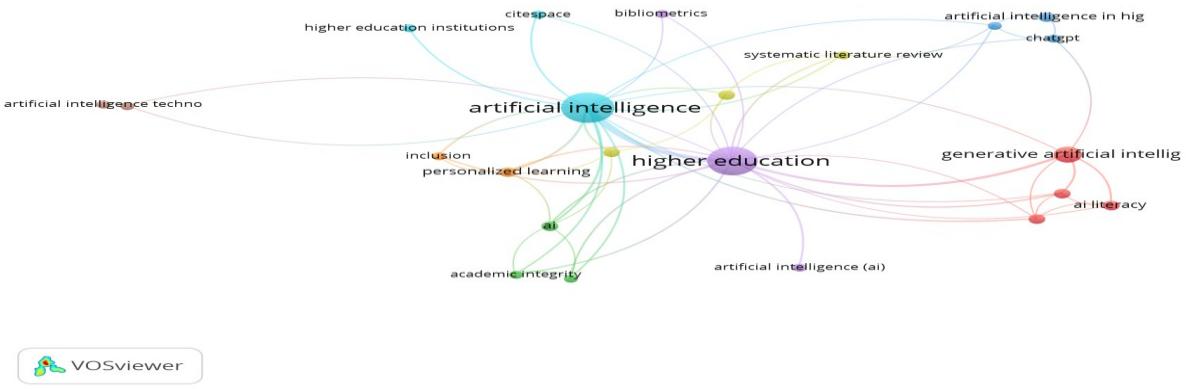
The results reveal a structured network composed of multiple interconnected countries. The map indicates the presence of distinct clusters, reflecting country groupings based on citation relationships. Overall, the network demonstrates a moderate level of connectivity, with numerous links formed between 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.

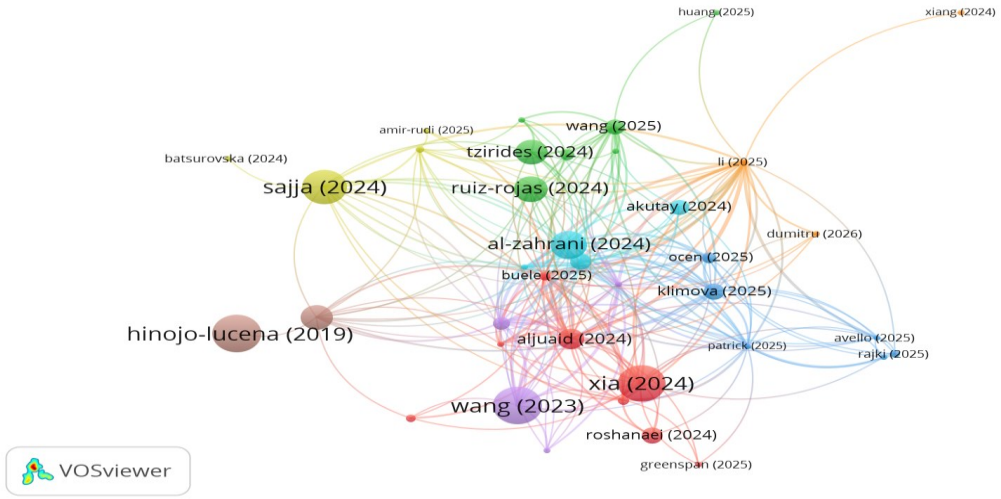
The results reveal a total of 13 keywords (units) forming 3 distinct clusters, with 32 links and a total link strength of approximately 118**.** These values indicate a moderately dense keyword network, reflecting the thematic structure of the research field.

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.

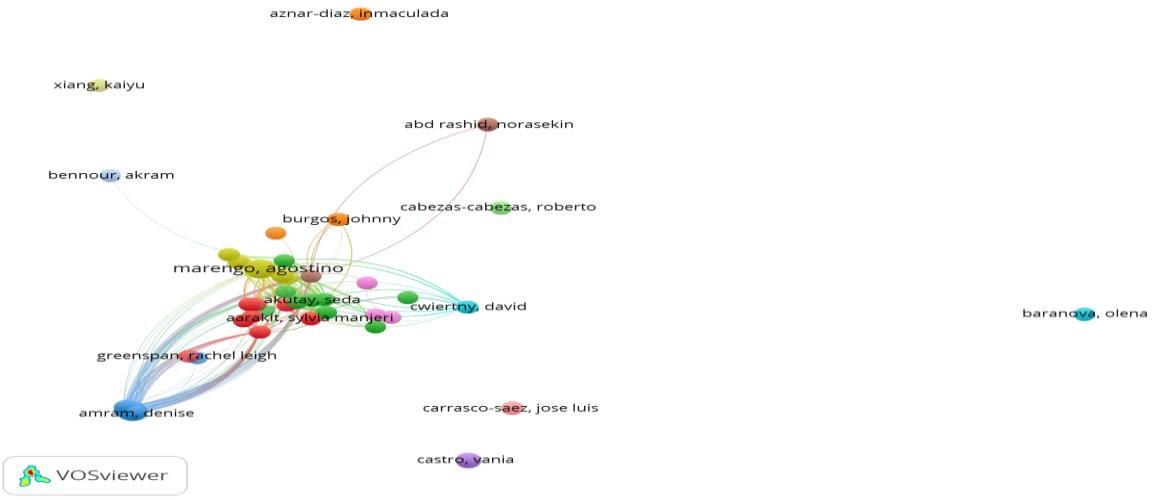
According to the analysis, a total of 731 publications (units) were identified as interconnected within the network. The structure consists of 25 clusters**,** 4,069 links, and a total link strength of 7,237**,** indicating a highly dense and strongly connected network of shared references.

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

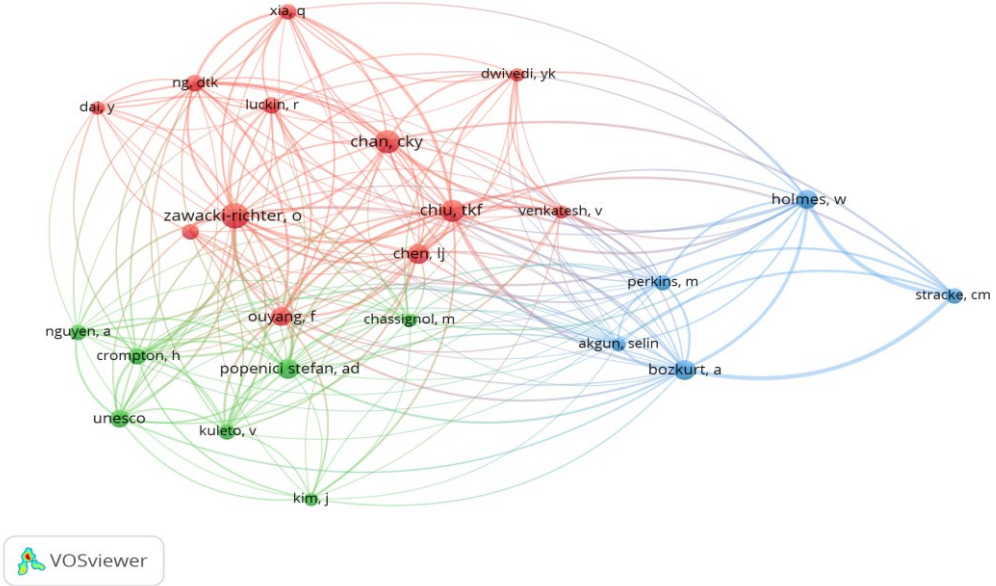


The network map shows the bibliographic coupling relationships among authors based on shared references. The structure reveals a dense central cluster and several peripheral authors**.**

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.

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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).

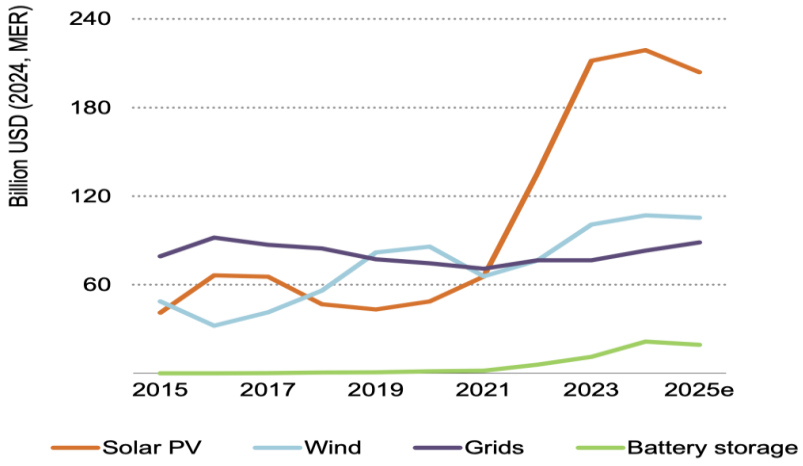
A decision-making unit identified as efficient by Data Envelopment Analysis may lose its efficiency over time. To capture the evolution of efficiency across periods, the Malmquist Total Factor Productivity (TFP) Index, which incorporates a temporal dimension, was developed (Dinçer, 2008). However, this 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

$$D(x, y, b; g_y, g_e) = max \{\beta : (y + \beta g_y, b - \beta g_e) \in P(x)\}, \tag{2}$$

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

$$GML(t, t + 1) = [1 + D^G(x_t, y_t, b_t; g)] / [1 + D^G(x_{t+1}, y_{t+1}, b_{t+1}; g)], \tag{3}$$

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:

$$ln\ GML_{it} = \alpha + \beta_1\ ln\ Solar_{it} + \gamma' Z_{it} + \varepsilon_{it}. \quad (4)$$

The second specification augments equation (4) with province and year fixed effects, yielding the two-way within estimator

$$ln\ GML_{it} = \beta_1\ ln\ Solar_{it} + \gamma' Z_{it} + \mu_i + \lambda_t + \varepsilon_{it}, \quad (5)$$

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:

$$ln\ GML_{it} = \beta_1\ ln\ Solar_{it} + \beta_2\ Curt_{it} + \beta_3\ (ln\ Solar_{it} \times Curt_{it}) + \gamma' Z_{it} + \mu_i + \lambda_t + \varepsilon_{it}. \quad (6)$$

In equation (6) the marginal effect of capacity expansion is no longer a constant but a function of the prevailing curtailment environment,

$$\partial\ ln\ GML_{it} / \partial\ ln\ Solar_{it} = \beta_1 + \beta_3\ Curt_{it}, \quad (7)$$

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):

$$ln\ GML_{it} = \theta_1\ ln\ Solar_{it} \cdot I(q_{it} \le \gamma) + \theta_2\ ln\ Solar_{it} \cdot I(q_{it} > \gamma) + \delta' Z_{it} + \mu_i + \lambda_t + \varepsilon_{it}, \quad (8)$$

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) $W\text{-}\bar{t}$ 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 ($\beta_3 = -0.0285$, $p = .028$), 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.

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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.

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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.

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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.

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YEŞİL EKONOMİNİN AEB ÜLKELERİNİN SÜRDÜRÜLEBİLİR KALKINMASINA ETKİSİ

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ÖZET

Bu araştırma, Avrasya Ekonomik Birliği (EAEU) ülkelerinde yeşil ekonominin sürdürülebilir kalkınma üzerindeki etkisini incelemektedir. Çalışmanın temel amacı, yeşil ekonomi göstergelerinin insani kalkınma ve sürdürülebilir kalkınma üzerindeki etkisini ortaya koymaktır. Çalışmada teorik ve ampirik yöntemler kullanılmıştır.

Çalışmanın ilk bölümü, yeşil ekonominin teorik temellerini incelemektedir. Bu bölümde, yeşil ekonomi kavramı, temel ilkeleri ve sürdürülebilir kalkınma ile ilişkisi açıklanmaktadır. Ayrıca, yeşil ekonomi alanında gelişmiş ülkelerin deneyimleri de gözden geçirilmektedir.

İkinci bölümde, EAEU ülkelerindeki yeşil ekonomi ve sürdürülebilir kalkınma göstergelerinin mevcut durumu analiz edilmektedir. Kırgızistan, Kazakistan, Rusya, Beyaz Rusya ve Ermenistan'ın çevre politikaları, yenilenebilir enerji kullanımı, enerji verimliliği ve yeşil stratejileri değerlendirilmektedir.

Üçüncü bölümde ise ampirik analiz sunulmaktadır. Yeşil ekonominin sürdürülebilir kalkınma üzerindeki etkisi, 2000–2022 dönemine ait bir panel veri seti kullanılarak ekonometrik yöntemlerle tahmin edilmektedir. Analiz sonuçları, yenilenebilir enerji kaynaklarının kullanımının artırılmasının, enerji verimliliğinin yükseltilmesinin ve çevresel performansın iyileştirilmesinin sürdürülebilir kalkınma üzerinde olumlu bir etkiye sahip olduğunu göstermiştir.

Çalışmanın sonuçları, yeşil ekonominin bazı göstergelerinin sürdürülebilir kalkınma üzerinde olumlu ve istatistiksel olarak anlamlı bir etkiye sahip olduğunu ortaya koymuştur. Özellikle, çevre koşullarının iyileştirilmesinin, sosyal altyapının geliştirilmesinin ve yaşam standartlarının yükseltilmesinin insani gelişme endeksinin artışına katkıda bulunduğu tespit edilmiştir. Ayrıca, EAEU ülkelerinde yeşil ekonominin geliştirilmesine yönelik politikanın güçlendirilmesinin, sürdürülebilir kalkınmanın sağlanmasında önemli bir faktör olduğu kanıtlanmıştır.

Anahtar Kelimeler: *Yeşil Ekonomi, Sürdürülebilir Kalkınma, İnsani Gelişme Endeksi, EAEU, Panel Regresyonu, Driscoll–Kraay.*

JEL KODLARI: *C01, C23, I28.*

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THE IMPACT OF THE GREEN ECONOMY ON THE SUSTAINABLE DEVELOPMENT OF THE EAEU COUNTRIES

ABSTRACT

This research examines the impact of the green economy on sustainable development in the countries of the Eurasian Economic Union (EAEU). The main objective of the study is the impact of green economy indicators on human development and sustainable development. The study used theoretical and empirical methods.

The first section of the study examines the theoretical foundations of the green economy. This section explains the concept of the green economy, its main principles and its relationship with sustainable development. In addition, the experience of developed countries in the field of green economy is reviewed.

The second section analyzes the current state of the green economy and sustainable development indicators in the EAEU countries. The environmental policy, use of renewable energy, energy efficiency and green strategies of Kyrgyzstan, Kazakhstan, Russia, Belarus and Armenia are assessed.

The third section provides empirical analysis. The impact of the green economy on sustainable development is estimated using econometric methods using a panel data set for 2000–2022. The results of the analysis showed that increasing the use of renewable energy sources, increasing energy efficiency and improving environmental performance have a positive impact on sustainable development.

The results of the study showed that some indicators of the green economy have a positive and statistically significant impact on sustainable development. In particular, it was found that improving environmental conditions, developing social infrastructure and increasing living standards contribute to the growth of the human development index. It was also proven that strengthening the policy on the development of the green economy in the EAEU countries is an important factor in achieving sustainable development.

Keywords: *Green Economy, Sustainable Development, Human Development İndex, EAEU, Panel Regression, Driscoll–Kraay***.**

JEL Codes: *C01, C23, I28.*

1. INTRODUCTION

Over the last decade, the world economy has shown growing interest in new development models oriented towards environmental protection, rational use of resources and low-carbon growth. One of the most important of these models is the green economy. The green economy combines economic growth with environmental security, social well-being and resource efficiency, and is aimed at ensuring the long-term sustainable development of countries. This model relies on a set of priorities such as resource

saving, increasing energy efficiency, reducing waste, cutting the carbon footprint and introducing environmental technologies.

The countries of the Eurasian Economic Union (EAEU) — Russia, Kazakhstan, Belarus, Kyrgyzstan and Armenia — have begun to actively develop green economic policies in recent years. A distinctive feature of the economies of this region is a high dependence on natural resources, the carbon intensity of production, and the severity of environmental problems. Under these conditions, the introduction of green economy mechanisms is becoming a necessary condition for the sustainable development of the region.

Environmental integration within the EAEU, carbon regulation, green finance, renewable energy and resource efficiency are areas where a joint policy can increase the competitiveness of member states and open the way to sustainable economic growth. The relevance of this study is determined by the necessity of the EAEU countries' transition to a green economy and the importance of a comprehensive analysis of its impact on sustainable development. Assessing the effectiveness of green economy policy, identifying its main challenges and opportunities, and developing effective mechanisms for environmental and economic development at the regional level are among the most pressing issues of the present day.

The purpose of this study is to analyze the impact of the green economy on the sustainable development of the EAEU countries and to identify its main directions, dynamics and potential. To achieve this goal, the following tasks are set: to examine the theoretical foundations and fundamental principles of the green economy; to analyze the current state of green economy development in the EAEU countries; to study the main indicators and systems of sustainable development; to assess the impact of green economy factors on sustainable development; to identify the main challenges and opportunities in the transition to a green economy in the EAEU countries; and to develop recommendations aimed at ensuring sustainable development in the region. The object of the study is the economic system of the EAEU member states, while the subject is the factors of the green economy and their impact on the sustainable development of these countries.

2. THEORETICAL FRAMEWORK AND LITERATURE REVIEW

International organizations such as the United Nations Environment Programme (UNEP), the United Nations Conference on Trade and Development (UNCTAD), the UN Department of Economic and Social Affairs (UN DESA), the UN Commission on Sustainable Development (UNCSD), the Green Economy Coalition (GEC) and the Global Green Growth Institute (GGGI) have published numerous definitions and interpretations of the concepts of green economy and green economic growth (Zomonova, 2016). In 2011, UNEP defined the green economy as one that improves human well-being and social equity while significantly reducing environmental risks and ecological scarcities — that is, a low-carbon, resource-efficient and socially inclusive economy (UNEP, 2011). UNCTAD (2010)

similarly defined it as an economy that seeks long-term social benefit without exposing future generations to significant environmental risks.

According to the Green Economy Coalition, an inclusive green economy rests on five key principles: well-being, equity, planetary boundaries, efficiency and sufficiency, and good governance (Green Economy Coalition, 2025). These principles were also elaborated at the UN Conference on Sustainable Development (Rio+20, 2012). Table 1 summarizes the main principles of the green economy grouped by their economic, social and environmental orientation.

Table 1. Main Principles of the Green Economy

Dimension	Principles
Economic	1. Internalizing externalities
Social	2. Employment and green job creation 3. Improving public governance and ensuring the rule of law 4. Ensuring equity, justice and fairness 5. Improving quality of life
Environmental	6. Protecting ecosystems and biodiversity 7. Resource saving and achieving energy efficiency 8. Recognizing the scarcity of natural resources and ecological services
Other	9. Seeking means to achieve sustainable development 10. Applying an integrated approach in decision-making 11. Measuring progress with indicators beyond GDP

Source: Zomonova (2016).

The green economy is regarded as an instrument for achieving the goals of sustainable development. By encouraging the use of renewable energy (wind and solar) and reducing dependence on fossil fuels, it helps preserve ecosystems and natural resources, thereby reducing greenhouse gas emissions and mitigating climate change. It also contributes to agricultural development and food security through organic farming and biodiversity conservation, limits air, water and soil pollution, and supports the protection of endangered species (OECD, 2021). Innovative technologies have become the principal tool of green growth, enabling better waste treatment, recycling and monitoring while also strengthening safe and orderly trade, including agricultural markets.

A popular model for implementing the green economy is the circular economy, based on the rational use of resources, extending product life cycles, and developing systems for collecting, recycling and reusing secondary raw materials. According to the Ellen MacArthur Foundation, the circular economy aims to reduce waste through closed production cycles and material reuse. Large multinational corporations such as Coca-Cola, Nestlé, Unilever and PepsiCo have announced a gradual shift toward recyclable, reusable or compostable packaging as part of their sustainability strategies, while regulation of plastic use is being tightened at the state level — for example, through the EU Single-Use Plastics Directive (European Commission).

Developed countries provide instructive experience in implementing the green economy. Germany has substantially reduced its dependence on fossil fuels through large investments in wind and solar energy, combined with state support for environmental projects (International Energy Agency, 2023). Denmark is a world leader in offshore wind energy and has set the goal of climate neutrality by 2050 (Movsesov, 2025). Sweden has achieved high results in building a low-carbon economy through its policy on sustainable transport, waste recycling and biofuels. The Netherlands is a clear example of implementing circular-economy principles, where production processes are designed around the full product life cycle (Government of the Netherlands, 2016). The United States has focused on wind and solar energy development along with federal clean-energy stimulus programs (U.S. Energy Information Administration, 2023). South Korea has integrated environmental modernization into its national growth strategy, investing in green technologies, industrial digitalization and energy-saving infrastructure (OECD, 2020), while Japan is implementing a large-scale "green transformation" strategy focused on reducing carbon emissions and developing a hydrogen economy (International Energy Agency, 2021).

These experiences indicate that the successful implementation of the green economy depends on several key factors: an active role of the state, substantial investment, the development of environmental legislation, and increased environmental responsibility of businesses. The formation of an environmental culture in society is equally important, as it promotes responsible and rational consumption of resources.

A growing body of empirical literature has examined the relationship between green economy indicators and economic or human development. Yunusova Ceviz (2025), using CCEMG and PCSE methods on a panel of countries for 2013–2023, found that green finance affects economic growth with a time lag, with significant effects observed mainly in the long run. Qorraj, Gara and Fetai (2025), applying fixed and random effects and the Hausman–Taylor model on OECD and candidate countries (2010–2021), found that the green economy positively affects economic growth, with consumption as the strongest driver and corruption and imports exerting significant negative effects. Işık, Simionescu and Ongan (2023), using a dynamic panel threshold model for the G-7 and BRIC countries (1996–2018), showed that renewable energy accelerates the turning point for reducing CO2 emissions, while economic freedom reduces emissions and policy uncertainty reduces them in the long run. Hao (2022), using PMG and CCE estimators on a broad panel of developing countries (1990–2019), found that the effect of economic and social factors on the environment depends on countries' development level, with renewable energy development seen as the principal tool for reducing pollution.

Rahman and Sultana (2024) found a positive and statistically significant relationship between renewable energy and human development in low-income and developing countries (2002–2019) using panel econometric methods. Susmaz and Sakar (2020), studying OECD countries (1990–2017) with cointegration tests accounting for structural breaks, identified a long-run relationship between renewable energy and human development. Al-Ghamdi et al. (2024), applying panel econometric analysis with a

fixed-effects model to a group of countries for 1998–2022, found that renewable energy and emissions had a limited and sometimes contradictory effect on GDP. Studies by Sichigea et al. (2024), Musolesi et al. (2023), Shabir and Javed (2025), Batrancea and Pop (2021), Brozyna et al. (2023), Simionescu et al. (2022), Kwilinski et al. (2023) and Dzwigol and Kwilinski et al. (2023) further confirm that institutional quality, trade openness, green investment and environmental regulation shape the transition toward green economic growth, although the strength and direction of these effects vary across country groups (see the summary in the Appendix references).

Overall, the literature confirms the contribution of international scholars to the study of the relationship between sustainable development, environmental sustainability and green economy development, mostly using examples of developed and developing countries. However, the review shows that EAEU countries remain underrepresented in this body of empirical research. This study aims to fill part of this gap by analyzing the factors influencing the sustainable development of EAEU countries from the perspective of the green economy.

3. THE CURRENT STATE OF THE GREEN ECONOMY IN THE EAEU COUNTRIES

The Eurasian Economic Union is a regional international economic integration organization founded on 1 January 2015 on the basis of the Treaty on the Eurasian Economic Union, uniting Armenia, Belarus, Kazakhstan, Kyrgyzstan and Russia, and ensuring free movement of goods, services, capital and labor as well as coordinated policy across economic sectors (EAEU, official website). The basis for introducing green principles within the EAEU is the agreement of the heads of member states set out in the Strategic Directions for the Development of Eurasian Economic Integration until 2025, approved by the Supreme Eurasian Economic Council on 11 December 2020, which incorporates proposals on implementing green transformation principles prepared earlier by the Eurasian Economic Commission.

Despite differences in economic conditions and resource potential, all EAEU member states are taking steps toward integrating environmental agendas into their national strategies. Kyrgyzstan has adopted successive national green economy development programmes (2019–2023, 2024–2028, and up to 2029), focused on increasing energy efficiency, reducing the carbon footprint and creating green jobs through public and private investment. Russia, with substantial natural resource potential and a large share of traditional energy in its economic structure, is implementing a Low-Carbon Development Strategy until 2050 and the national project “Ecology”, focused on improving environmental conditions, waste management and biodiversity conservation. Kazakhstan has promoted the green economy through its 2013 Concept for Transition to a Green Economy and its 2021 Environmental Code, aiming to increase the share of renewable sources in the energy balance and encourage sustainable use of natural resources. Belarus participates in EAEU integration initiatives on greening industry, including joint projects on energy efficiency, within the framework of its National Strategy for Sustainable Socio-Economic Development until 2035. Armenia is gradually forming a national green economy strategy,

with a growing share of renewable, particularly solar, energy in its energy balance, supported by its Nationally Determined Contribution (NDC) under the Paris Agreement.

Based on the analysis, the following common principles for green economy development within the EAEU can be identified: increasing transparency and investment attractiveness for environmental cooperation projects among member states; transferring national climate policy instruments and accumulated experience between member states; prioritizing economic efficiency in selecting green project implementation methods and technologies; and ensuring a reduction of the growing gap between economic growth and the anthropogenic impact on the environment and climate.

To assess progress toward sustainable development in the EAEU, a five-block system of green economy indicators is commonly used, covering: (1) carbon and energy productivity (e.g., CO2 emission intensity, energy intensity, electricity consumption, share of renewable energy); (2) natural resources (e.g., share of clean water, forest area, mineral extraction volume); (3) environmental quality of life (e.g., air pollutant emissions, access to basic sanitation and safe drinking water); (4) economic opportunities and policy responses (e.g., tourism's share in GDP, environmental payments, environmental investment); and (5) socio-economic context and growth characteristics (e.g., GDP per capita, employment rate, poverty rate, life expectancy). Data availability across these blocks varies among EAEU countries, with gaps particularly notable for Kyrgyzstan and Armenia in some indicators; nevertheless, a sufficient core of indicators is consistently available through World Bank databases to allow comparative and empirical analysis.

Analysis of key indicators over 2000–2022 (World Development Indicators, 2026) shows several general trends. CO2 emission intensity remains substantially higher in Russia and Kazakhstan, reflecting the scale of their economies and energy intensity, while remaining comparatively low and stable in Armenia, Belarus and Kyrgyzstan. The share of renewable energy is highest in Kyrgyzstan due to active use of hydropower resources, moderate in Armenia and Belarus, and comparatively low in Kazakhstan and Russia. Access to basic sanitation services has improved across all five countries, with Belarus showing the highest levels. Access to safe drinking water has likewise improved everywhere, with the most notable gains recorded in Kyrgyzstan. The poverty rate has declined across the region, most sharply in Kyrgyzstan in the early 2000s before stabilizing, and more gradually in Kazakhstan, Belarus, Russia and Armenia. Forest area has remained comparatively stable, with Russia's vast forest cover far exceeding that of the other member states. GDP per capita and electricity consumption both show a rising trend across the region, driven by expanding economic activity, with Russia recording the highest absolute levels.

Taken together, these trends indicate that while social and economic indicators of quality of life are generally improving across the EAEU, this improvement is often accompanied by rising

environmental pressure, underlining the need for a further shift toward a sustainable development model focused on emission reduction and efficient use of natural resources.

4. DATA AND METHODOLOGY

This study analyzes the impact of the green economy on the sustainable development of the EAEU countries using panel data. The sample covers all five EAEU member states — Armenia, Belarus, Kazakhstan, Kyrgyzstan and Russia — over the period 2000–2022, resulting in a balanced panel of 115 country-year observations. The primary data source is the World Bank's World Development Indicators (WDI) database, supplemented by official EAEU statistics and national statistical agencies of the member states.

The dependent variable is the Human Development Index (HDI), a composite indicator reflecting quality of life, education and life expectancy, used to represent the level of sustainable development. The independent variables were selected on the basis of prior empirical literature and data availability, and include: CO2 emission intensity from stationary sources (L_CO2), electricity consumption (L_EC), the share of the population using basic sanitation services (SAN), access to safely managed drinking water (WATER), the poverty rate (POV_LIFE), GDP per capita (L_GDPPC), forest area (L_FOR), mean annual exposure to PM2.5 particulate matter (L_PM2.5), and the share of renewable energy in total final energy consumption (REN). Several variables with strongly differing scales were transformed logarithmically (prefix L_) to reduce distributional asymmetry and improve the reliability of the model's parameter estimates, while variables already expressed as percentages were retained in their original form.

The general panel regression model is specified as follows:

$$L_HDI_{it} = \beta 0 + \beta 1 L_CO2_{it} + \beta 2 L_EC_{it} + \beta 3 SAN_{it} + \beta 4 WATER_{it} + \beta 5 POV_LIFE_{it} + \beta 6 L_GDPPC_{it} + \beta 7 L_FOR_{it} + \beta 8 L_PM2.5_{it} + \beta 9 REN_{it} + \varepsilon_{it}$$

where HDI is the Human Development Index, β0 is the constant term, β1…β9 are the coefficients of the independent variables, εit is the error term, i denotes country and t denotes year.

Table 2. Descriptive Statistics of Panel Variables

Variable	Mean	Std. Dev.	Min.	Max.
L_HDI	0.763	0.059	0.627	0.847
L_FOR	2.430	1.370	0.132	3.908
L_CO2	2.485	1.852	-2.332	4.548
L_GDPPC	9.641	0.732	8.199	10.562
L_EC	4.811	0.267	4.267	5.398
SAN	92.829	5.029	81.650	99.688

Variable	Mean	Std. Dev.	Min.	Max.
WATER	77.404	11.670	46.414	92.982
REN	22.597	7.285	10.505	43.290
POV_LIFE	21.659	10.392	7.900	66.200

Note: N = 115 (5 countries × 23 years). Source: World Development Indicators (2026); author's calculations.

The descriptive statistics show that the mean HDI value across the EAEU countries over the study period is 0.763, indicating a relatively high average level of human development, while the poverty rate ranges from 7.9% to 66.2%, reflecting substantial social inequality between the member states. The wide range in GDP per capita and renewable energy shares similarly points to considerable heterogeneity in economic development and energy structure across the region, with Kyrgyzstan's high maximum renewable-energy value largely explained by intensive use of hydropower resources.

Before estimating the panel regression, a Pearson correlation analysis was conducted to check for multicollinearity among the independent variables. The results (not shown in full) indicate the strongest positive correlation between HDI and GDP per capita ($r \approx 0.95$) and between HDI and access to safe water ($r \approx 0.74$), while HDI correlates negatively with CO2 emission intensity ($r \approx -0.47$) and with the poverty rate ($r \approx -0.84$). To formally test for multicollinearity, Variance Inflation Factor (VIF) values were calculated for all explanatory variables. In the initial specification, the mean VIF was 5.07, with GDP per capita, access to water and the poverty rate showing moderate multicollinearity (VIF between 5 and 7). Since none exceeded the conventional threshold of 10 but WATER and POV_LIFE displayed the highest pairwise correlation with GDP per capita, these two variables were removed from the final specification. The revised mean VIF fell to 2.98, with all individual values below the threshold of 7, confirming that multicollinearity is no longer a concern in the final model (Table 3).

Table 3. Variance Inflation Factor (VIF) — Final Specification

Variable	VIF
L_CO2	3.25
L_FOR	3.21
SAN	3.21
REN	2.94
L_EC	2.75
L_GDPPC	2.54
Mean VIF	2.98

Source: Author's calculations.

Two standard panel estimators — fixed effects (FE) and random effects (RE) — were estimated for the final specification. The Hausman test was applied to determine the appropriate model, yielding Prob > chi2 = 0.0000, which rejects the null hypothesis of no correlation between individual effects and

the regressors. This confirms that the fixed-effects model is the methodologically appropriate choice. However, further diagnostic tests were required before finalizing the model. A modified Wald test for groupwise heteroscedasticity yielded Prob > chi2 = 0.0002, rejecting the null hypothesis of homoscedasticity. The Baltagi–Wu Locally Best Invariant (LBI) statistic (0.943, well below the threshold of 2) together with a Durbin–Watson statistic of 0.832 indicated the presence of first-order autocorrelation. Finally, the Breusch–Pagan LM test for cross-sectional dependence produced chi2(10) = 53.237 (p = 0.0000), confirming statistically significant cross-sectional dependence among the panel units.

Because the model exhibits heteroscedasticity, autocorrelation and cross-sectional dependence simultaneously, conventional robust or clustered standard errors would not fully correct the inference. Therefore, following Driscoll and Kraay (1998) and Hoechle (2007), the final model was estimated using Driscoll–Kraay standard errors, which are robust to all three problems and provide an appropriately corrected covariance matrix for the fixed-effects estimator.

5. EMPIRICAL RESULTS

Table 4 presents the results of the final fixed-effects model estimated with Driscoll–Kraay standard errors.

Table 4. Panel Regression Results (Fixed Effects, Driscoll–Kraay Standard Errors)

Independent Variable	Coefficient	P-value
L_CO2	-0.0056	0.020
L_FOR	0.2907	0.000
L_GDPPC	0.1374	0.000
SAN	0.0029	0.041
REN	0.0010	0.003
Constant	-2.5845	0.000

Dependent variable: L_HDI. Prob > F = 0.000; R^2 = 0.9675. **Source:** Author's calculations.

All explanatory variables are statistically significant at conventional levels ($p < 0.05$). The overall model is highly significant (Prob > F = 0.000) and explains approximately 96.8% of the variation in the Human Development Index across the panel ($R^2 = 0.9675$). The estimated model can be written as:

$$L_HDI_{it} = -2.585 - 0.0056 \cdot L_CO2_{it} + 0.0029 \cdot SAN_{it} + 0.1374 \cdot L_GDPPC_{it} + 0.2907 \cdot L_FOR_{it} + 0.0010 \cdot REN_{it} + \varepsilon_{it}$$

Holding other factors constant, a 1% increase in CO2 emission intensity is associated with an average 0.0056% decrease in the Human Development Index, confirming that environmental degradation exerts a statistically significant negative effect on sustainable development in the EAEU countries. This finding is consistent with the results of Işık, Simionescu and Ongan (2023).

A 1% increase in forest area is associated with an average 0.291% increase in HDI, indicating that the preservation and expansion of forest resources contributes positively to sustainable development. Similarly, a 1% increase in GDP per capita is associated with an average 0.137% increase in HDI, confirming the important role of economic well-being in raising the level of human development — a result consistent with the findings of Yunusova Ceviz (2025) and Qorraj, Gara and Fetai (2025).

A one-percentage-point increase in the share of the population with access to basic sanitation services is associated with an average 0.289% increase in HDI, highlighting the importance of social infrastructure. Finally, a one-percentage-point increase in the share of renewable energy in total final energy consumption is associated with an average 0.102% increase in HDI. This result is consistent with the findings of Susmaz and Sakar (2020) and Rahman and Sultana (2024), which likewise identified a positive relationship between renewable energy development and human development.

Overall, the empirical results confirm that the expansion of renewable energy use, improvements in energy and resource efficiency, and better environmental performance have a positive effect on the sustainable development of the EAEU countries, while rising carbon emission intensity works against it.

6. CONCLUSION

This study examined the impact of the green economy on the sustainable development of the EAEU countries, combining a theoretical review with an empirical panel-data analysis for 2000–2022. The theoretical section clarified the concept and principles of the green economy and its relationship with sustainable development, drawing on the experience of developed countries such as Germany, Denmark, Sweden, the Netherlands, the United States, South Korea and Japan. The review of the current state of green economy development in the EAEU countries showed that, despite differences in resource endowment, institutional capacity and economic structure, all member states are taking steps to integrate environmental objectives into their national development strategies, though at markedly different rates: Russia, Kazakhstan and Belarus display relatively higher levels of environmental modernization and energy efficiency, whereas Kyrgyzstan and Armenia still require further development of renewable energy and stronger institutional reform.

The empirical analysis, based on a balanced panel of five EAEU countries over 2000–2022 and estimated with Driscoll–Kraay standard errors to correct for heteroscedasticity, autocorrelation and cross-sectional dependence, confirmed that an increase in the share of renewable energy, improvements in energy efficiency and better environmental indicators have a statistically significant positive effect on sustainable development, while higher CO2 emission intensity has a significant negative effect. GDP per capita, forest area and access to basic sanitation likewise show significant positive effects on the Human Development Index.

The study concludes that the transition to a green economy in the EAEU countries strengthens long-term economic stability, reduces environmental risks and improves the population's quality of life. At the same time, several obstacles remain in the green transition process, including insufficient investment, technological deficiencies and institutional weaknesses. Based on these findings, several recommendations can be formulated: (1) developing environmental protection infrastructure, particularly expanding access to clean drinking water and quality sanitation, since these directly raise human development and quality of life; (2) strengthening cooperation among EAEU member states in the green economy sphere through joint environmental projects, exchange of green technologies and the development of green finance mechanisms; and (3) intensifying measures to reduce air pollution, including the implementation of stricter environmental standards for industrial facilities and the adoption of modern cleaning technologies. Overall, developing the green economy remains one of the principal directions for ensuring sustainable economic growth, reducing environmental risk and improving quality of life in the EAEU region, making continued interstate cooperation, increased green investment, and the introduction of innovative technologies and improved environmental policy essential conditions for achieving sustainable development.

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IS GREEN TRANSITION PREDICTIVE? A MACHINE LEARNING EVALUATION OF CARBON PRICE SPILLOVERS ON EUROPEAN EQUITY SECTORS

Onur POLAT*

ABSTRACT

This study examines whether EU Emissions Trading System (EU ETS) carbon prices can predict the conditional return distributions of European equity sectors by combining Quantile-on-Quantile Regression (QQR) with machine learning (ML) quantile forecasting. Using 3,858 daily observations from 2010 to 2025, we extract asymmetric dependence features from the QQR slope matrix and feed them into Random Forest (RF) and Gradient Boosting Machine (GBM) models to forecast sector return quantiles. ML models reduce Pinball Loss by 31–63% relative to linear Quantile Regression across Clean Energy, Utilities, and Energy sectors. The clean energy sector exhibits the highest predictability (~54% average improvement). GBM outperforms RF at tail quantiles, while RF dominates at the median. Rolling causality-in-quantiles tests reveal a post-2020 structural elevation in carbon's predictive content.

Keywords: *Carbon Pricing, EU ETS, Machine Learning, Quantile-on-Quantile Regression, Random Forest, Gradient Boosting, Green Transition.*

JEL Codes: *C32, C45, G17, Q54.*

1. INTRODUCTION

The transition to a low-carbon economy represents one of the most consequential structural shifts in global financial markets. Central to this transformation is the European Union Emissions Trading System (EU ETS), which has emerged as the world's largest carbon market and a critical policy instrument for internalizing the social cost of emissions. Since 2018, EU ETS carbon allowance prices have risen by more than 400%, fundamentally altering the cost structures of carbon-intensive industries while simultaneously enhancing the relative competitiveness of renewable energy technologies (Tiwari et al., 2022; Umar et al., 2022).

The transmission of carbon price shocks to financial asset returns is theoretically well established through two principal channels. The "cost channel" posits that rising allowance prices compress profit margins for fossil-fuel-dependent firms such as utilities and energy producers (Mo et al., 2012; Da Silva et al., 2016). Conversely, the "substitution channel" suggests that higher carbon prices improve the relative competitiveness of clean energy firms, thereby stimulating investment flows toward renewable assets (Kumar et al., 2012; Dutta, 2017). However, the empirical evidence on these transmission mechanisms has been mixed, partly because conventional econometric approaches such as Ordinary

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Least Squares (OLS) focus on mean-conditional relationships and fail to capture the asymmetric, nonlinear dynamics that characterize financial markets under different regimes.

The post-2020 period has introduced additional complexity. The COVID-19 pandemic, the subsequent recovery, and the 2021–2022 energy crisis driven by the Russia-Ukraine conflict have generated unprecedented volatility in European energy and carbon markets. These structural disruptions raise a fundamental question: has the informational content of carbon prices for equity returns evolved, and can machine learning methods exploit this structure more effectively than traditional linear models?

This study proposes a hybrid methodological framework that integrates QQR with machine learning quantile forecasting to address three research questions. First, can EU ETS carbon prices predict the conditional distribution of equity returns across clean and dirty sectors? Second, do machine learning models, specifically RF and GBM, outperform linear Quantile Regression (QR) across tail quantiles? Third, which features carry the most predictive information for sector-level return quantiles?

Our approach contributes to the literature in two key respects. First, rather than treating QQR solely as an analytical tool, we use the estimated slope coefficients $\beta_1(\theta,\tau)$ as engineered features for machine learning models, creating a bridge between econometric theory and predictive modelling. Second, by evaluating forecast accuracy through Pinball Loss, a proper scoring rule for quantile forecasts, across multiple quantiles and sectors, we provide a rigorous out-of-sample assessment of whether the asymmetric dependence structures identified by QQR translate into superior predictive performance.

The remainder of this paper is organized as follows. Section 2 reviews the relevant literature. Section 3 describes the data and methodology. Section 4 presents the empirical findings. Section 5 discusses the results and their implications. Section 6 concludes.

2. LITERATURE REVIEW

The relationship between carbon pricing and financial market performance has been examined from multiple perspectives. Early research focused on the cost channel, whereby rising carbon allowance prices reduce the profitability of carbon-intensive firms. Oberndorfer (2009) found that EU allowance price changes were positively correlated with electricity utility stock returns during the EU ETS pilot phase, suggesting effective cost pass-through to consumers. As the market matured, Mo et al. (2012) documented increasingly negative effects on corporate stock values as free allocations declined. Da Silva et al. (2016) demonstrated that carbon price volatility substantially increased the systematic risk of utility portfolios. Tian et al. (2016) applied a Markov-switching model and identified regime-dependent effects, with carbon prices exhibiting a strong negative correlation with oil and gas producers only in high-volatility regimes.

A parallel literature has examined the substitution channel, whereby higher carbon prices benefit renewable energy firms. Kumar et al. (2012) were among the first to document a positive relationship between clean energy stock indices and carbon pricing using a VAR framework. Dutta (2017) found unidirectional volatility spillovers from carbon to clean energy equity markets. Reboredo (2015) identified strong positive long-term coherence between carbon prices and renewable energy stocks using wavelet coherence. Lin and Chen (2019) observed that the correlation between carbon prices and new energy stocks increased following the introduction of the Market Stability Reserve.

A significant limitation of these studies is their reliance on mean-conditional methods, which obscure asymmetric market behavior under extreme conditions. Quantile-based approaches have addressed this gap. Sim and Zhou (2015) introduced QQR to model how specific quantiles of an explanatory variable affect the conditional quantiles of an outcome variable. Zhu et al. (2022) applied QQR to the carbon-finance nexus and found that positive carbon price shocks exert the greatest upward pressure on renewable stocks when both markets are bullish. Nguyen et al. (2020) demonstrated that the negative effect of carbon prices on high-emitting sectors is considerably more pronounced at lower stock return quantiles.

Recent studies have also documented structural breaks in the carbon-financial nexus, particularly following the 2020 pandemic and the 2022 energy crisis. Umar et al. (2022) applied time-varying Granger causality and found that carbon costs became the primary determinant of natural gas and power prices after the Russia-Ukraine conflict. Tiwari et al. (2022) identified a distinct crisis regime after 2021 with significantly negative correlations between carbon prices and the STOXX 600 index.

Despite these advances, the existing literature has not systematically evaluated whether the asymmetric dependence structures revealed by quantile-based methods can be exploited for out-of-sample prediction. Machine learning methods, particularly ensemble approaches such as Random Forest and Gradient Boosting, have demonstrated superior forecasting performance in financial applications (Gu et al., 2020), yet their application to carbon-equity quantile forecasting remains unexplored. This study addresses this gap by integrating QQR feature extraction with ML quantile forecasting.

3. DATA AND METHODOLOGY

3.1. Data

The dataset comprises 3,858 daily observations spanning from 2010 to 2025, covering three major market phases: pre-2020 stability, the COVID-19 pandemic shock, and the 2021–2022 energy crisis. The primary independent variable is the EU ETS carbon price, representing emission allowance prices. Four dependent variables capture distinct segments of European financial markets: the S&P Global Clean Energy Price Index (clean energy sector), the STOXX Europe 600 Utilities Price Index (conventional power generation), the STOXX Europe 600 Energy Price Index (fossil-fuel-based

energy), and the STOXX Europe 600 Price Index (broad market). All series are transformed into logarithmic returns: r*t* = ln(P*t*/P*t-1*) × 100.

Table 1. Summary Statistics of Log-Returns

Statistic	EU ETS Carbon	Utilities	Energy	Clean Energy	STOXX 600
Mean	0.00042	0.00006	0.00005	0.00002	0.00019
Variance	0.00092	0.00016	0.00021	0.00021	0.00010
Skewness	−0.824***	−1.009***	−0.767***	−0.229***	−0.903***
Kurtosis	15.695***	12.302***	16.169***	5.248***	10.277***
JB Test	40082***	25014***	42455***	4468***	17525***
ERS Stat	0.017	0.026	0.027	0.019	0.036
Q(20)	110.6***	48.6***	74.6***	102.9***	46.2***

Notes: ***, **, * represent 1%, 5%, and 10% significance levels. JB: Jarque-Bera (1980) normality test. ERS: Elliott et al. (1996) unit-root test. Q(20): Ljung-Box portmanteau test at lag 20.

Table 1 presents the descriptive statistics for the return series. All variables exhibit negative skewness and excess kurtosis, indicating leptokurtic distributions with frequent extreme observations. Carbon returns have the highest variance (0.00092), identifying the carbon market as the largest risk source in the system. The Jarque-Bera test rejects normality at the 1% level for all series, while the ERS test confirms stationarity. These distributional properties, particularly the fat tails and asymmetry, justify the use of quantile-based methods rather than OLS.

3.2. Quantile-on-Quantile Regression

The QQR approach of Sim and Zhou (2015) extends quantile regression by enabling the examination of how specific quantiles of an explanatory variable affect the conditional quantiles of an outcome variable. The θ-quantile of the dependent variable y is modelled as a function of the independent variable x:

$$y_t = \beta^R(x_t) + \varepsilon_t^R \qquad (1)$$

To analyze the relationship between the θ-quantile of y and the τ-quantile of x, a first-order Taylor expansion linearizes the function $\beta^R(x_t)$ around xτ:

$$\beta^R(x_t) \approx \beta_0(\theta,\tau) + \beta_1(\theta,\tau)(x_t - x\tau) \qquad (2)$$

The resulting slope coefficients $\beta_1(\theta,\tau)$ form a matrix that captures how each quantile of carbon price returns affects each quantile of sector returns, providing a three-dimensional characterization of market dependence.

3.3. Machine Learning Quantile Forecasting

The key innovation of this study is to use the QQR slope matrix as a feature engineering device for machine learning models. For each observation, we map the carbon return and sector return to their respective empirical quantile positions (τ and θ) and extract the corresponding $\beta_1(\theta,\tau)$ coefficient from the estimated QQR surface. The complete feature set comprises 17 variables: the $\beta_1(\theta,\tau)$ slope, τ and θ quantile positions, 5 lagged carbon returns, 5 lagged sector returns, and 5-day rolling realized variance for both carbon and sector returns.

Two ensemble machine learning models are employed for quantile forecasting: RF generates quantile predictions by retaining the per-tree prediction distributions from 500 trees, with quantile estimates derived from the empirical distribution of individual tree forecasts. GBM directly optimizes the quantile loss function (also known as Pinball Loss or check function) across 1,000 trees, producing forecasts that minimize quantile-specific prediction errors.

Forecast accuracy is evaluated using Pinball Loss, a proper scoring rule for quantile forecasts defined as:

$$L(y, \hat{y}, \tau) = \tau(y - \hat{y}) \text{ if } y \geq \hat{y}, \text{ else } (\tau - 1)(y - \hat{y}) \quad (3)$$

Lower Pinball Loss indicates superior forecast accuracy. Models are evaluated at five quantiles: $\tau \in \{0.10, 0.25, 0.50, 0.75, 0.90\}$. A linear Quantile Regression serves as the benchmark. A 60/40 temporal train/test split preserves the time-series ordering.

3.4. Rolling Quantile Causality

The nonparametric causality-in-quantiles test of Balcilar et al. (2016) is employed within a 200-day rolling window (step = 5 days) to assess time-varying predictability of carbon prices for each sector's return distribution. The null hypothesis of no Granger causality at quantile τ is tested against the alternative that carbon prices contain predictive information at the specified quantile. The test statistic follows a $\chi^2(1)$ distribution with critical values of 3.841 (5%) and 2.706 (10%).

4. FINDINGS

4.1. QQR Results

The QQR slope coefficient surfaces reveal pronounced sectoral heterogeneity in how financial markets price carbon risk. The Brent Oil surface exhibits a predominantly positive dependence with asymmetric tail behavior. The highest slope coefficients appear in the upper quantiles of both variables, supporting the demand-pull hypothesis: during periods of strong economic activity, demand for both fossil fuels and emission allowances rise simultaneously. The relatively flat surface in the median quantiles indicates that under normal market conditions, idiosyncratic supply factors dominate.

The STOXX 600 surface displays a quasi-planar topography, with slope coefficients remaining within a narrow range near zero across the entire quantile grid. This flatness supports the portfolio diversification hypothesis: opposing sectoral shocks from carbon-intensive and low-carbon firms offset each other at the index level. The broad market exhibits stochastic neutrality to carbon pricing under normal conditions.

In contrast, the Clean Energy Index surface exhibits pronounced convexity with steeply positive slope coefficients, particularly in the upper-right quadrant where extreme carbon price quantiles coincide with strong clean energy returns. This pattern provides robust support for the substitution hypothesis. Elevated carbon prices serve as credible policy signals, reinforcing the long-term viability of green technologies and encouraging capital reallocation toward renewable assets during bullish market regimes.

The Utilities Index surface shows a pronounced concave topography with consistently negative slope coefficients, indicating that higher carbon prices impose an immediate negative supply shock on traditional utilities. The persistent negativity even in upper quantiles demonstrates that carbon risk imposes a structural constraint on the sector's upside potential, functioning as a systematic tax on equity valuation.

4.2. Machine Learning Performance

Table 2 presents the Pinball Loss comparison across all sectors, quantiles, and models. Both RF and GBM substantially outperform linear QR at every sector-quantile combination, with improvement rates ranging from 31.4% to 62.9%.

Table 2. Quantile-Level Pinball Loss Comparison

Sector	τ	QR	RF	GBM	Best ML	Impr. (%)
Clean Energy	0.10	0.002925	0.001350	0.001299	GBM	55.6
	0.25	0.004647	0.002385	0.002450	RF	48.7
	0.50	0.005687	0.002938	0.003049	RF	48.3
	0.75	0.004820	0.002231	0.002334	RF	53.7
	0.90	0.003083	0.001180	0.001144	GBM	62.9
Utilities	0.10	0.002061	0.001215	0.001215	RF	41.1
	0.25	0.003446	0.002218	0.002261	RF	35.6
	0.50	0.004250	0.002836	0.002898	RF	33.3
	0.75	0.003482	0.002191	0.002219	RF	37.1

	0.90	0.002074	0.001136	0.001105	GBM	46.7
Energy	0.10	0.002598	0.001481	0.001585	RF	43.0
	0.25	0.004133	0.002691	0.002825	RF	34.9
	0.50	0.004989	0.003424	0.003538	RF	31.4
	0.75	0.004252	0.002665	0.002702	RF	37.3
	0.90	0.002759	0.001446	0.001415	GBM	48.7

Notes: Bold indicates the best-performing model at each quantile. Improvement = (QR – best ML) / QR × 100. RF: Random Forest (500 trees). GBM: Gradient Boosting Machine (1,000 trees, quantile distribution).

The clean energy sector exhibits the highest average ML improvement (~54%), consistent with its stronger regime-sensitivity to carbon pricing. At the extremes of the return distribution, GBM systematically outperforms RF: at the 10th and 90th percentiles, GBM achieves the lowest Pinball Loss for all three sectors. This pattern suggests that gradient boosting's sequential error-correction mechanism better captures the asymmetric loss structure at distributional tails, which is critical for climate risk management applications. In contrast, RF performs best at the median and interquartile range, indicating that bagging's variance reduction provides superior point estimates under moderate market conditions.

4.3. Feature Importance Analysis

GBM feature importance analysis reveals a consistent pattern across all three sectors. The dominant predictor is the θ-quantile position (theta quantile), which accounts for 80–88% of total variable importance. This finding indicates that the model's primary learned structure is that the current market regime—specifically, where in the return distribution the observation falls—matters more than any single predictor. Recent realized variance (rv5_sector) is the second most important feature, contributing 5–12% of importance and confirming that short-run volatility clustering persists across all sectors.

Carbon price returns and their lagged values contribute modestly but consistently (0.5–1.3% each), confirming that the carbon signal provides incremental predictive content beyond realized variance and regime identification. The QQR-derived $\beta_1(\theta,\tau)$ slope feature contributes at similar levels, suggesting that the asymmetric dependence structure captured by QQR provides additional information that the ML model exploits, albeit as one component within a richer feature set.

4.4. Rolling Quantile Causality Results

The rolling causality-in-quantiles analysis reveals an important nuance. Test statistics remain below the 5% critical value of 3.841 across all sectors and periods, indicating that formal Granger causality from carbon prices to sector returns is not rejected at conventional significance levels.

However, a consistent post-2020 elevation of 9–15% in test statistics is observed across all sectors, suggesting an emerging structural shift in carbon-sector linkages.

This elevation aligns temporally with the 2021–2022 energy crisis period, during which carbon prices rose sharply and became more closely integrated with energy market dynamics. The pattern suggests that while the carbon signal has not yet achieved formal statistical significance in the Granger causality framework, its informational content is increasing. This finding motivates the machine learning approach adopted in this study: even sub-threshold causality may contain exploitable predictive structure that nonlinear models can capture, as evidenced by the substantial Pinball Loss improvements documented in Table 2.

5. DISCUSSION

The empirical results support several key conclusions regarding the evolving role of carbon pricing in European financial markets. The QQR analysis confirms the theoretical predictions of the cost channel and substitution channel hypotheses but reveals that these mechanisms operate asymmetrically and are regime-dependent. Carbon pricing does not simply shift average returns; rather, its effects are concentrated in specific quantile regions, particularly the tails, where risk management decisions are most consequential.

The substantial outperformance of ML models over linear QR has important methodological implications. The 31–63% reduction in Pinball Loss demonstrates that the relationship between carbon prices and equity returns contains significant nonlinear structure that linear models fail to capture. The finding that the clean energy sector is most predictable (~54% average improvement) is consistent with the stronger and more systematic dependence structure revealed by the QQR analysis for this sector. The superiority of GBM at tail quantiles suggests that practitioners focused on tail risk—including value-at-risk estimation and climate stress testing—should prioritize gradient boosting approaches.

The feature importance results provide insight into the mechanisms driving predictability. The dominance of the θ-quantile position suggests that the model's primary contribution is regime identification: distinguishing between bull and bear market states and adjusting predictions accordingly. The incremental contribution of carbon-specific features confirms that carbon pricing provides predictive content beyond what can be inferred from the market regime alone, albeit as a secondary factor relative to realized variance and distributional positioning.

The rolling causality results present a nuanced picture. The absence of formal Granger causality at the 5% level contrasts with the strong out-of-sample predictability documented in the ML analysis. This apparent contradiction suggests that the linear causality framework may lack sufficient power to detect the nonlinear, regime-dependent predictability that ML models exploit. The consistent post-2020 elevation in test statistics indicates that this predictive structure is strengthening, warranting continued monitoring as carbon markets mature.

6. CONCLUSION

This study demonstrates that EU ETS carbon prices contain significant predictive information for the conditional return distributions of European equity sectors, and that machine learning methods can exploit this information far more effectively than conventional linear approaches. By integrating QQR-based feature extraction with RF and GBM quantile forecasting, we document Pinball Loss reductions of 31–63% across clean energy, utilities, and energy sectors. The clean energy sector emerges as the most predictable, with an average ML improvement of approximately 54%, while GBM demonstrates particular strength at tail quantiles, a critical advantage for risk management applications.

For institutional investors, these findings suggest that EU ETS carbon prices should be treated as a systematic input to quantile-based climate risk models rather than merely a sectoral cost variable. The substantial tail predictability documented here implies that carbon price dynamics can enhance value-at-risk and expected shortfall estimates for portfolios with European equity exposure. For policymakers, the results confirm that the EU ETS exerts measurable and asymmetric effects on financial markets, with the substitution channel operating most strongly during bullish regimes. The emerging structural shift detected in the rolling causality analysis suggests that the financial-market relevance of carbon pricing is increasing over time.

Several avenues for future research emerge from this analysis. The methodological framework could be extended to other major carbon markets, such as China's ETS, to assess whether the predictive structures identified here are global in scope. Additionally, investigating the efficacy of carbon futures and green derivatives in hedging the sector-specific risks documented in the QQR analysis could provide valuable tools for portfolio construction. Finally, incorporating additional macroeconomic and geopolitical features into the ML framework may further enhance forecasting performance.

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THE RELATIONSHIP BETWEEN RENEWABLE ENERGY CONSUMPTION, UNEMPLOYMENT, AND INFLATION IN GREECE

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ABSTRACT

In recent years, growing global concerns about climate change, environmental degradation, and the depletion of fossil fuel resources have prompted countries to shift their focus to renewable energy sources. During this process, investments in renewable energy have gained importance not only in terms of environmental sustainability but also in terms of macroeconomic indicators such as economic growth, employment, and price stability. Green transition policies, particularly those implemented in Europe, have made the impact of the energy sector on the economic structure more visible. Greece, a member of the European Union, is prioritizing renewable energy policies to reduce energy dependence, lower carbon emissions, and support sustainable growth. Energy investments have become a key policy tool during the country's economic recovery, particularly after the 2008 crisis. This study investigates the relationship between energy consumption, unemployment, and inflation in Greece. For this purpose, annual time series data from 1981 to 2024 are examined using econometric methods based on the Fourier approximation, which accounts for both sharp and smooth structural breaks. The Fourier ADF unit root test results show that all three variables become stationary after first differencing, indicating the presence of a unit root at the level. Findings from the Fourier ADL cointegration test reveal that macroeconomic indicators influence renewable energy. Accordingly, a one-unit increase in renewable energy consumption increases the unemployment rate by 0.28 units, while a one-unit increase in inflation decreases the unemployment rate by 0.37 units; meanwhile, a one-unit increase in renewable energy consumption decreases inflation by 0.83 units, while a one-unit increase in the unemployment rate decreases inflation by 0.35 units. On the other hand, inflation and unemployment are found to have no statistically significant impact on renewable energy consumption. In conclusion, increased investment in renewable energy leads to higher unemployment while contributing to lower inflation. Therefore, it is important for policymakers to support the green transition with active labor market policies and reskilling programs to minimize job losses.

Keywords: *Renewable Energy, Unemployment, Inflation, Greece.*

JEL Codes: *E24, E31, Q43.*

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1. INTRODUCTION

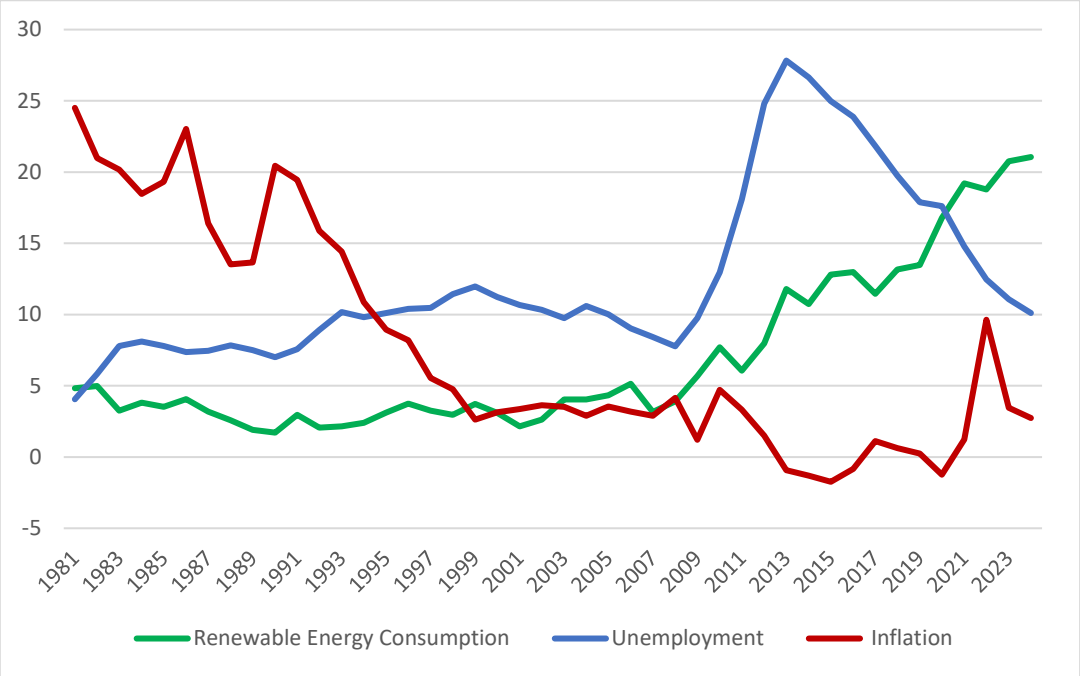
In recent years, with the increasing depletion of fossil fuel resources and the serious environmental pollution problem, countries worldwide have been compelled to accelerate the transition of their energy sectors towards cleaner and more sustainable alternatives (Pham et al., 2026). In this process, renewable energy sources have become a strategic element not only in ensuring environmental sustainability but also in supporting economic and social development. Expanding the use of renewable energy sources such as solar, wind, hydroelectric, and biomass contributes to reducing greenhouse gas emissions while also offering significant opportunities to reduce dependence on energy imports, strengthen energy supply security, and support sustainable growth. Therefore, many countries consider energy transformation as a fundamental component of their long-term development strategies.

Increased investments in renewable energy directly and indirectly affect not only the energy sector but also macroeconomic indicators. The impacts on key indicators such as employment, unemployment, inflation, and economic growth have been extensively discussed in academic literature in recent years. While some argue that the renewable energy sector supports the labor market by creating new employment opportunities (Khobai, 2020), others suggest that the transformation in the production structure, inter-sectoral labor transfers, and technology-intensive production processes may lead to varying employment outcomes (Yılancı et al., 2020; Saboori et al., 2022). Similarly, the effects of renewable energy on the general price level vary depending on the country (Chung and Kim, 2024) and the time period (Deka and Dube, 2021).

Over recent years, Greece has made significant progress in renewable energy thanks to policies and investments aimed at transforming its energy sector. In line with its goals of reducing dependence on fossil fuels, increasing energy supply security, and lowering greenhouse gas emissions, the country has prioritized the utilization of solar and wind energy resources. National energy and climate plans, prepared in line with the European Union's climate and energy policies, have encouraged renewable energy investments and ensured a steady increase in the share of renewable sources in electricity production.

Among European countries, Greece has established a substantial share of renewable energy within its energy portfolio while pursuing ambitious policies to achieve carbon neutrality by 2050. In addition, renewable energy technologies enjoy broad public support across the country (Ioannidis et al.,2023). Thanks to its geographical location, high sunshine hours, favorable wind potential, and island structure, Greece possesses significant advantages for the implementation of renewable energy technologies.

Figure 1. Renewable Energy Consumption, Unemployment, and Inflation in Greece



Source: OWID, 2026; IMF, 2026; WB, 2026.

Figure 1 shows renewable energy, unemployment, and inflation rates in Greece between 1981 and 2024. It is noteworthy that renewable energy consumption has been on an upward trend, especially since the 2008 global crisis. The unemployment rate peaked in 2013 due to the impact of the global crisis and the European debt crisis, and has since declined steadily. Inflation generally tends to fall, and even experiences deflationary trends for a few years. The deflationary trend is largely due to fiscal austerity policies (Mastromatteo and Rossi, 2015). In recent years, an increase has only been seen due to the Covid-19 pandemic.

This study aims to contribute to the literature by analyzing the relationship between renewable energy consumption, unemployment, and inflation in the case of Greece using current econometric methods based on the Fourier approach. Its distinctive features include the use of Fourier-based methods, which allow for the modeling of both abrupt and smooth transitions in structural changes, and the analysis conducted with a current dataset covering the period 1981–2024. The findings are expected to contribute to a better understanding of the macroeconomic impacts of renewable energy policies in the green transition process and to guide policy designs that consider energy, employment, and price stability simultaneously. The study begins with a review of the relevant literature. Following this, the dataset, variables, and econometric method used in the research are introduced. The empirical findings are presented and evaluated. Finally, the results are summarized, policy recommendations are developed based on the findings, and considerations for future research are provided.

2. LITERATURE REVIEW

Several studies exist in the literature examining the relationship between renewable energy and unemployment. Some have yielded mixed results. Yılancı et al. (2020) examined 12 selected countries for the period from 1995 to 2016. Findings from the FADL cointegration test showed that renewable energy consumption increased unemployment in 3 countries and decreased it in 5 countries. Saboori et al. (2022) studied 51 US states for the period 1977-2017. While the fixed effects model suggests that renewable energy reduces unemployment, the Seemingly Unrelated Regression Equations (SURE) model shows that renewable energy increases unemployment in 20 states.

Some studies have found a positive correlation between these variables. Apergis and Salim (2015) examined 80 selected countries for the period 1990-2013 using nonlinear panel causality and cointegration tests. Their findings showed that renewable energy increases unemployment. Furthermore, the importance of the cost of adopting renewable energy technologies and their efficiency levels is emphasized. Rafiq et al. (2018) employed the Westerlund panel cointegration test for 41 selected countries over the 1980-2014 period and found similar results.

On the other hand, the study by Zhao and Luo (2017) investigated the period from 1978 to 2013 in China. Similarly, Xolmurodov et al. (2025) analyzed Uzbekistan for the period 2000–2022. In these studies, which employed the ARDL bounds test approach, it was found that renewable energy increased employment and decreased unemployment, respectively. Tsaurai (2022) evaluated 5 African countries for the period 1992-2019, while Omarova et al. (2025) evaluated 8 selected developed countries for the period 2000-2023. These studies, which used the fixed effects model, reached similar findings.

There are also studies focusing on the relationship between renewable energy and inflation. Some have found an inverse relationship between these variables. Durani et al. (2025) studied China for the period 1990-2021 using the Wavelet quantile correlation approach. The findings revealed that inflation reduces renewable energy consumption in the short, medium, and long term. Kusuma et al. (2025) investigated the period from 1990 to 2022 for Indonesia using the Engle-Granger cointegration test. They argued that renewable energy supports price stability. Cornejo et al. (2025) examined 18 Latin American and Caribbean countries for the period from 2005 to 2021. The findings showed that renewable energy reduces the impact of global energy price volatility on local inflation. Akusta (2026) analyzed Türkiye through the ARDL bounds test approach. The study, which examined the period from 1980 to 2022, revealed that renewable energy supports price stability both directly and indirectly.

Some studies have determined that the variables mentioned move in the same direction. The study by Arslan and Yıldız (2022) examined 20 European Union countries for the period 1985-2018 using the Westerlund panel cointegration test. Test results showed that the use of renewable energy increases inflation in the long term, but has no effect in the short term. Zhang et al. (2024) analyzed G7 countries using the MM-QREG technique and Dynamic GMM. Their study, covering the years 1997-2021, found that renewable energy production and consumption led to inflation. Other studies have obtained similar

findings using the ARDL bounds test approach. Deka and Dube (2021) analyzed Mexico for the period 1990-2019 and found a bidirectional positive relationship between the variables. Deka et al. (2022) examined Brazil for the period 1990-2019 and stated that inflation encouraged the use of renewable energy. Kushawaha et al. (2026) examined India for the period 1974-2023 and observed that renewable energy led to energy inflation.

3. DATA SET AND METHODOLOGY

This study investigates the effects of renewable energy consumption on unemployment and inflation rates in Greece. Renewable energy consumption data are obtained from Our World in Data (OWID), unemployment rate data from the International Monetary Fund (IMF), and inflation rate data from the World Bank (WB) (OWID, 2026; IMF, 2026; WB, 2026). The annual time series covers the years from 1981 to 2024 and consists of 44 observations.

To test for the existence of a cointegration relationship between the series, the Fourier ADL method recommended by Banerjee et al. (2017) is used. This method is known as an improved version of the ADL cointegration test introduced by Banerjee et al. (1998). Fourier functions allow us to account for breaks with an undefined time, number, and structure. Furthermore, because no dummy variables are used, there is no power loss, and it provides powerful results even in small sample sizes (Alola and Adebayo, 2023). In line with this, the following equations have been estimated:

$$UNE_t = \alpha_0 + \alpha_1 sin\left(\frac{2\pi k^* t}{T}\right) + \alpha_2 cos\left(\frac{2\pi k^* t}{T}\right) + \alpha_3 UNE_{t-1} + \alpha_4 REN_{t-1} + \alpha_5 INF_{t-1} + \alpha_6 \Delta UNE_{t-1} + \alpha_7 \Delta REN_{t-1} + \alpha_8 \Delta INF_{t-1} + e_t \quad (1)$$

$$INF_t = \beta_0 + \beta_1 sin\left(\frac{2\pi k^* t}{T}\right) + \beta_2 cos\left(\frac{2\pi k^* t}{T}\right) + \beta_3 INF_{t-1} + \beta_4 REN_{t-1} + \beta_5 UNE_{t-1} + \beta_6 \Delta INF_{t-1} + \beta_7 \Delta REN_{t-1} + \beta_8 \Delta UNE_{t-1} + \varepsilon_t \quad (2)$$

$$REN_t = \gamma_0 + \gamma_1 sin\left(\frac{2\pi k^* t}{T}\right) + \gamma_2 cos\left(\frac{2\pi k^* t}{T}\right) + \gamma_3 REN_{t-1} + \gamma_4 UNE_{t-1} + \gamma_5 INF_{t-1} + \gamma_6 \Delta REN_{t-1} + \gamma_7 \Delta UNE_{t-1} + \gamma_8 \Delta INF_{t-1} + \zeta_t \quad (3)$$

Equations (1), (2), and (3) present the models where *UNE*, *INF*, and *REN* are the dependent variables, respectively. Here, *UNE* represents the unemployment rate, *INF* the inflation rate, *REN* renewable energy consumption, e_t, ε_t, and ζ_t error terms, *sin* and *cos* trigonometric terms, *k* frequency value, *t* trend, and *T* sample size.

For Model 1 $\alpha_3 = 0$; for Model 2 $\beta_3 = 0$; and for Model 3 $\gamma_3 = 0$ the null hypotheses stating that the series are not cointegrated are tested. The following equation is used to calculate the test statistics:

$$t_{ADL}^F = \frac{\hat{\alpha}_3}{se(\hat{\alpha}_3)}, \quad t_{ADL}^F = \frac{\hat{\beta}_3}{se(\hat{\beta}_3)}, \quad t_{ADL}^F = \frac{\hat{\gamma}_3}{se(\hat{\gamma}_3)} \quad (4)$$

Here, $\hat{\alpha}_3$, $\hat{\beta}_3$, $\hat{\gamma}_3$ refer to the ordinary least squares estimator of α_3, β_3, γ_3 and $se(_{\hat{\alpha}_3})$, $se(_{\hat{\beta}_3})$, $se(_{\hat{\gamma}_3})$ refer to the standard error of $\hat{\alpha}_3$, $\hat{\beta}_3$, $\hat{\gamma}_3$. If the calculated value is greater than the table value, the null hypothesis is rejected, and the series are considered cointegrated.

4. FINDINGS

The stationarity of the series is examined using the Fourier ADF unit root test introduced by Enders and Lee (2012). The results are reported in Table 1.

Table 1. FADF Unit Root Test Results

Variables	k	Min SSR	F Statistic	Lag	FADF Test Statistic	ADF Test Statistic
REN	5	63.06923	3.027641	2	2.818765	2.328685
UNE	3	97.72866	1.348001	2	-1.595114	-2.601095
INF	1	263.7767	0.477102	9	-1.431422	-2.179689
DREN	1	61.22258	4.490385	1	-6.111529*	-6.809103*
DUNE	3	57.27261	1.713716	1	-3.374493**	-3.347779**
DINF	3	289.9018	4.078537	6	-1.362659	-7.023994*

Note: * and ** show significance at the 1% and 5% levels, respectively.

Table 1 presents the results of the Fourier ADF (FADF) unit root test for the variables. When the F-statistics are examined, it is seen that the trigonometric terms are not statistically significant. Therefore, the traditional ADF test results were used in the stationarity analysis. According to the ADF test results, renewable energy consumption (REN), unemployment rate (UNE), and inflation (INF) variables contain unit roots at their level values and are not stationary. Therefore, the same procedure was repeated by taking the first differences of the variables. Since the F-test results for the first differences also showed that the trigonometric terms were not significant, the evaluations were again made according to the traditional ADF test results. The findings show that all series become stationary when the first differences are taken. Therefore, it has been determined that all variables are integrated at the I(1) level, and the application of the FADL cointegration test is deemed appropriate. The test results are presented in Table 2.

Table 2. FADL Cointegration Test Results

Dependent Variable	Independent Variables		Optimal k	Minimum AIC	FADL Test Stat.
UNE (1)	REN (2)	INF (1)	2	3.065334	-3.919532***
INF (1)	REN (2)	UNE (1)	1	4.592891	-4.741833**
REN (2)	UNE (1)	INF (1)	5	3.274431	2.148206

Note: ** and *** show significance at the 5% and 10% levels, respectively. The lag length is restricted to a maximum of 3. The optimal number of lags is determined according to the AIC. The values in parentheses indicate the lag length.

Table 2 presents the results of the FADL cointegration test. Examining the findings, it is observed that in the first model, where the dependent variable is the unemployment rate (UNE), and the second

model, where the dependent variable is inflation (INF), a long-term cointegration relationship exists between the variables. This result indicates that renewable energy consumption, unemployment rate, and inflation variables move together in the long run in these models. In contrast, no cointegration relationship was found in the third model, where the dependent variable is renewable energy consumption (REN). Therefore, it is not possible to speak of a long-term equilibrium relationship between the variables in this model. Based on these findings, the estimation of long-term coefficients continues only for the first two models where a cointegration relationship was detected. The results are reported in Table 3.

Table 3. FMOLS Estimations

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Dependent Variable: UNE				
REN	0.276896**	0.130223	2.126319	0.0400
INF	-0.365467*	0.100465	-3.637752	0.0008
C	13.74557*	1.500075	9.163256	0.0000
SIN	-0.129422	0.980046	-0.132057	0.8956
COS	-2.942298*	0.886097	-3.320513	0.0020
Dependent Variable: INF				
REN	-0.825743*	0.121279	-6.808652	0.0000
UNE	-0.347600*	0.099297	-3.500588	0.0012
C	17.43280*	1.462957	11.91614	0.0000
SIN	1.337090	0.962282	1.389499	0.1728
COS	7.649985*	0.757757	10.09557	0.0000

Note: * and ** show significance at the 1% and 5% levels, respectively. The lag length is restricted to a maximum of 3. The optimal number of lags is determined according to the AIC.

According to Table 3, the estimated coefficients are statistically significant. A 1-unit increase in REN increases UNE by 0.28 units, while a 1-unit increase in INF decreases UNE by 0.37 units, indicating that both variables have a meaningful impact on UNE. For INF as the dependent variable, a 1-unit increase in REN decreases INF by 0.83 units, while a 1-unit increase in UNE decreases INF by 0.35 units. Overall, the results show that REN has a positive effect on UNE and a negative effect on INF, while UNE is also negatively associated with INF.

5. CONCLUSION

Renewable energy has become not only an environmental policy tool but also a crucial element affecting key macroeconomic indicators such as employment and price stability. In Greece, a member of the European Union, the green transition process is a structural policy priority aimed at reducing dependence on fossil fuels, increasing energy diversification, and promoting sustainable growth. In this context, analyzing the macroeconomic impacts of renewable energy consumption is critical for policy design.

This study examines the relationship between renewable energy consumption, unemployment, and inflation using econometric methods based on the Fourier approach for the period 1981-2024. The findings indicate that renewable energy consumption has a positive effect on unemployment and a negative effect on inflation. The findings of this study support Cornejo et al. (2025) Kusuma et al. (2025), and Akusta (2026), who argue that renewable energy promotes price stability, in contrast to Deka and Dube (2021), Arslan and Yıldız (2022), and Zhang et al. (2024), who found that renewable energy leads to inflation. In addition, it supports Apergis and Salim (2015) and Rafiq et al. (2018), who state that renewable energy causes unemployment, in contrast to Omorova et al (2025), Tsaurai (2022) and Xolmuratov et al. (2025), who claim that renewable energy reduces unemployment.

The results show that renewable energy consumption has a mitigating effect on inflation and an increasing effect on unemployment. From an inflationary perspective, this result suggests that increased renewable energy use strengthens energy supply security, reduces production costs in the medium and long term, and alleviates cost pressures on the general price level by supporting supply-side capacity. In this context, renewable energy investments are considered to contribute to price stability by supporting macroeconomic stability through the supply-side channel.

Conversely, the high-technology and capital-intensive production structure of the renewable energy sector can lead to a decrease in demand, particularly for low and medium-skilled labor, potentially increasing unemployment rates. Rather than increasing direct government intervention in the market, it could be argued that the government should focus on increasing flexibility in the labor market, facilitating cross-sectoral integration of workers, and prioritizing reskilling programs to reduce the adaptation costs arising from the green transition process. However, it should be noted that this effect is not homogeneous across the entire economy, and the impact of renewable energy investments on employment may vary depending on the labor intensity of the sectors, the level of technological transformation, and the skill structure of the workforce. Therefore, examining the effects of renewable energy consumption on employment at the sectoral level will contribute to a more accurate interpretation of the findings.

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COMPARATIVE ANALYSIS OF AI REGULATION IN CHINA AND EURASIAN COUNTRIES: IMPLICATIONS FOR TRADE AND ECONOMIC ENGAGEMENT

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ABSTRACT

This article presents a comparative analysis of the artificial intelligence regulatory frameworks in the People's Republic of China and key Eurasian states, specifically Kazakhstan and Russia, examining their implications for international trade and economic engagement. It argues that governance of AI is a fundamental manifestation of divergent political philosophies and socio-economic priorities, leading to significant market fragmentation. China's paradigm is characterized by a mature, state-centric model that strategically subordinates technological development to objectives of national rejuvenation, digital sovereignty, and regime security, creating a cohesive but insular ecosystem. In contrast, Eurasian states exhibit strategic hybridity: Kazakhstan's legislative approach adapts EU-inspired risk-based structures to local contexts emphasizing state-led development, while Russia employs strategic ambiguity and experimental tools like regulatory sandboxes to pursue technological autarky. The analysis reveals that core incompatibilities in data governance, risk calculus, and ethical imperatives act as substantial non-tariff barriers, complicating cross-border data flows, collaborative R&D, and supply chain integration. Furthermore, these regulatory divergences are intensified by geopolitical contestation, instrumentalizing technology policy as economic statecraft and forcing Eurasian states into a precarious balancing act between major normative powers. The study concludes that the global AI governance landscape is moving toward enduring pluralism rather than convergence, necessitating pragmatic multilateral dialogue, technical cooperation, and adaptive business strategies to navigate fragmentation and foster sustainable economic engagement in the AI age.

Keywords: *AI Regulation, China-Eurasia Comparison, Digital Sovereignty, Regulatory Fragmentation, Trade Barriers.*

JEL Codes: *O33, F13, P26.*

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1. INTRODUCTION

The governance of artificial intelligence (AI) has swiftly ascended to the forefront of global policy agendas, evolving from a speculative discourse into a concrete pillar of national strategy, economic planning, and societal oversight. As AI technologies permeate every sector—from healthcare and finance to national security and public administration—their dual potential as engines of unprecedented growth and as sources of profound disruption necessitates robust regulatory intervention. This imperative is universally acknowledged, yet the paths nations choose diverge significantly, reflecting deep-seated differences in political philosophy, economic models, and cultural values. These divergent regulatory landscapes do not exist in isolation; they actively shape the terrain of international commerce, investment flows, and technological collaboration (Sheehan, 2023). In an increasingly interconnected yet geopolitically fragmented world, understanding these regulatory architectures—particularly those emerging from major powers and strategically pivotal regions—is critical for navigating the future of global trade and economic engagement. This article undertakes a comparative analysis of AI regulation in the People's Republic of China and selected Eurasian states, with a focused examination of Kazakhstan and Russia, to illuminate how distinct governance frameworks are constructed, the priorities they enshrine, and the complex challenges they pose for cross-border economic integration (Filipova, 2024a).

The selection of China and Eurasian nations as comparative subjects is particularly instructive. China represents a paradigm of centralized, state-led technological governance, where AI development is explicitly intertwined with national rejuvenation, digital sovereignty, and the consolidation of strategic autonomy. Its approach is characterized by top-down strategic planning, rapid iterative policy issuance, and a clear subordination of technological trajectories to overarching state objectives, including social stability and national security. In contrast, the Eurasian region—comprising states with diverse post-Soviet legacies, varying levels of institutional capacity, and unique geopolitical positioning—presents a mosaic of nascent regulatory experiments. Countries like Kazakhstan and Russia are actively formulating their responses to the AI revolution, but they do so while balancing the imperatives of economic modernization, technological catch-up, and the preservation of political sovereignty (Franks et al., 2024). Their frameworks often exhibit hybrid characteristics, drawing selectively from international models such as the European Union's risk-based approach while adapting them to domestic contexts marked by distinct security concerns and developmental aspirations. This regulatory diversification is not merely an academic concern; it has tangible and escalating implications for international trade and economic cooperation. AI is not a conventional commodity but a foundational, cross-cutting technology whose development, deployment, and exchange are deeply embedded in data flows, algorithmic transparency, ethical standards, and security protocols. When major economies and their regional partners adopt fundamentally different rules governing these elements—from data localization requirements and risk classification schemas to certification procedures and

ethical guardrails—the result can be significant market fragmentation (Roberts et al., 2021). For multinational corporations, technology startups, and investors, this fragmentation translates into increased compliance costs, legal uncertainty, and operational complexity, potentially stifling innovation and hindering the formation of efficient global AI supply chains and service markets. Furthermore, as AI becomes a focal point of geopolitical competition, exemplified by export controls on advanced semiconductors and restrictions on research collaboration, regulatory frameworks are increasingly instrumentalized as tools of economic statecraft, further complicating the landscape for purely market-driven engagement. Therefore, this analysis seeks to move beyond a simple cataloguing of legal differences. It aims to dissect the foundational philosophies underpinning the AI regulatory regimes in China and Eurasia, exploring how these philosophies are institutionalized through laws, policies, and governance mechanisms. It will investigate how these domestic frameworks interact with, and are shaped by, broader national innovation agendas and international alignment choices. Ultimately, the core inquiry revolves around the practical economic consequences: What specific frictions arise at the intersection of China's mature, state-centric regulatory ecosystem and the evolving, sometimes inconsistent legal environments of Eurasian states? How do divergent approaches to core issues like data governance, algorithmic accountability, and human rights protections create barriers to trade in AI goods and services, joint ventures, and research partnerships? By addressing these questions, this study aims to provide a nuanced understanding of the real-world trade-offs between sovereign policy space and the benefits of regulatory harmonization, offering insights into the strategies—both multilateral and bilateral—that could mitigate fragmentation and foster more predictable and prosperous economic engagement in the AI age. The ensuing chapters will delve into the theoretical context, methodological approach, detailed case studies, and a systematic comparison to build this comprehensive assessment (Lucero, 2019).

2. LITERATURE REVIEW OF THE THEORETICAL AND POLICY FRAMEWORKS FOR AI REGULATION

The burgeoning field of artificial intelligence governance has spawned a rich and multidisciplinary academic literature, traversing law, political science, science and technology studies (STS), ethics, and international relations. This body of work grapples with the core tension between fostering innovation and mitigating risk, a dilemma framed by divergent national philosophies, institutional capacities, and geopolitical ambitions. A comprehensive review reveals that scholarly analysis has evolved from abstract ethical principles and anticipatory governance models towards concrete, comparative examinations of regulatory instruments and their socio-economic implications. This literature provides the essential scaffolding for understanding the specific regulatory trajectories of China and the Eurasian states, situating them within global paradigms and theoretical debates. Early scholarship on AI governance was largely normative and future-oriented, focusing on articulating ethical principles. Foundational works, such as those by Luciano Floridi and colleagues, proposed high-level

frameworks emphasizing fairness, accountability, transparency, and human-centricity. These principles, while influential in shaping discourse, often existed in a political vacuum, lacking clear pathways for implementation within specific state structures (Alimkhanov, 2024). As AI moved from laboratory to marketplace, the literature shifted towards analyzing emergent regulatory models anchored in distinct political economies. The European Union's approach has become a canonical subject of study, characterized by scholars as a comprehensive, ex-ante, risk-based regulatory model. This model, crystallized in the EU AI Act, is fundamentally rooted in a rights-based legal tradition, prioritizing the protection of fundamental rights (privacy, non-discrimination, human dignity) through a conformity assessment framework that scales obligations with the perceived risk level of an AI system. Its proactive, hierarchical classification of prohibited, high-risk, and limited-risk applications represents an attempt to embed ethical principles directly into the product lifecycle, establishing a precedent for a "Brussels Effect" in digital regulation. In stark contrast, the United States' approach is extensively documented as a decentralized, sectoral, and innovation-centric model. Relying on a patchwork of existing federal agencies (e.g., FTC, FDA, EEOC) and state-level initiatives, the U.S. framework emphasizes market dynamism, post-hoc enforcement, and industry self-governance through standards and best practices. This model reflects a deep-seated political culture wary of centralized industrial planning and prioritizes maintaining technological leadership through a relatively permissive regulatory environment, albeit with growing scrutiny on issues of algorithmic bias and competition (Küçüksolak & Fırat, 2023).

China's model has been the subject of intense and evolving analysis. Initial Western interpretations often framed it through a simplistic lens of authoritarian control. However, more nuanced scholarship now recognizes it as a sophisticated paradigm of state-led, strategic governance. As analyzed by researchers like Katterbauer (2024), China's AI governance is not merely about restriction but about directed creation—orchestrating national resources to achieve technological sovereignty and economic supremacy. It is characterized by a top-down, iterative process where high-level strategic documents (e.g., the Next Generation AI Development Plan) set ambitious targets, followed by a cascade of implementing regulations, guidelines, and technical standards issued by ministries, cyberspace authorities, and standardization bodies. This approach subordinates the development and deployment of AI to overarching state objectives, including social stability, national security, and the consolidation of the Party's leadership (Filipova, 2024b). The Chinese model demonstrates a unique integration of industrial policy with regulatory oversight, where the state acts simultaneously as planner, regulator, and primary investor. This creates a cohesive but complex ecosystem for domestic firms, while presenting foreign entities with a landscape marked by strategic opacity, dynamic policy shifts, and unwavering emphasis on data sovereignty and ideological security. Beyond descriptive model comparison, the literature is deeply engaged with the theoretical foundations that underpin these regulatory divergences. A central theoretical axis is the reinterpretation of sovereignty in the digital age. The work of scholars like Langdon Winner, who critiqued the political dimensions of technological

artifacts, finds resonance in contemporary debates. China's regulatory architecture exemplifies a project of "digital sovereignty" or "techno-sovereignty," where control over data flows, algorithmic logic, and critical infrastructure is seen as inseparable from national sovereignty itself. This stands in tension with more liberal, transnational governance ideals that envision a global, open internet. Eurasian states, as post-Soviet entities, are acutely sensitive to this tension, navigating between the pragmatic need for technological integration and the political imperative of guarding against external influence, making their regulatory choices a live experiment in balancing sovereignty with interoperability (Parzyan, 2021).

A second critical theoretical lens is the sociology of risk and regulation. The EU's risk-based approach is informed by a precautionary principle and a technocratic rationality that seeks to objectively categorize and manage technological risk. In contrast, China's conception of risk is inherently more holistic and politically embedded; it encompasses not only technical safety and individual rights but, more fundamentally, risks to social order, political security, and strategic autonomy. As Feenberg's critical theory of technology suggests, technological design and regulation are arenas for the exercise of social and political power. Thus, while both the EU and China employ risk classifications, the underlying calculus—rights-based versus stability-based—reflects profoundly different social priorities. The emerging Eurasian frameworks, particularly Kazakhstan's, attempt a synthesis, adopting the EU's risk-tiered language while inflecting it with local concerns about economic modernization and public trust, demonstrating what Jasanoff terms "sociotechnical imaginaries"—collectively held visions of a desirable future that are enacted through policy and regulation. Furthermore, the literature on participatory regulation and algorithmic accountability offers insights into governance mechanisms. Western models increasingly emphasize stakeholder engagement, algorithmic impact assessments, and explainability ("XAI") as tools for accountability. China's model, while incorporating elements of public consultation in standard-setting, ultimately channels participation through state-defined corporatist structures, prioritizing harmony and strategic alignment over adversarial accountability. The question of how "human-centered" principles are institutionalized—whether through individual legal redress or through state-managed social welfare optimization—remains a key point of theoretical and practical divergence, directly impacting the design of regulatory instruments in comparative contexts (Khan, 2024).

Literature specifically addressing AI regulation in post-Soviet Eurasia is nascent but growing. It identifies these states not as passive norm-takers but as active, pragmatic actors in a crowded normative marketplace. Their regulatory development is analyzed as a process of strategic hybridity. As evidenced by Kazakhstan's 2025 law, these countries are selectively borrowing from international models—the EU's risk framework, elements of OECD principles—while adapting them to local institutional realities and political-economic goals, such as attracting foreign investment without ceding control over critical digital infrastructure. Russia's approach, as examined in strategic documents, reflects a different hybrid:

it combines aspirations for technological autarky and great-power competition with a reliance on experimental governance tools like regulatory sandboxes, a concept borrowed from agile financial regulation. This creates a landscape of "strategic ambiguity," where high-level goals are proclaimed but detailed, enforceable rules are deferred, allowing the state flexibility. Scholarship also frames Eurasian AI regulation within the context of legal and economic transition. These states are building AI governance atop evolving, and sometimes unstable, foundations of data protection, cybersecurity, and administrative law. The regulatory capacity—the state's ability to monitor, enforce, and technically audit compliance—varies significantly, creating a gap between law-on-the-books and law-in-action. This gap is a critical factor for international economic engagement, as foreign firms must assess not just the formal rules but the likelihood and manner of their enforcement. Furthermore, the literature suggests that for smaller Eurasian states, AI regulation is a form of normative entrepreneurship—a tool to signal modernity, attract responsible investment, and carve out a recognizable position in the global digital order, potentially acting as bridges or buffers between larger regulatory blocs like the EU, China, and Russia (Bissaliyev et al., 2025).

While the existing literature provides robust analysis of the EU and U.S. models and growing insight into China's approach, there remains a relative paucity of detailed, comparative work that systematically analyzes the interaction between these major regulatory poles and the emerging frameworks in pivotal regions like Eurasia. Most studies treat national models in isolation or in binary U.S.-China or EU-China comparisons. This article addresses this gap by placing the China-Eurasia regulatory dynamic at its center. It builds upon the theoretical foundations of digital sovereignty, risk sociology, and socio-technical imaginaries to move beyond cataloguing legal texts. It seeks to explicate how the philosophical and institutional contrasts between a mature, state-centric ecosystem (China) and evolving, hybrid regimes (Kazakhstan, Russia) translate into tangible frictions and opportunities for trade, investment, and technological cooperation—a crucial next step in understanding the real-world political economy of a fragmented global AI governance landscape (Kosherbayeva & Kylbayev, 2025).

3. RESEARCH METHODOLOGY

This study employs a qualitative, comparative case study design to systematically analyze and contrast the artificial intelligence (AI) regulatory frameworks of the People's Republic of China and selected Eurasian states—specifically Kazakhstan and Russia—with a focus on their implications for international trade and economic engagement. The methodological approach is interdisciplinary, drawing from policy analysis, legal studies, and political economy to construct a nuanced understanding of how regulatory architectures are formulated, implemented, and interact within the global landscape. The research is primarily desk-based, utilizing document analysis as its core technique, supplemented by a process-tracing method to track the evolution of policies and their socio-political drivers.

The primary data consists of an extensive corpus of official documents, legal texts, and policy statements. For China, this includes national strategic plans such as the Next Generation Artificial Intelligence Development Plan, regulatory guidelines issued by the Cyberspace Administration of China (CAC), the Ministry of Industry and Information Technology (MIIT), and the National Information Security Standardization Technical Committee (TC260), as well as white papers and announcements related to the Global AI Governance Initiative. For the Eurasian cases, the analysis focuses on Kazakhstan's Law "On Artificial Intelligence" (adopted November 2025), Russia's National Strategy for AI Development until 2030, and relevant draft legislation and policy directives from Uzbekistan and other regional actors. Secondary sources include academic literature, reports from international organizations (e.g., OECD, UN), and analyses from reputable think tanks to contextualize and critique the primary materials. This document analysis is not merely descriptive but interpretive, aiming to excavate the underlying regulatory philosophies—such as digital sovereignty, risk perception, and socio-technical imaginaries—that are embedded within and enacted through these texts. To ensure a structured comparison, the study adopts a framework organized around key analytical dimensions derived from the theoretical literature. These dimensions include: (1) Regulatory Philosophy and Objectives (e.g., state-centric control vs. rights-based governance vs. innovation-led experimentation); (2) Institutional Architecture and Governance Mechanisms (e.g., centralized command vs. hybrid models, role of regulatory sandboxes, standard-setting bodies); (3) Core Regulatory Instruments (e.g., risk classification schemas, data governance rules, transparency and accountability requirements); and (4) Linkages to Broader Economic and Trade Policy (e.g., integration with industrial strategy, digital sovereignty measures, alignment with international blocs). Each case study is analyzed through this multidimensional lens, allowing for a systematic identification of convergences and divergences that move beyond a superficial listing of legal provisions to understand the deeper logics of governance (Younas, 2020).

The process-tracing element of the methodology is crucial for understanding the dynamic and often path-dependent nature of regulatory development. It involves chronologically mapping the policy formulation process in each jurisdiction—from the issuance of high-level strategic visions to the drafting, consultation, and enactment of specific rules—and identifying the key domestic and international actors, discourses, and events that shaped these trajectories. For instance, tracing how Kazakhstan's AI law evolved from earlier digital transformation strategies and was influenced by both EU norms and local economic modernization goals provides insight into its hybrid character. Similarly, examining the iterative issuance of Chinese guidelines in response to technological breakthroughs (like generative AI) reveals the adaptive yet dirigiste nature of its regulatory state. This historical-institutional analysis helps explain not just the what of regulation, but the why and how, illuminating the political trade-offs and strategic calculations involved. Finally, to assess the implications for trade and economic engagement, the study synthesizes findings from the comparative and process-tracing analyses. It

identifies specific points of regulatory friction—such as incompatible data localization requirements, divergent risk classification criteria, or differing certification procedures—and evaluates their potential impact on market access, compliance costs, and supply chain integration for businesses. This assessment is necessarily prospective and qualitative, given the nascent stage of many Eurasian regulations, but it is grounded in established patterns of trade barrier analysis and insights from the political economy of digital fragmentation. The methodological rigor lies in the transparent linkage between identified regulatory differences, their philosophical and institutional roots, and their logically deduced consequences for cross-border economic activity, thereby providing a coherent analytical chain from governance theory to practical economic challenge (Kosherbayeva & Kylbayev, 2025).

4. CHINA'S AI REGULATORY FRAMEWORK AND STRATEGIC PRIORITIES

China's approach to artificial intelligence governance represents a paradigm of state-centric, strategic regulation that is deeply integrated with the nation's broader ambitions for technological sovereignty, economic modernization, and geopolitical influence. Unlike regulatory models that emerge primarily from legislative bodies or judicial precedent, China's AI framework is orchestrated through a top-down, iterative process where overarching strategic documents set the vision, and a cascade of implementing regulations, technical standards, and administrative guidelines operationalize that vision across sectors. This ecosystem is characterized by its dynamism, its subordination of technological development to political and social objectives, and its explicit aim to position China as a global rule-maker in the digital age. The regulatory architecture is not merely a set of constraints but a tool for directed innovation, designed to cultivate national champions, secure critical supply chains, and project normative power internationally. This section delves deeper into the mechanisms, philosophical underpinnings, and economic implications of this complex system, moving beyond a descriptive summary to analyze how it functions as an instrument of state power and economic statecraft. The foundation of China's AI governance is its centralized strategic planning apparatus. The seminal document, The Next Generation Artificial Intelligence Development Plan (2017), established AI as a national priority, outlining a three-step roadmap to achieve world-leading AI capabilities by 2030. This plan is not aspirational but directive, mobilizing state resources, guiding public investment, and setting benchmarks for provincial and municipal governments as well as state-owned enterprises. It frames AI development as integral to the "Great Rejuvenation of the Chinese Nation," explicitly linking technological prowess to national security and comprehensive national power. This strategic vision is continuously refined and implemented through a multi-layered governance structure involving a constellation of powerful actors. At the apex, the Central Cyberspace Affairs Commission (CCAC) provides top-level political direction, ensuring alignment with the Communist Party's priorities on cybersecurity, ideology, and social stability. Operationally, the Cyberspace Administration of China (CAC) is the lead regulator for data security and content governance, issuing critical rules such as the Generative AI Service Management Measures (2023). Concurrently, the Ministry of Industry and

Information Technology (MIIT) focuses on industrial policy, fostering the AI hardware and software ecosystem, while the National Information Security Standardization Technical Committee (TC260) develops the technical standards that give regulatory teeth to often vaguely worded laws and guidelines (Du & Kamenova, 2023).

This multi-agency yet coordinated system enables a form of "governance by experimentation." Rather than waiting for a comprehensive AI law—a draft of which has been discussed but not yet promulgated—Chinese authorities rapidly issue sector-specific or technology-specific regulations in response to market developments. This was vividly demonstrated with the swift regulatory response to the explosive growth of generative AI. The 2023 measures imposed a licensing regime, content controls, and security assessments on service providers, effectively bringing a disruptive technology under state oversight within months of its widespread adoption. This agility contrasts with slower, legislative processes in democracies but creates a landscape of regulatory uncertainty for both domestic and foreign firms, who must navigate a fluid and sometimes opaque rulebook. The state's role is thus tripartite: it is the strategist setting the destination, the regulator setting the guardrails, and, through entities like the National Integrated Circuit Industry Investment Fund, a direct investor in the chosen technological pathways. This creates a cohesive but insular ecosystem where success is predicated on understanding and aligning with state objectives, which extend beyond commercial profitability to encompass data sovereignty, social management, and ideological safety.

The substantive content of China's AI regulations revolves around several interlocking principles: a politically-inflected risk management framework, an ethic of "intelligent toward good" (shanzhi), and uncompromising data sovereignty. China's risk classification for AI systems, while superficially similar to the EU's tiered approach, is driven by a fundamentally different calculus. Risk is not assessed primarily through the lens of individual rights (though consumer protection is noted) but through the prism of threats to national security, social stability, and "socialist core values." High-risk applications are those that could influence public opinion, disrupt economic order, or infringe upon state secrets. The AI Generated Content (AIGC) Service Safety Basic Requirements (draft standard) exemplifies this, mandating security assessments for models that could generate content affecting "social mobilization" or "social perceptions."

The ethical principle of "intelligent toward good" is a malleable construct that bundles technical safety (e.g., robustness, accuracy) with political and ideological conformity. It demands that AI systems be "reliable, controllable, and transparent" and uphold "the core values of socialism." This fusion of ethics with political compliance is a hallmark of the Chinese model, where ethical governance is channeled through state-defined parameters rather than independent oversight or citizen redress mechanisms. Furthermore, data governance is the bedrock of this regulatory edifice. The Data Security Law (2021) and Personal Information Protection Law (2021) establish stringent data localization requirements and security reviews for cross-border data transfers deemed important to national interests.

For AI development, which is inherently data-hungry, this creates a bifurcated data realm: a protected domestic pool for nurturing national AI capabilities and a heavily restricted interface for international data exchanges. These instruments collectively serve a control function, ensuring that the development and deployment of AI reinforce rather than challenge the state's authority, both domestically and in its quest for "digital sovereignty" — the assertion of exclusive jurisdiction over data and digital infrastructure within its borders (Dadhich, 2018).

China's AI regulatory framework is inextricable from its pursuit of technological self-sufficiency, a priority intensified by geopolitical frictions, particularly with the United States. Regulations are thus levers to reduce dependency and build resilient, indigenous innovation chains. This has direct and profound implications for international trade and economic engagement. First, the regulatory environment inherently favors domestic "national champion" firms that are deeply embedded in the state's strategic plans and familiar with its normative expectations. Foreign companies face a "strategic opacity," where formal market access may be granted but operational hurdles—such as passing security reviews for algorithms or data practices, meeting evolving technical standards, and navigating content moderation rules that are politically defined—can be formidable. The requirement for "secure and controllable" technology in critical sectors often translates into procurement preferences for domestic suppliers. Second, China is actively using its regulatory experience and market size to shape global norms, aiming to offset the influence of Western-led governance models. Initiatives like the Global AI Governance Initiative (2023) advocate for a "people-centered" and "prudential and flexible" approach to AI governance, promoting multilateral forums under the United Nations as the preferred venue. This represents a form of regulatory diplomacy, seeking to attract Global South countries wary of the EU's prescriptive model or U.S. corporate dominance. For Eurasian states, this creates a normative marketplace: they can choose to align more closely with China's state-centric, sovereignty-first model or with the EU's rights-based framework. However, this very act of choosing can create friction. A company operating in a Eurasian country aligned with EU-style transparency and data subject rights may face incompatible compliance demands when partnering with or selling into the Chinese market, where data localization and algorithmic security reviews take precedence. Finally, China's regulatory framework intersects with broader geopolitical contestation to exacerbate trade challenges. Export controls on advanced semiconductors, enacted by the U.S. and its allies, are directly targeted at throttling China's AI development. In response, China's regulatory and industrial policies double down on import substitution, affecting global supply chains. Furthermore, restrictions on international scientific collaboration, driven by mutual suspicions, hinder the cross-border knowledge flows that typically underpin technological advancement. For Eurasian states like Kazakhstan or Russia, caught between these competing blocs, this presents a difficult balancing act. Deepening AI cooperation with China offers access to investment, technology, and a large market but may come with expectations to adopt compatible data and security standards, potentially complicating ties with other partners. Conversely,

seeking alignment with alternative regulatory poles may limit the depth of engagement with China's AI ecosystem. Thus, China's domestic regulatory framework, designed to ensure control and sovereignty, projects outward, creating a gravitational pull that shapes the economic and technological choices of its neighbors and partners, making the navigation of AI trade and investment in Eurasia a deeply geopolitical endeavor (Xiao, 2025).

5. AI REGULATORY DEVELOPMENTS IN EURASIAN STATES

The development of artificial intelligence (AI) regulatory frameworks across Eurasian states represents a dynamic and strategically vital process, characterized by a blend of normative borrowing, domestic adaptation, and geopolitical calculation. Unlike the mature, top-down ecosystem observed in China, the Eurasian landscape—encompassing states such as Kazakhstan, Russia, Uzbekistan, and others—is marked by varying degrees of institutional capacity, divergent historical legacies, and competing external influences. This heterogeneity results in a mosaic of regulatory approaches that are not merely technical legal exercises but profound statements of national identity, economic aspiration, and sovereignty in the digital age. A deeper examination beyond the foundational statutes and strategic documents reveals the complex socio-political undercurrents shaping these frameworks, the operational challenges of implementation, and the nuanced ways in which these states position themselves within the global contest over AI governance norms. This extended analysis delves into the specificities of each jurisdiction, explores the regional interplay, and assesses the often-overlooked gap between legislative ambition and on-the-ground enforcement, providing a more granular understanding of how these evolving regimes will impact both domestic innovation and international economic engagement. Kazakhstan's enactment of the Law "On Artificial Intelligence" in November 2025, effective January 2026, positions it as a regional frontrunner in formal AI governance. This law is not an isolated legal text but the culmination of a deliberate strategy to modernize the nation's digital economy and signal its reliability as a destination for responsible investment. The law's core pillars—a risk- and autonomy-based classification system for AI systems, stringent transparency and labeling mandates, and explicit prohibitions on manipulative or discriminatory applications—demonstrate a clear intent to align with international, particularly European, governance trends. This alignment is strategic; it facilitates interoperability with major trading partners and reassures foreign technology firms seeking a predictable regulatory environment (Ashraf & Mustafa, 2025). However, beneath this apparent convergence with EU-style principles lies a distinct layer of domestic adaptation. The law's emphasis on "protection of human rights" and a "human-centered paradigm" is framed not only through the lens of individual liberties but also through the state's prerogative to ensure social stability and economic equity. The regulatory architecture, likely involving the Ministry of Digital Development, Innovation and Aerospace Industry, is designed to maintain state oversight over critical AI applications in sectors like public administration, finance, and critical infrastructure, ensuring that technological adoption reinforces rather than disrupts governmental control and national development goals. This creates a model of strategic

hybridity: Kazakhstan imports the lexicon and structural frameworks of Western risk-based regulation but infuses them with a post-Soviet sensibility that prioritizes state-led development and sovereignty. The true test, however, will be in implementation. The development of secondary regulations, technical standards, and certification bodies is still underway. The capacity of regulators to conduct sophisticated audits of algorithmic systems, assess bias in training data, or enforce transparency requirements against powerful domestic oligopolies remains uncertain. This gap between law-on-the-books and law-in-action introduces a significant element of risk for businesses, who must navigate not just the formal rules but also the informal practices and evolving interpretive guidance of state agencies.

Russia's approach to AI regulation stands in contrast to Kazakhstan's legislative clarity, favoring strategic planning and experimental, sectoral interventions over a comprehensive, codified statute. The National Strategy for AI Development until 2030 outlines broad goals of technological integration, import substitution, and safety, but it functions more as a declaratory document than a binding regulatory framework. This reflects a calculated preference for strategic ambiguity, which affords the state maximum flexibility. The state can promote AI development through targeted funding, regulatory sandboxes, and state-corporate partnerships (notably with entities like Yandex and Sber) without being constrained by rigid legal obligations that might hinder rapid pivots or cloak sensitive security applications in transparency. The emphasis on regulatory sandboxes, borrowed from fintech governance, allows for controlled experimentation in fields like autonomous transport or facial recognition, but it also centralizes the state's role as the gatekeeper of innovation, determining which projects merit a temporary reprieve from general legal norms. This model is deeply intertwined with Russia's drive for technological autarky (or "digital sovereignty"), a priority intensified by geopolitical isolation and sanctions. Recent directives calling for a national AI task force and reduced dependency on foreign infrastructure underscore that AI governance is viewed primarily through the prism of national security and great-power competition. Ethical principles, such as those mentioned in strategic documents, are subordinate to these imperatives. For instance, discussions of algorithmic fairness or human-centricity are unlikely to result in strong, justiciable rights for individuals against state deployment of AI for surveillance or social control. Instead, "safety" and "ethics" are framed as issues of system reliability and protection against foreign manipulation. Consequently, for international businesses, the Russian market presents a distinct challenge: the absence of a clear, standalone AI law does not mean an absence of regulation. Rather, AI systems are subject to a dense thicket of existing and evolving rules on data localization (the "sovereign internet" laws), cybersecurity, and state procurement, all enforced by powerful agencies like Roskomnadzor and the FSB. Compliance is less about checking boxes against a published AI statute and more about navigating a politicized environment where approval is contingent on alignment with state strategic interests and, often, on forming partnerships with domestic champions.

Uzbekistan's progress on AI legislation, exemplified by draft laws under parliamentary review, illustrates another variant of the Eurasian regulatory trajectory. Its proposed framework, which includes definitions of AI, responsibilities for personal data misuse, and labeling requirements, suggests an intent to establish foundational rules for a nascent digital economy. Like Kazakhstan, Uzbekistan seems to be looking outward for normative templates, but its institutional capacity for drafting, implementing, and enforcing sophisticated digital regulations is arguably more limited. The primary impetus may be as much about signaling modernity to international investors and organizations as about crafting detailed governance. Across other Eurasian jurisdictions, from Azerbaijan to Kyrgyzstan, the state of AI regulation is even more embryonic, often subsumed within broader, vague digital transformation or innovation strategies. This creates a region of stark contrasts: islands of relative regulatory sophistication (like Kazakhstan) set within a sea of underdeveloped and sometimes contradictory rules. This disparity itself becomes a barrier to regional economic integration. A company developing an AI-driven logistics platform might face a coherent, if demanding, set of rules in Kazakhstan, but encounter a regulatory vacuum or arbitrary enforcement in a neighboring country, complicating cross-border service provision. Furthermore, the influence of external actors is keenly felt. While the EU's normative power is evident in the risk-based language of Kazakh law, China's growing economic and technological footprint through the Belt and Road Initiative exerts a parallel pull. Chinese firms offer AI infrastructure, smart city solutions, and investment, often bundled with expectations of compatible technical standards and data practices. Eurasian states thus engage in a delicate balancing act, attempting to triangulate between the EU's regulatory model, China's techno-authoritarian offerings, and Russia's security-driven sphere of influence, all while preserving their own policy space (Katterbauer et al., 2025).

A critical, often under-analyzed dimension across all Eurasian states is the chasm between legislative proclamation and practical enforcement. The capacity of state bureaucracies to understand, monitor, and audit complex AI systems is generally low, a legacy of underfunded technical education and a historical lack of independent regulatory expertise. This can lead to several outcomes: regulations may be enforced selectively, targeting high-profile foreign firms while giving domestic actors more leeway; enforcement may focus on superficial compliance (e.g., registering an AI system) rather than substantive audits of algorithmic fairness or data provenance; or, in some cases, the rules may simply remain dormant due to a lack of resources or political will. This implementation gap creates a high degree of uncertainty for businesses. It also means that the de facto regulatory environment may be shaped less by the text of the law and more by informal negotiations, political connections, and the discretionary power of specific officials. For multinational corporations, this demands a risk-management strategy that goes beyond legal compliance to include deep stakeholder engagement, political risk insurance, and adaptive operational models. Moreover, the political economy of enforcement is tied to the structure of domestic markets, which in many Eurasian states are dominated by large, often state-linked conglomerates. These national champions may have significant influence

over the shaping and application of AI regulations, potentially crafting rules that create barriers to entry for foreign competitors while insulating themselves from stringent oversight. Therefore, understanding AI regulation in Eurasia requires analyzing not just the laws themselves, but the distribution of economic power, the strength of institutions, and the informal practices that determine how those laws are applied in reality (Papyshev & Yarime, 2024).

In summary, the Eurasian region is not a passive recipient of global AI norms but an active laboratory where different regulatory philosophies are being tested, hybridized, and instrumentalized for national ends. Kazakhstan's path shows a deliberate attempt to marry international best practices with sovereign control. Russia's approach demonstrates the use of strategic ambiguity and experimental tools to pursue autarky and power. Uzbekistan and others highlight the challenges of building regulatory capacity from the ground up. Across the board, the tension between the desire for economic integration and the imperative of political sovereignty is palpable. These divergent and evolving frameworks present a complex landscape for trade and investment. They necessitate that businesses adopt a highly nuanced, country-specific approach, moving beyond a one-size-fits-all compliance strategy. For policymakers in China, the EU, and elsewhere, engaging with Eurasia requires recognizing these states as normative entrepreneurs in their own right, whose ultimate alignment in the global AI governance order remains a pivotal, and still open, question. The region's development will significantly influence whether the world moves toward fragmented technological blocs or finds pathways for interoperable, if pluralistic,

6. COMPARATIVE DIMENSIONS OF AI REGULATORY FRAMEWORKS

The comparative analysis of AI regulatory frameworks across China and the Eurasian states reveals not merely a set of divergent legal provisions, but a profound clash of governance philosophies, institutional logics, and socio-political priorities. These differences are not superficial; they are embedded within the very fabric of each state's political economy and its vision for the future of technological society. Extending the examination beyond the core dimensions of regulatory philosophy, rights focus, and implementation capacity, it becomes essential to explore the deeper undercurrents that shape these frameworks: the constitutive role of the state, the nature of risk perception, the construction of ethical paradigms, and the ultimate objectives of technological development. In China, the regulatory framework is an explicit instrument of statecraft, designed to harness AI for the twin goals of national rejuvenation and regime security. The state is not a neutral arbiter or a reactive regulator but the central architect, investor, and beneficiary of the AI ecosystem. Its "strategic, top-down" approach is characterized by a seamless integration of industrial policy, national security doctrine, and social governance. AI development is subordinated to the overarching political objectives outlined in documents like the Next Generation AI Development Plan, where technological prowess is inextricably linked to the "Great Rejuvenation of the Chinese Nation." This results in a regulatory model where agility is prized—evident in the rapid-fire issuance of guidelines like the Generative AI Service

Management Measures—but where this agility serves to tighten state control over emergent technologies before they can develop outside prescribed parameters. The core regulatory instruments, such as data localization mandates under the Data Security Law and the politically-inflected risk classifications, are less about creating a predictable commercial environment and more about constructing a walled garden of "digital sovereignty." Within this garden, domestic champions are nurtured through preferential policies and aligned with state goals, while foreign entities navigate a landscape of "strategic opacity," where compliance is as much about political alignment as it is about technical adherence to standards. The ethical principle of "intelligent toward good" (shanzhi) perfectly encapsulates this fusion, bundling technical safety with mandatory conformity to "socialist core values," thereby rendering ethics a function of political compliance rather than an independent check on power.

In contrast, the emerging Eurasian frameworks, particularly Kazakhstan's pioneering law, represent a conscious project of strategic hybridity and normative entrepreneurship. These states are not blank slates but active agents in a crowded global marketplace of regulatory ideas, selectively borrowing and adapting norms to suit their unique positions. Kazakhstan's 2025 AI law is a prime example: it adopts the lexicon and structural appearance of the EU's risk-based model, complete with transparency mandates and prohibitions on discriminatory AI, to signal modernity, attract responsible foreign investment, and facilitate interoperability with European markets. However, this external facade is underpinned by a domestic logic that retains a strong post-Soviet emphasis on state-led development and sovereignty. The "human-centered" paradigm is interpreted not solely through the lens of inviolable individual rights, but also through the state's prerogative to ensure social stability and direct economic transformation. The institutional architecture, likely centered on a ministry like the Ministry of Digital Development, Innovation and Aerospace Industry, is designed to maintain oversight over critical applications, ensuring that AI serves national development goals as defined by the state. This creates a distinct hybrid model—one that speaks the language of Brussels while operating with a sensibility forged in Nur-Sultan (Astana). Meanwhile, Russia's approach exemplifies strategic ambiguity and instrumentalized experimentation. Eschewing comprehensive codification, Russia favors high-level strategic documents like its National Strategy for AI Development until 2030, coupled with tactical tools like regulatory sandboxes. This allows the state maximum flexibility to promote sectors deemed strategically vital (e.g., through partnerships with Yandex or Sber) while avoiding the constraints of transparent, legally binding rules, especially in sensitive areas like surveillance and social control. Governance is less about establishing clear rules of the game and more about maintaining a discretionary gatekeeping role, where innovation is permitted so long as it reinforces state priorities of technological autarky and great-power competition. Here, concepts of "safety" and "ethics" are reframed as matters of system reliability and defense against foreign interference, rather than individual redress or algorithmic fairness. The wider Eurasian mosaic, from Uzbekistan's draft laws to the more embryonic strategies in Kyrgyzstan or Azerbaijan, further illustrates a region grappling with acute capacity constraints and

competing gravitational pulls (Papyshev & Yarime, 2023). These states often lack the technical expertise, institutional memory, and financial resources to enforce sophisticated AI regulations, leading to a significant gap between legislative ambition and on-the-ground reality. This implementation gap itself becomes a critical feature of the regulatory landscape, creating an environment where enforcement can be selective, unpredictable, and influenced by informal networks and political considerations.

The implications of these deep-seated differences for trade and economic engagement are multifaceted and severe. Regulatory divergence leads to tangible market fragmentation. A company developing an AI diagnostic tool faces fundamentally different pathways to market: in China, it must pass a security review focused on data sovereignty and social impact; in Kazakhstan, it might need to undergo an assessment for bias and transparency aligned with EU-inspired norms; and in Russia, its approval may hinge on partnership with a domestic entity and vague "national interest" criteria. This lack of harmonization forces firms to maintain multiple, incompatible compliance profiles, dramatically increasing costs and complexity, particularly for small and medium-sized enterprises and startups, thereby stifling cross-border innovation (Katterbauer et al., 2024). The challenge of data governance and cross-border data flows is particularly acute. AI is inherently data-hungry, yet the regimes governing this vital resource are diametrically opposed. China's strict data localization and security review requirements for cross-border transfers create a controlled domestic data pool, essentially segmenting the global data economy. For a multinational corporation attempting to train a regional AI model using data from China and Kazakhstan, this presents a near-insurmountable hurdle. Kazakhstan, while potentially more open, must still reconcile its own emerging data rules with the pressure to accommodate Chinese infrastructure and standards brought in via Belt and Road Initiative projects. This incompatibility not only hinders collaborative research and development but also obstructs the provision of cloud-based and AI-as-a-service platforms across borders. Furthermore, the geopolitical instrumentalization of technology exacerbates these regulatory frictions. U.S. and allied export controls on advanced semiconductors, aimed at curbing China's AI advancement, force a decoupling of global supply chains. Eurasian states are then caught in a vice: partnering with Chinese AI firms may offer investment and technology but risks secondary sanctions and alienation from Western markets and components. This geopolitical layer transforms regulatory compliance from a commercial/legal exercise into a high-stakes strategic choice. Consequently, the quest for regulatory certainty becomes a mirage. In China, certainty is derived from alignment with state objectives, not from static legal texts. In Eurasia, certainty is undermined by evolving rules, capacity gaps, and the region's precarious balancing act between major powers. For investors, this translates into heightened political risk, necessitating strategies that go beyond legal due diligence to include deep stakeholder engagement, political risk insurance, and flexible, adaptive business models.

Ultimately, the comparative analysis underscores that AI regulation is a proxy for broader contests over governance models, sovereignty, and the future shape of the international order. China's framework

projects a vision of cyber-sovereignty and state-centric techno-development. The Eurasian experiments reflect a pragmatic, sometimes precarious, navigation between competing normative worlds. The resulting landscape is not one of simple binary choice but of complex, nested fragmentation that demands a sophisticated, context-specific approach from all economic and political actors engaged in the region. The pathways to mitigating these frictions—through multilateral dialogue in forums like the UN or SCO, bilateral technical working groups, and the development of interoperable standards—are fraught with the very geopolitical and philosophical tensions that created the divisions in the first place. Therefore, the future of AI-driven trade and economic engagement in Eurasia will depend less on the emergence of a single, dominant regulatory model and more on the development of pragmatic interfaces, mutual recognition agreements, and resilient business strategies capable of operating within a state of enduring pluralism—and friction.

7. CONCLUSION

This comparative analysis of artificial intelligence regulatory frameworks in China and key Eurasian states—specifically Kazakhstan and Russia—reveals that governance of this foundational technology is far more than a technical or legal exercise; it is a profound manifestation of competing political philosophies, economic strategies, and visions for societal order in the digital age. The investigation demonstrates that the divergent paths taken by China, with its mature, state-centric ecosystem, and the Eurasian nations, with their hybrid and evolving regimes, are not accidental but deeply rooted in historical context, institutional capacity, and geopolitical positioning. China's paradigm of strategic, top-down governance—where AI development is explicitly harnessed for national rejuvenation, digital sovereignty, and regime security—creates a cohesive but insular innovation environment. Its regulatory agility, exemplified by rapid iterative policy issuance, serves to subordinate technological trajectories to overarching state objectives, embedding political compliance within the very fabric of ethical and risk-management frameworks. In contrast, the Eurasian landscape presents a mosaic of strategic hybridity and normative entrepreneurship. Kazakhstan's legislative approach seeks to marry the lexicon and structures of EU-style, risk-based regulation with a post-Soviet emphasis on state-led development and sovereignty. Russia favors strategic ambiguity and experimental tools like regulatory sandboxes to pursue technological autarky and great-power competition without the constraints of transparent codification. Across the region, a persistent gap between legislative ambition and enforcement capacity adds a layer of operational uncertainty, making the de facto regulatory environment often a product of informal practices and discretionary state power. The implications of this regulatory fragmentation for international trade and economic engagement are severe and multifaceted. Core incompatibilities—in data governance philosophies, risk classification calculi, certification procedures, and ethical imperatives—act as significant non-tariff barriers, segmenting markets and stifling cross-border innovation. The AI sector's inherent dependence on large-scale data flows and collaborative R&D is particularly hampered by schisms between China's strict data

localization regime and the more permeable, though still evolving, rules in Eurasia. For businesses, from multinational corporations to startups, this translates into proliferating compliance burdens, legal unpredictability, and heightened operational complexity, disadvantaging smaller actors and distorting efficient global supply chain formation. Furthermore, as this analysis underscores, AI regulation has become inextricably linked to geopolitical contestation. Export controls, investment screening, and restrictions on scientific collaboration instrumentalize technology policy as a tool of economic statecraft, forcing Eurasian states into a precarious balancing act. Their attempts to triangulate between the gravitational pulls of China's techno-authoritarian model, the EU's rights-based framework, and Russia's security-driven sphere of influence turn regulatory alignment into a high-stakes strategic choice with direct consequences for market access and technological partnerships.

Ultimately, this study concludes that the emerging global AI governance landscape is characterized not by convergence toward a single model, but by enduring and potentially deepening pluralism. The friction between China's sovereignty-first architecture and Eurasia's hybrid experiments reflects a broader contest over the norms that will govern the digital future. Navigating this fragmented terrain will not be achieved through the imposition of a hegemonic framework. Instead, the path forward for fostering sustainable trade and economic engagement must involve pragmatic, multi-level strategies. These include advancing dialogue in multilateral forums (such as the UN, SCO, or OECD) to identify minimal consensus on safety and interoperability; establishing bilateral technical working groups to bridge specific regulatory gaps; and promoting the development of interoperable standards and mutual recognition agreements for low-risk AI applications. For businesses, success will require moving beyond static compliance checklists toward adaptive strategies that incorporate deep stakeholder engagement, political risk assessment, and resilient, context-specific operational models. The future of AI-driven prosperity in Eurasia and beyond will thus depend less on the illusion of regulatory homogeneity and more on the skillful management of pluralism—forging pragmatic interfaces that acknowledge profound philosophical differences while enabling the cross-border collaboration essential for harnessing the transformative, and globally interconnected, potential of artificial intelligence.

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CHINA'S AI COMPANIES FINANCIAL PERFORMANCE – WHAT DOES THE FUTURE HOLD FOR THEM

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ABSTRACT

China's artificial intelligence (AI) industry has experienced rapid growth over the past decade, driven by strong government support, a vast consumer base, and continuous technological advancements. As a global leader in AI innovation, the sector comprises major technology conglomerates and specialized AI firms, with financial performance serving as a key indicator of sustainability and competitiveness. Leading companies such as Baidu, Alibaba, and Tencent have integrated AI into various sectors, including cloud computing, e-commerce, and gaming, while firms like SenseTime and iFlytek specialize in facial recognition and speech processing. Despite challenges such as regulatory risks and high research and development costs, these companies continue to expand through AI-driven innovations. Investment trends, including strong government backing and venture capital funding, further shape the industry's trajectory. However, factors like stock market volatility and competitive pressures highlight the complexities of maintaining profitability in China's evolving AI landscape.

Keywords: *AI, Financial Performance, Clustering Analysis, China.*

JEL Codes: *O33, G32, L86.*

1. INTRODUCTION

China has emerged as a dominant force in artificial intelligence (AI), solidifying its position as a global leader in the research, development, and application of AI technologies. With substantial government investment, an extensive reservoir of data, and a rapidly growing ecosystem of innovative companies, China is making significant strides in AI across multiple sectors. In 2017, the country unveiled its "New Generation Artificial Intelligence Development Plan," a comprehensive blueprint outlining its ambition to become the world leader in AI by 2030. This strategic initiative highlights key

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priorities, including investing heavily in AI research and development, fostering AI-driven industries, cultivating and attracting top AI talent, establishing robust regulations and ethical frameworks, and expanding AI applications in governance and security. The plan is an essential component of China's broader strategy to achieve technological self-sufficiency and drive economic transformation. By integrating AI into various aspects of its economy and governance, China aims to enhance efficiency, strengthen national security, and maintain its competitive edge in the global technological race. Through aggressive policy support, strategic partnerships, and the rapid commercialization of AI innovations, China continues to shape the future of AI on a global scale while navigating the challenges of data privacy, regulatory oversight, and international competition (Hu, Nian, & Wang, 2019; Geng, et al., 2016).

China's AI landscape is shaped by several key players, including technology giants and innovative startups that are at the forefront of AI research and development. Baidu, a leader in AI-driven search engines and autonomous driving technology, has made significant advancements in natural language processing and deep learning. Alibaba, through its AI research unit DAMO Academy, focuses on AI applications in e-commerce, cloud computing, and smart cities. Tencent utilizes AI in gaming, healthcare, and finance, with its AI Lab developing cutting-edge solutions in computer vision and speech recognition. SenseTime, a global leader in facial recognition and computer vision, provides AI technology for security, retail, and healthcare industries, while Megvii (Face++) specializes in facial recognition and smart surveillance, playing a crucial role in China's public security systems. Additionally, Huawei has established itself as a major player in AI chip development and telecommunications, integrating AI into smartphones, cloud computing, and 5G networks (Yang, Ying, & Gao, 2020). The rapid progress of AI in China is heavily influenced by strong government policies and significant investments. The government actively supports AI development through funding, policy initiatives, and regulatory frameworks designed to propel the country to the forefront of global AI leadership. Key policies shaping this growth include Made in China 2025, a strategic plan aimed at enhancing China's technological capabilities in AI, robotics, and semiconductor manufacturing, and the AI Development Plan (2017-2030), which sets clear milestones for AI research, industrialization, and ethical guidelines. Additionally, the Smart Cities Initiative promotes AI-driven urban management systems that improve traffic control, surveillance, and public services, while military AI advancements reflect China's integration of AI into national defense, including drone technology and cyber warfare capabilities (Li, et al., 2023). These combined efforts highlight China's ambition to leverage AI as a transformative force in both economic and strategic domains, reinforcing its position as a global powerhouse in artificial intelligence (Chen & Zhang, 2024).

China's AI capabilities are being deployed across a wide range of sectors, significantly transforming industries and enhancing efficiency. In healthcare, AI is revolutionizing diagnostics, drug discovery, and patient care, with companies like Ping An Good Doctor leading AI-powered telemedicine

solutions that improve accessibility and medical decision-making. The finance sector is also experiencing major changes, with AI-driven fraud detection, algorithmic trading, and automated customer service enhancing security and efficiency in banking and investment operations. In retail and e-commerce, AI optimizes supply chain logistics, personalized recommendations, and smart warehouses for industry giants like Alibaba and JD.com, streamlining operations and improving customer experiences. AI is also playing a pivotal role in education, with AI-powered tutoring systems, facial recognition attendance tracking, and adaptive learning platforms reshaping how students learn and teachers interact with them. Meanwhile, surveillance and public security have become one of the most prominent applications of AI in China, as facial recognition and big data analytics are extensively used for law enforcement, social credit scoring, and national security monitoring, raising both efficiency and ethical concerns. However, despite rapid advancements, China faces several challenges in AI development. Data privacy and ethics remain contentious issues, as the extensive use of facial recognition and surveillance technology sparks concerns about individual rights and government overreach. Another major challenge is dependence on foreign AI chips, as China continues to rely on Western semiconductor technology despite significant investments in domestic chip production to achieve self-sufficiency. Additionally, regulatory uncertainty poses a challenge, with authorities needing to balance innovation with oversight, particularly in areas like autonomous vehicles and AI-driven finance, where safety and accountability are crucial. There is also a talent shortage, as high-level AI expertise remains in short supply, despite the government's investment in AI education and training programs. Lastly, geopolitical tensions, particularly U.S.-China trade restrictions, impact AI collaborations, chip manufacturing, and software development, posing significant obstacles to China's AI ambitions (Cheng, Du, Yan, & Goodell, 2025). While China continues to push forward with its AI-driven future, these challenges must be addressed to sustain its leadership in the global AI race (Song, Ai, & Li, 2015).

China's advancements in AI are reshaping the global landscape, influencing technological competition, geopolitics, ethics, and economic structures. One of the most significant global ramifications is the technological competition with the U.S., as China's rapid progress in AI fuels an intense rivalry, leading to technological decoupling and a race for innovation dominance. This competition extends beyond economic gains, affecting national security and global influence, as both nations strive to establish leadership in emerging AI technologies (Gyau, Appiah, Gyamfi, Achie, & Naeem, 2024). In addition to competition, AI-powered geopolitics is becoming a crucial factor in China's international strategy, as the country exports AI-driven smart city projects to developing nations, reinforcing its global presence and strengthening diplomatic ties through technological collaboration. However, China's approach to AI governance and surveillance has sparked international AI ethics debates, particularly regarding digital sovereignty and human rights concerns, with many nations questioning the implications of China's AI-driven monitoring systems. Beyond the political

sphere, China's AI leadership is driving economic shifts, as AI-powered automation and industrial AI solutions reshape global supply chains, positioning China at the center of this transformation by enhancing manufacturing efficiency and reducing dependence on human labor. As China aggressively pushes forward with its AI ambitions, these developments are not only redefining industries and economies but also altering global power dynamics (Peng, Han, & Yuan, 2023). With strong government support, vast amounts of data, and an expanding AI ecosystem, China remains well on track to achieving its 2030 AI leadership goals. However, its trajectory will be influenced by several critical factors, including ethical concerns surrounding data privacy and surveillance, regulatory challenges in balancing AI governance with innovation, and growing international scrutiny over its AI policies. As AI continues to evolve, China's role in the global AI race will be instrumental in shaping the technological advancements of the 21st century, determining how AI is integrated into societies, economies, and governance worldwide.

2. AI REGULATIONS IN CHINA

China has rapidly developed into a global leader in artificial intelligence (AI), leveraging its vast data resources, strong governmental support, and a dynamic technology ecosystem. However, as AI technologies continue to advance, the Chinese government has implemented a comprehensive regulatory framework to manage risks, ensure ethical usage, and maintain control over AI applications. Over time, China's AI regulations have evolved in response to the increasing influence of AI on society, with distinct phases marking this development. Pre-2017, AI governance in China was relatively unstructured, with broad policies focusing on data security and digital economy frameworks but lacking specific AI-related guidelines. The landscape began to change between 2017 and 2020 when the government introduced foundational regulations, notably the New Generation Artificial Intelligence Development Plan (2017), which provided structured guidelines for AI research, industrial development, and ethical considerations. This phase laid the groundwork for AI governance, setting China on a clear path to AI leadership while addressing emerging concerns related to data use, automation, and security. From 2021 to the present, China has focused on refining and enforcing AI laws through more targeted regulations, such as the Personal Information Protection Law (PIPL), which governs data privacy and security, and specific AI-generated content regulations aimed at curbing misinformation and ensuring responsible AI deployment. These evolving regulations reflect China's strategic approach to AI governance, balancing technological progress with state control and ethical oversight. As China continues to refine its AI policies, its regulatory framework will not only shape domestic AI applications but also influence global discussions on AI ethics, digital sovereignty, and international AI governance (Cheng, Du, Yan, & Goodell, 2025).

China's AI governance framework is shaped by several key policies and regulations that ensure ethical AI development, data security, and compliance with national priorities. One of the most

significant initiatives is the New Generation Artificial Intelligence Development Plan (2017), which laid out China's strategic roadmap to achieve AI leadership by 2030. This plan not only emphasized industrial AI applications but also incorporated ethical considerations and regulatory oversight to guide AI's growth. In line with global trends in data protection, China enacted the Personal Information Protection Law (PIPL) (2021), often compared to the EU's GDPR, which regulates the collection, storage, and processing of personal data to prevent AI systems from infringing on individual privacy. Complementing the PIPL, the Data Security Law (DSL) (2021) was introduced to strengthen governance over data storage, cross-border data transfers, and AI-related data security, ensuring national security while preventing the misuse of AI-driven data technologies.

Beyond data privacy, China has also implemented regulations to control AI-powered algorithms and digital content. The Algorithmic Recommendation Regulations (2022) issued by the Cyberspace Administration of China (CAC) mandate transparency and fairness in AI-driven recommendation systems, requiring platforms to avoid promoting harmful content and giving users control over algorithm-based recommendations. With the rise of AI-generated content, the government introduced Deepfake and Generative AI Regulations (2023) to curb misinformation, requiring that AI-generated and altered media be labeled to prevent misuse in political, social, and media contexts. Expanding on these controls, the Interim Measures for Generative AI Services (2023) target AI models similar to ChatGPT, enforcing strict compliance with government-approved data sources and national security standards (People's Republic of China, 2024). These regulations collectively highlight China's proactive approach to AI governance, balancing technological innovation with stringent oversight to maintain control over AI's societal and geopolitical impact (Sheehan, 2023).

China employs a multi-layered enforcement approach to ensure AI regulations are strictly followed, combining government oversight, corporate responsibility, legal consequences, and public accountability. Key government oversight bodies, including the Cyberspace Administration of China (CAC), the Ministry of Industry and Information Technology (MIIT), and the State Council, play a central role in monitoring AI policies and enforcing compliance. These agencies oversee everything from algorithmic transparency to data security, ensuring that AI applications align with national priorities. Corporate compliance is another crucial aspect, as major tech giants like Alibaba, Tencent, and Baidu are required to integrate AI governance frameworks into their operations, ensuring that their AI-driven services meet regulatory standards. Companies that fail to adhere to these regulations face legal penalties, which can include heavy fines, restrictions on data access, or even business suspensions, demonstrating the government's firm stance on AI governance. Additionally, public accountability plays a role in enforcement, as AI platforms must provide channels for user complaints and implement self-regulation mechanisms to ensure they operate within legal boundaries (Lucero, 2019).

China's strict AI regulations have significantly influenced various industries, reshaping business operations and technological development. In the tech industry, companies must navigate complex

regulatory requirements, balancing innovation with state oversight to ensure AI technologies align with ethical and national security concerns. The financial sector is also heavily impacted, as AI-driven fintech services must comply with transparency rules and risk assessment measures to prevent fraud, unethical lending, and market manipulation. In healthcare, AI applications in medicine, including diagnostics and patient data management, are subject to strict privacy laws and ethical guidelines to ensure medical safety and data security. Social media and content platforms, where AI plays a critical role in content moderation and recommendation systems, face some of the most stringent regulations, with tight government controls designed to curb misinformation, prevent social unrest, and maintain stability in digital spaces. These industry-wide changes highlight China's approach to AI governance—prioritizing control and security while still fostering AI-driven advancements that align with national interests (Du & Kamenova, 2023).

China's AI regulations are not only shaping domestic AI governance but also influencing global AI policies, international trade, and geopolitical dynamics. By implementing strict yet comprehensive regulatory measures, China is setting a regulatory precedent that other nations, particularly those in the Global South, may seek to emulate as they develop their own AI governance frameworks. Countries looking to balance technological advancement with state oversight are closely observing China's approach, making its regulatory model a potential blueprint for AI governance beyond its borders. Furthermore, China's AI strategy reflects a delicate balance between innovation and control, ensuring that while AI research and development continue to thrive, state authorities maintain significant oversight over AI's societal and economic impact. This controlled approach contrasts sharply with more open AI ecosystems in Western countries, where private sector-led innovation often drives AI policy (Cao & Power, 2025).

However, China's AI regulations have also intensified geopolitical tensions, particularly with the U.S. and EU, as regulatory differences create barriers to international AI collaborations, impact trade relations, and fuel global debates on AI ethics, digital sovereignty, and surveillance practices. The divergence in AI policies between China and Western nations influences everything from cross-border data flows to the ethical considerations of AI-powered surveillance and content moderation. As AI technology continues to evolve, China's stringent governance model will remain a key reference point in the global AI governance debate, shaping how different regions approach AI policy, data security, and the future of AI-powered economies. Ultimately, China's AI regulations reflect its dual ambition: to lead in AI innovation while ensuring that AI development aligns with national security interests and societal stability (Katterbauer, Özbay, Yılmaz, & Meral, 2024).

3. CHINESE AI ENTERPRISE DEVELOPMENT

China's artificial intelligence (AI) sector has emerged as a key player in the global technology landscape, with AI-driven companies attracting significant interest from investors, policymakers, and

analysts. As the industry continues to expand, the stock price performance of leading Chinese AI firms reflects broader economic trends, regulatory influences, and technological breakthroughs. China's AI industry benefits from strong government support, a vast data ecosystem, and deep integration across sectors such as cloud computing, big data analytics, autonomous driving, and facial recognition. Major AI companies leading this transformation include Baidu, Inc. (BIDU), which has established itself as a frontrunner in AI-powered search engines, autonomous driving, and cloud services; Alibaba Group (BABA), which leverages AI across its expansive e-commerce, cloud computing, and logistics operations; and Tencent Holdings (TCEHY), which integrates AI in gaming, healthcare, and financial technology (fintech) solutions. Additionally, companies like SenseTime Group (0020.HK) and Megvii Technology have built strong reputations in computer vision and facial recognition, while iFlytek (002230.SZ) has become a leader in AI-driven speech recognition and natural language processing. Despite their innovative capabilities, these companies have experienced fluctuating stock performances due to factors such as China's economic conditions, evolving regulatory policies, geopolitical tensions, and global AI competition (Shi, Feng, Zhang, Shuai, & Niu, 2023). Investors closely monitor these trends, as shifts in AI regulations, trade restrictions, and technological breakthroughs can have a profound impact on the valuation and future growth prospects of China's AI sector. As AI continues to evolve, the stock performance of these companies will remain a critical indicator of both China's AI ambitions and the broader global AI market (Dixon, 2023).

The stock price trends of leading Chinese AI companies have been shaped by a combination of technological advancements, government policies, and macroeconomic factors. Baidu (BIDU) has seen volatility in its stock performance as it transitions into an AI-first company, with investments in autonomous driving and AI cloud services boosting investor confidence, though U.S.-China trade tensions and economic conditions have introduced uncertainty. Alibaba (BABA) has heavily leveraged AI in cloud computing and e-commerce, but regulatory scrutiny and crackdowns on China's tech sector have led to stock price declines in recent years. Tencent (TCEHY) has benefited from AI-driven investments in gaming and fintech, but regulatory restrictions on gaming and online platforms in China have contributed to price fluctuations. SenseTime (0020.HK), a leader in AI-driven facial recognition, has faced stock challenges due to U.S. sanctions and ethical concerns over surveillance technology, while iFlytek (002230.SZ) has maintained relative stability, benefiting from government contracts in AI-driven education and smart assistants (Li, et al., 2018).

Several key factors influence AI stock performance in China. Government regulations play a significant role, as tighter oversight on data privacy, algorithmic transparency, and monopolistic practices impact AI firms' operations and market valuations. Companies involved in surveillance technologies also face restrictions from global markets, affecting investor sentiment. The U.S.-China trade war and sanctions have further complicated AI stock performance, particularly due to U.S. restrictions on semiconductor exports, which hinder AI firms reliant on advanced chips for deep learning

and cloud computing. AI leaders like SenseTime and Huawei have been blacklisted by the U.S., affecting their access to foreign markets and technology. Meanwhile, technological advancements in self-driving cars, generative AI, and AI chips have driven stock price gains for firms investing in these high-growth areas. However, macroeconomic conditions, including China's economic slowdown, global inflation, and fluctuating investor sentiment toward high-growth tech stocks, have created market uncertainty. Lastly, global AI adoption trends in sectors like healthcare, finance, and retail have driven long-term optimism, with Chinese AI firms expanding into global markets to strengthen their investment appeal. As AI technology continues to evolve, the stock performance of these companies will remain a key indicator of both China's AI ambitions and its position in the global AI market (Chen & Zhang, 2024).

The future outlook for AI stocks in China remains a mix of opportunities and challenges. Continued AI investment is expected to drive industry growth, as the Chinese government remains committed to AI leadership through policies promoting research, infrastructure, and commercialization. However, regulatory uncertainty poses risks, as evolving government policies on data privacy, AI ethics, and monopolistic practices could impact business operations and investor sentiment. At the same time, technological innovation, particularly in AI chips, autonomous systems, and generative AI, may serve as a catalyst for stock performance, with companies investing in these areas likely to benefit from long-term growth trends. Additionally, global expansion is a key factor for future success—Chinese AI firms with international partnerships and deployments may attract stronger investor interest, as global demand for AI solutions in sectors like healthcare, finance, and smart cities continues to rise. Overall, the stock price performance of AI companies in China reflects a dynamic balance between innovation-driven growth and regulatory challenges (Song, Ai, & Li, 2015). While short-term volatility remains a concern due to geopolitical tensions, economic conditions, and policy shifts, the long-term prospects for AI firms appear promising. As China continues to lead in AI adoption and technological advancements, investors should closely monitor policy developments, market trends, and global AI movements to make well-informed decisions about AI stocks in China.

4. FINANCIAL PERFORMANCE ANALYSIS OF CHINESE AI COMPANIES

The artificial intelligence (AI) industry in China has experienced rapid growth over the past decade, driven by strong government support, a vast consumer base, and continuous advancements in AI technologies. As one of the global leaders in AI innovation, China's AI sector consists of both large technology conglomerates and specialized AI firms, making the financial performance of these companies a critical indicator of the industry's sustainability, competitiveness, and global impact. This article provides an in-depth analysis of the revenue growth, profitability, funding trends, and challenges faced by leading AI firms in China. The key players in the industry include Baidu, Inc. (BIDU), which leads in AI-powered search engines, autonomous driving, and cloud computing; Alibaba Group

(BABA), which integrates AI into e-commerce, cloud computing, and smart logistics; and Tencent Holdings (TCEHY), which focuses on AI applications in gaming, fintech, and healthcare. Other notable firms include SenseTime Group (0020.HK), a dominant player in facial recognition and computer vision; iFlytek (002230.SZ), which specializes in AI-powered speech recognition and language processing; and Megvii Technology, a key player in facial recognition and smart security solutions. The financial performance of these companies varies depending on market conditions, regulatory developments, and technological advancements, highlighting both the opportunities and challenges within China's dynamic AI landscape (Cao & Power, 2025).

China's AI industry has witnessed remarkable revenue growth and market expansion, with leading companies leveraging AI-driven innovations to strengthen their financial performance and competitive positioning. Baidu has made substantial investments in AI-driven search, autonomous vehicles, and cloud services, with its AI Cloud and Apollo self-driving technology playing a key role in revenue generation. Alibaba, on the other hand, has seen significant revenue contributions from its AI-powered cloud computing division, Alibaba Cloud, while its smart logistics and retail solutions have further solidified its market dominance. Tencent has capitalized on AI to enhance its gaming, fintech, and healthcare sectors, with AI-powered recommendation algorithms and cloud services playing a crucial role in boosting its earnings. SenseTime, despite facing challenges such as U.S. blacklisting, has continued to experience strong revenue growth in AI surveillance and smart city projects, while also expanding into AI-driven healthcare and financial services. Similarly, iFlytek has benefited from its AI-driven educational tools and enterprise AI solutions, with government contracts and partnerships in speech recognition technology driving steady revenue growth. These companies continue to shape China's AI landscape, demonstrating resilience and adaptability in an evolving market.

The profitability and cost structures of Chinese AI companies vary widely, influenced by factors such as research and development (R&D) expenses, infrastructure costs, and revenue diversification. Many firms operate with high R&D expenditures, which, while crucial for innovation, can limit short-term profitability. Baidu and Tencent have successfully integrated AI into multiple revenue streams, allowing them to achieve profitability through a diversified business model. In contrast, companies like SenseTime and Megvii have faced challenges in maintaining profitability due to high infrastructure costs and heavy reliance on government contracts. Alibaba Cloud, despite being a major revenue driver for Alibaba, is still working toward sustained profitability as it navigates intense competition in the cloud computing space. Investment and funding trends in China's AI sector also play a crucial role in shaping its growth. Chinese AI startups have secured billions in venture capital (VC) funding, with prominent investors such as Sequoia China, Hillhouse Capital, and SoftBank fueling industry expansion. In addition to private investments, the Chinese government has been a strong financial backer, allocating substantial funds to AI infrastructure, research grants, and startup incubation programs to ensure the sector's long-term development. However, publicly traded AI firms like SenseTime and iFlytek have

encountered stock price volatility due to regulatory risks and macroeconomic factors, highlighting the complexities of operating in an evolving AI landscape (Clarke, 2019).

Chinese AI companies face a range of challenges and risks that impact their financial stability and growth potential. Regulatory scrutiny remains a significant concern, as firms must navigate strict regulations related to data privacy, AI ethics, and market competition. Additionally, global trade restrictions, particularly U.S. sanctions on Chinese AI firms, have created financial risks by limiting access to critical semiconductor supply chains. The high cost of research and development (R&D), coupled with the need for advanced computing infrastructure, further affects profitability, making it difficult for some companies to sustain long-term growth. Market competition is another key challenge, with firms aggressively competing for government contracts and corporate clients in an increasingly crowded industry. Moreover, China's broader economic slowdown has had a ripple effect on investment levels and consumer demand for AI-powered services, adding another layer of uncertainty for AI firms. Despite these challenges, the future outlook for China's AI industry remains promising. Government-driven growth, supported by continued state investment in AI infrastructure and research, is expected to fuel industry expansion. Efforts to reduce reliance on foreign semiconductor technology through advancements in AI chips will be crucial for ensuring long-term financial health and technological self-sufficiency. Furthermore, companies that successfully expand into international markets will improve their financial stability and reduce dependence on domestic demand. AI's integration across various industries, including healthcare, finance, and logistics, is also set to unlock new revenue opportunities, positioning Chinese AI firms for sustained growth and innovation in the global market (Shi, Feng, Zhang, Shuai, & Niu, 2023).

The financial performance of AI companies in China reflects a mix of rapid growth, regulatory challenges, and evolving market dynamics. While the sector remains promising, firms must navigate high costs, policy risks, and global trade uncertainties. Investors and industry stakeholders should monitor technological advancements, government policies, and financial trends to assess the long-term viability of China's AI industry.

Table 1. Key Financial Performance Indicators for the Chinese AI Companies

Financial Key Performance Indicators
Price To Book
Cash Per Share
Return On Equity
Debt To Equity
quick Ratio

enterprise To Revenue
Enterprise To EBITDA
Current Ratio
Forward PE

To assess the financial performance of the Chinese AI companies, the key financial performance indicators for the 51 Chinese AI companies were evaluated. The financial key performance indicators represent an important assessment criterion to determine both the similarity between the corporation's performance, as well as the focus on ratios enables to assess various enterprises irrespective of their size, denominated currency, and listing place. The evaluated indicators are outlined in Table 1. The price-to-book (P/B) ratio evaluates a company's market valuation relative to its book value. Typically, market value exceeds book value, and value investors use the P/B ratio to identify potential investments. A P/B ratio below 1.0 is often seen as a solid investment, though what constitutes a good ratio varies by industry. The P/B ratio measures how the market values a company's equity relative to its book value. Investors use it to identify undervalued stocks, hoping to profit when the market corrects the stock's price based on their analysis. Cash Per Share (CPS) measures the cash and cash equivalents a company has per share, reflecting its financial health and liquidity. It indicates readily available funds without needing asset sales, new financing, or additional revenue. The metric is used for liquidity analysis, investment decisions, and comparative analysis. It helps assess a company's ability to cover short-term liabilities, indicates financial strength for growth or debt reduction, and allows investors to compare stability across industry peers.

Return on Equity (ROE) is calculated by dividing net income by shareholders' equity, measuring a company's profitability and efficiency in generating returns. A higher ROE indicates effective equity financing, though its significance varies by industry. Comparing ROE to industry peers or the S&P 500 average provides valuable insights.

The debt-to-equity (D/E) ratio measures a company's reliance on debt by comparing total liabilities to shareholder equity. It varies by industry and is most useful for comparing competitors or tracking changes over time. A higher D/E ratio indicates greater risk, while a very low one may suggest underutilized debt financing. Investors often adjust the ratio to focus on long-term debt, which carries higher risk.

The quick ratio assesses a company's ability to cover current liabilities using its most liquid assets, excluding inventory and prepaid expenses. It provides a more conservative measure than the current ratio and is calculated by dividing cash, marketable securities, and receivables by total current liabilities.

A higher ratio indicates stronger liquidity, while a lower one suggests potential difficulty in meeting obligations.

The enterprise value-to-revenue (EV/R) multiple compares a company's enterprise value to its revenue, helping investors assess whether a stock is fairly priced. Also known as the enterprise value-to-sales multiple, it is commonly used in acquisitions and is useful for valuing companies that do not yet generate profits.

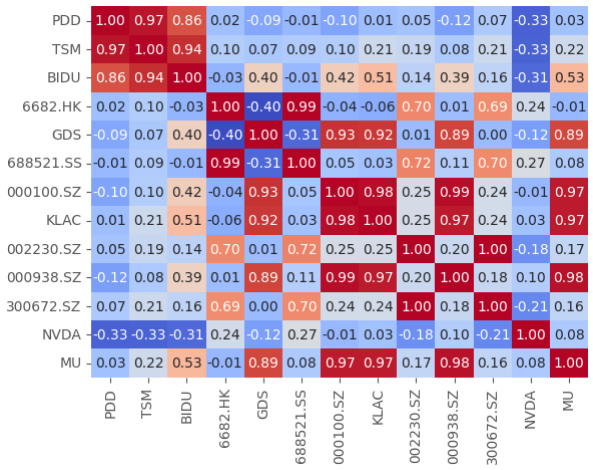
The enterprise multiple (EV/EBITDA) measures a company's value by dividing enterprise value by EBITDA. It accounts for debt, cash levels, and stock price while reflecting cash profitability. Industry variations affect multiples, with higher values in high-growth sectors and lower ones in slower-growing industries.

The current ratio compares a company's total current assets to its current liabilities, helping investors assess its ability to cover short-term debts. While useful for comparing companies within the same industry, it's less effective across different sectors due to varying industry norms. Limitations include overgeneralization of asset and liability balances and a lack of trending data.

Forward P/E is a variation of the price-to-earnings ratio that uses projected earnings for the calculation. Since it relies on estimated earnings per share (EPS), it can lead to inaccurate results if actual earnings differ. Analysts typically combine forward and trailing P/E ratios with other financial metrics for a more informed assessment (Malichová & Ďurišová, 2015).

These financial metrics represent an important cornerstone of the assessment of the various Chinese companies and determine their relationships and performance similarities. The first analysis represents the correlation between those that are weakest correlated with all other enterprises. Figure 1 displays the correlations of 13 companies that are weakest correlated based on the mean average correlation factor.

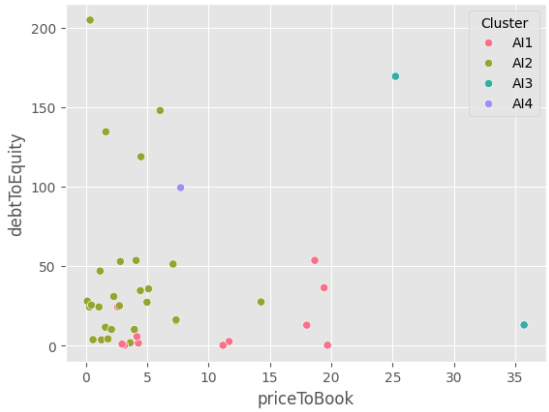
Figure 1. Correlations between the Chinese AI Companies



While there is a strong correlation between the companies such as PDD, TSM and BIDU with average correlations hovering around and above 0.8 outlining that the performance indicators show strong similarities in terms of behavior and pattern. In contrast, the correlation between the other Chinese AI-related stocks is fairly weak being relatively close to zero. In contrast, the other Chinese corporations exhibit a mixed picture but show some correlation depending on the place of listing. Generally, the results and performance indicate stronger dependence based on general market factors, rather than individual stock performance.

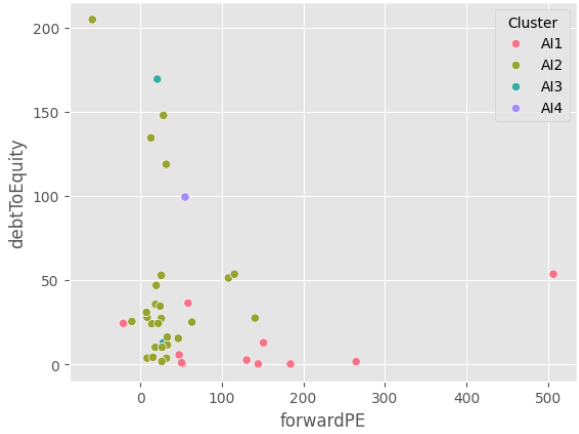
In the next step, all the corporations were clustered into four different clusters utilizing the k-means clustering technique.

Figure 2. Clustering Comparison between Debt-to-Equity, and Price-to-Book Ratios



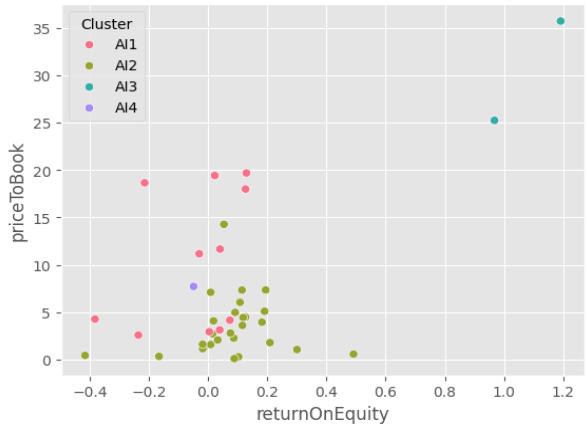
The first comparison is the clustering between debt-to-equity and price-to-book ratios in Figure 2. The results indicate that clustering is highly structured around those with high debt-to-equity and limited price-to-book ratios. Additionally, the cluster AI3 is highly dependent on the price-to-book ratio, primarily encompassing KLA Corporation (KLAC), and Nvidia (NVDA).

Figure 3. Clustering Comparison between Debt to Equity, and forward PE



The next is the clustering comparison between debt to equity and forward PE in Figure 3 and return on equity as well as the price to book ratio in Figure 4.

Figure 4. Clustering Comparison between Price to Book and Return on Equity



The next group is AI4 which consists of Shijiazhuang ChangShan BeiMing Technology Co., Ltd (000158.SZ) as a single entity. This serves primarily to indicate an outlier rather than a specific clustering group performing the stock and presence. The main cluster is represented by AI2 distinguished by high debt-to-equity with low price-to-book ratios. This contrasts with the cluster AI1 which is distinguished by high price-to-book ratios with limited debt-to-equity.

Table 2. Clustering Allocation of the Chinese AI Companies

Company	*Price To Book*	*Return On Equity*	*Cluster*
0020.HK	2.600619	-0.236	AI1
0700.HK	5.11206	0.19084	AI2
9988.HK	0.302874	0.10274	AI2
BABA	0.31707	0.10274	AI2
BIDU	0.121581	0.08852	AI2
GDS	0.351416	-0.16596	AI2
GOTU	0.453951	-0.41627	AI2
0981.HK	19.42085	0.02246	AI1
1810.HK	7.344712	0.11428	AI2
6682.HK	4.282761	-0.38249	AI1
KLAC	25.23421	0.96809	AI3

MU	2.276709	0.08657	AI2
NVDA	35.7112	1.19177	AI3
PDD	0.586499	0.49151	AI2
600271.SS	1.271063	-0.01379	AI2
600718.SS	1.598862	0.00869	AI2
600745.SS	1.165523	-0.01836	AI2
600797.SS	2.736065	0.01485	AI2
603160.SS	4.169874	0.07358	AI1
603486.SS	4.988551	0.09132	AI2
603893.SS	19.69468	0.12941	AI1
688041.SS	17.99954	0.12645	AI1
688521.SS	18.65555	-0.21472	AI1
000100.SZ	1.631082	-0.01857	AI2
000158.SZ	7.728969	-0.04931	AI4
000938.SZ	6.054192	0.10779	AI2
000977.SZ	4.494198	0.12627	AI2
000988.SZ	4.4485	0.11827	AI2
002230.SZ	7.109649	0.00857	AI2
002236.SZ	1.80863	0.20912	AI2
002241.SZ	2.810737	0.07554	AI2
002273.SZ	3.618873	0.11601	AI2
002415.SZ	3.953852	0.18208	AI2
300124.SZ	7.354852	0.1945	AI2
300223.SZ	3.14644	0.03906	AI1
300339.SZ	14.2795	0.05341	AI2
300474.SZ	11.67023	0.04018	AI1

300496.SZ	2.956647	0.00383	AI1
300672.SZ	4.098404	0.01821	AI2
300766.SZ	11.17719	-0.03003	AI1
TSM	1.071342	0.30036	AI2
TAL	2.088953	0.03232	AI2

The distribution in terms of the clusters indicates a strong differentiation that is primarily based on the significant valuations of those in the AI1 cluster based on both forward PE, as well as price-to-book ratios as compared to those in AI2 that exhibit higher debt levels and limited price movements. While there is massive potential for those in AI2, these entities are mostly at an earlier development stage and experience higher debt levels due to the request to scale up.

5. CONCLUSION

China's artificial intelligence (AI) industry has rapidly expanded over the past decade, driven by government support, a large consumer market, and continuous technological advancements. Leading companies such as Baidu, Alibaba, and Tencent have integrated AI into various sectors, including cloud computing, e-commerce, and gaming, while firms like SenseTime and iFlytek specialize in facial recognition and speech processing. Despite facing regulatory challenges and high research and development costs, these companies continue to grow through AI-driven innovations. Investment trends, including venture capital and government funding, play a crucial role in shaping the industry. However, factors such as market volatility and competition highlight the challenges of maintaining profitability in China’s evolving AI landscape.

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STANDARDIZATION OF COMMUNICATION TERMINOLOGY AMONG TURKIC STATES: A MODEL PROPOSAL FROM THE PERSPECTIVE OF PUBLIC DIPLOMACY

Prof. Dr. Mehmet YÜCE[*]

ÖZET

Son yıllarda Türk Devletleri arasındaki artan siyasi, ekonomik ve kültürel iş birliği, iletişim alanında ortak bir terminoloji ihtiyacını ortaya çıkarmıştır. Ancak tarihsel, dilsel ve kurumsal farklılıklar nedeniyle iletişim kavramlarının ülkeden ülkeye değişmesi, kamu diplomasisi faaliyetlerinde anlam kaymalarına ve etkinlik kaybına yol açmaktadır. Bu çalışma, iletişim terminolojisinin standardizasyon gerekliliğini kamu diplomasisi perspektifinden incelemektedir. Nitel yöntem kapsamında Türkiye ve Özbekistan başta olmak üzere seçili Türk devletlerine ait resmî belgeler, medya içerikleri ve iletişim materyalleri karşılaştırmalı olarak analiz edilmiştir. Bulgular, aynı kavramların farklı şekillerde kullanıldığını ve bunun mesaj iletimini zorlaştırdığını göstermektedir. Bu doğrultuda çalışma, kurumsal koordinasyon, dijital terminoloji veri tabanı ve eğitim süreçlerini içeren çok Paydaşlı bir model önermektedir. Sonuç olarak, terminoloji standardizasyonu, kamu diplomasisinin etkinliğini artıracak stratejik bir araçtır.

***Anahtar Kelimeler**: Türk Devletleri, İletişim Terminolojisi, Kamu Diplomasisi, Stratejik İletişim, Kültürlerarası İletişim.*

***JEL Codes:** F50, Z13, D83.*

STANDARDIZATION OF COMMUNICATION TERMINOLOGY AMONG TURKIC STATES: A MODEL PROPOSAL FROM THE PERSPECTIVE OF PUBLIC DIPLOMACY

ABSTRACT

In recent years, increasing political, economic, and cultural cooperation among Turkic States has revealed the need for a common communication terminology. However, differences in historical, linguistic, and institutional backgrounds lead to variations in communication concepts across countries, causing semantic shifts and reduced effectiveness in public diplomacy practices. This study examines the necessity of standardizing communication terminology from a public diplomacy perspective. Using a qualitative approach, official documents, media content, and communication materials from selected Turkic States, particularly Türkiye and Uzbekistan, are analyzed comparatively. Findings indicate that similar concepts are used differently, complicating effective message transmission. Accordingly, the study proposes a multi-stakeholder model including institutional coordination, a digital terminology

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database, and educational processes. In conclusion, terminology standardization is a strategic tool to enhance public diplomacy effectiveness.

Keywords: *Turkic States, Communication Terminology, Public Diplomacy, Strategic Communication, Intercultural Communication.*

JEL Codes: *F50, Z13, D83.*

1. INTRODUCTION

Following the end of the Cold War, political, economic, and cultural relations among the Turkic states that gained independence have developed significantly. In recent years, growing regional cooperation initiatives and multilateral mechanisms have demonstrated a strong commitment to fostering a more integrated structure within the Turkic world. These developments have highlighted the need for a common ground not only in institutional and economic domains but also in the fields of communication and language.

Official contacts, media interactions, and public diplomacy activities among the Turkic states require an effective and consistent language of communication. However, differences arising from distinct historical trajectories, changes in writing systems, language policies, and terminological preferences have resulted in variations in the concepts and terminology used in the field of communication across countries. This situation, particularly in the context of public diplomacy, makes it more difficult to convey messages accurately and effectively to target audiences and may occasionally lead to shifts in meaning and communication gaps.

Against this background, the central problem addressed by this study is the conceptual fragmentation observed in communication terminology among the Turkic states and its adverse effects on strategic communication processes. The absence of a common terminology constitutes not merely a technical linguistic challenge but also a significant obstacle in terms of perception management, message consistency, and institutional communication.

Building upon this problem, this study aims to examine the need for the standardization of communication terminology among the Turkic states from a public diplomacy perspective. Accordingly, the study focuses on the following research questions:

- What types of differences exist in communication terminology among the Turkic states?

- How do these differences affect public diplomacy processes?

- Is it possible to develop a common communication terminology, and what kind of model could be proposed for this purpose?

The answers to these questions are expected to contribute to the development of a more effective, consistent, and strategic communication framework within the Turkic world.

2. CONCEPTUAL AND THEORETICAL FRAMEWORK

2.1. The Concept of Public Diplomacy

The increasing complexity of international relations in the twenty-first century has transformed public diplomacy into a significant instrument of foreign policy. Public diplomacy seeks to foster cooperation and strengthen societal relations through engagement and communication with target audiences. Activities conducted in areas such as culture, education, media, and humanitarian assistance vary according to international circumstances and are strategically guided by states. Although public diplomacy is fundamentally communication-oriented, it is supported by political, economic, and social instruments and is closely associated with multiple disciplines. In relation to the concept of power, the notion of "integrated power," which considers soft power together with elements of hard power, offers a more comprehensive framework for understanding public diplomacy (Aydın, 2025: 2017-2011).

Unlike traditional diplomacy, public diplomacy encompasses communication not only between states but also among societies. Joseph S. Nye Jr. conceptualizes public diplomacy within the framework of "soft power" and defines it as a country's capacity to influence other societies through its values, culture, and policies (Nye, 2004: 5-11). The changing nature of international politics has increased the significance of intangible forms of power. National cohesion, universal cultural values, and international institutions have gained increasing importance. This is because power is shifting from "capital-rich" actors toward "knowledge-rich" actors (Nye, 2004: 164).

Public diplomacy refers to the communication activities undertaken by a state to influence and understand foreign publics and to explain its policies to them. It constitutes a process of relationship-building aimed at understanding the societies, cultures, and needs of other countries; communicating appropriate messages accurately; addressing misconceptions; and creating a basis for cooperation around shared objectives. In this respect, public diplomacy encompasses the range of positive relationships established by state and non-state actors with foreign publics. Such a process facilitates the recognition of the values, traditions, beliefs, and social structures of different societies. It thereby contributes to reducing prejudices, strengthening mutual understanding, identifying common ground, and creating an environment conducive to consensus (CIB, 2022: 11).

In conclusion, public diplomacy has its own distinctive methods and instruments. Accordingly, as a field rooted in both international relations and communication, public diplomacy is increasingly developing toward recognition as a distinct area of study. States can often achieve rapid and direct outcomes through military and economic power. Soft power, however, differs from these more coercive instruments in that its effects are more difficult to control and unfold over an extended period. A significant portion of its sources lies beyond the direct control of states, while its effectiveness depends to a considerable extent on the voluntary acceptance of the societies concerned. Soft power therefore represents a more subtle and profound form of influence: its effects may not become immediately

visible, but over time it can shape perceptions, attitudes, and ultimately the policy environment. Public diplomacy consequently encompasses multidimensional networks of relationships, with its effects unfolding gradually over time.

2.2. Strategic Communication and the Role of Language

Strategic communication refers to communication activities that are deliberately planned and coordinated in order to achieve specific objectives. It encompasses coordinated actions, messages, visual materials, and other forms of communication and engagement. Its purpose is to inform, influence, and persuade selected audiences in support of national objectives. The concept establishes a fundamental link between national objectives and the systematic implementation of processes, strategies, and communication aimed at achieving defined goals and generating positive change. In political terms, strategic communication involves shaping communication strategies in ways that influence particular perspectives and behaviors in pursuit of a common objective. Strategic communication is therefore not merely a media-oriented campaign; rather, it encompasses comprehensive political, diplomatic, economic, and military engagement with selected target audiences. The concept of strategic communication is implemented in coordination with public diplomacy and seeks to mitigate the negative connotations traditionally associated with propaganda (Zainab, 2024: 71).

Strategic communication is not merely a communication activity; it represents a multidimensional process of interaction in which political will plays a determining role and which encompasses the entire institutional structure of the state as well as the broader social sphere. Once understood primarily as a military approach or, in a narrower sense, as a media strategy, the concept has evolved into a comprehensive form of "grand strategy" based on two-way flows of information and feedback. Within this framework, strategic communication is structured around four principal components: information operations, psychological operations, public diplomacy, and public affairs (Cornish et al., 2011: 4–5).

The language employed in this process is one of the fundamental factors determining not only how a message is communicated but also how it is perceived, interpreted, and ultimately translated into impact. Through the choice of language, concepts, tone, discursive forms, and cultural references, communication constructs a particular field of meaning in the minds of target audiences. Language in strategic communication should therefore not be regarded as a neutral instrument but rather as a constitutive component with the capacity to generate direct effects. James P. Farwell, for instance, defines strategic communication as the "planned use of communication in the process of perception management and persuasion" (Farwell, 2012: 18), highlighting the deliberate and consistent use of language as one of the critical dimensions of strategic planning.

From this perspective, inconsistencies in the language and terminology employed by different institutions or actors not only undermine the coherence of messages but may also lead to a loss of credibility, confusion in perception, and diminished persuasive capacity among target audiences.

Particularly in the context of public diplomacy, the absence of a strategically coherent linguistic framework can fragment a state's narrative and weaken its overall impact. Language therefore occupies a central position in strategic communication to the extent that it cannot be considered independently of content; it functions simultaneously as the vehicle through which messages are conveyed and as a determining instrument in the construction of meaning.

2.3. Terminology Standardization

Terminology can be defined as the field of study concerned with concepts, the terms that represent those concepts in language, and the relationships among them. As a field interconnected with numerous disciplines, terminology is of direct relevance to specialists working across all specialized languages and subject fields (Girişen, 2020: 56). Terminology standardization, in turn, can be defined as the process of harmonizing concepts used within a particular field through common definitions and expressions. This process seeks to ensure clarity and consistency in communication, particularly in multilingual and multicultural environments. The International Organization for Standardization (ISO) defines terminology as "concepts belonging to a particular subject field and their designations" and describes standardization as the process of harmonizing these concepts and their designations (ISO, 2009: 1-3).

Accordingly, terminology constitutes a field of knowledge and communication that enables the systematic definition, naming, and representation of concepts generated within a particular domain of knowledge while organizing the linguistic and conceptual information associated with them. In this context, terminology treats concepts not merely as units of thought but also as units of knowledge, representing them through terms, symbols, definitions, codes, and audiovisual elements. Its principal objective is to ensure that communication within a particular field of expertise is conducted clearly, consistently, and comprehensibly while minimizing conceptual ambiguity and semantic confusion.

Language requires a robust and systematic terminology in order to function effectively as a language of science. As scientific developments occur and new fields of knowledge emerge, terminology continuously expands and becomes more sophisticated. This process advances through the production of scientific research, the compilation of terminological dictionaries, and the development of educational materials. Terminology is indispensable to the generation and transmission of scientific knowledge, while terms constitute fundamental building blocks of scientific thought by expressing concepts with clear and delimited meanings (Minsafina, 2021: 3).

In the Turkic world, the standardization of terminology, particularly in the field of communication, is of considerable importance for ensuring the consistency and effectiveness of information flows through the establishment of a shared semantic foundation. Differences among Turkic varieties and national terminological preferences may result in the same concept being expressed in different ways, potentially leading to semantic shifts and communication gaps in academic production,

media discourse, and institutional communication. In a field such as communication, where speed, accuracy, and effectiveness are particularly important, the availability of common and clearly defined equivalents for key concepts would not only strengthen regional cooperation but also contribute to enhancing the visibility and effectiveness of the Turkic world within the global communication environment. Terminology standardization should therefore be regarded not merely as a linguistic arrangement but also as a critical requirement for promoting common knowledge production, cultural integration, and the enhancement of strategic communication capacity.

2.4. Intercultural Communication Context

Intercultural communication is a multidisciplinary field that examines the processes through which meaning is constructed, transmitted, interpreted, and negotiated among individuals and societies with different cultural backgrounds. Within this framework, language functions not merely as a technical instrument of communication, but also as a carrier of cultural elements, including values, norms, symbols, and collective memory. Edward T. Hall's distinction between high-context and low-context cultures demonstrates the decisive role of contextual cues and implicit cultural codes in communication (Hall, 1976: 85-90), while Geert Hofstede's cultural dimensions approach-including power distance, individualism versus collectivism, and related dimensions-explains how cultural differences are reflected in patterns of communication and social interaction (Hofstede, 2001: 9-28). Similarly, the cultural communication patterns developed by Edward T. Hall and Mildred Reed Hall demonstrate that meaning is constructed not solely through linguistic expressions, but also through contextual, relational, and behavioral indicators.

Within this framework, the effective and sustainable conduct of intercultural communication among the Turkic states depends not only on shared linguistic elements, but also on the development of a common or mutually compatible conceptual and terminological framework. Michael Byram's approach to intercultural communicative competence emphasizes that individuals and institutions require not only linguistic proficiency but also the capacity to accurately interpret, negotiate, and convey culturally embedded meanings (Byram, 1997: 33-58). From this perspective, terminological standardization facilitates the harmonization of meanings generated within different cultural contexts, thereby reducing the risk of semantic ambiguity and misinterpretation while establishing a shared communicative foundation. This need becomes particularly pronounced in the field of communication, where concepts and terms may acquire different cultural connotations, interpretive frameworks, and associative meanings across societies.

Accordingly, the development of a common terminology across the Turkic World should be understood not merely as an instrument of linguistic convergence, but as a strategic process of harmonizing cultural codes, deepening mutual understanding, and strengthening the collective capacity for strategic communication. A shared terminological framework can therefore serve as an important

institutional and conceptual infrastructure for facilitating more coherent communication practices, enhancing intercultural communicative competence, and reinforcing the capacity of the Turkic states to articulate and convey common narratives within an increasingly interconnected international communication environment.

3. LITERATURE REVIEW

3.1. Studies on Language and Communication in the Turkic World

The issues of linguistic unity and communication in the Turkic world have gained increasing academic and political significance, particularly following the dissolution of the Soviet Union. During this period, issues such as a common alphabet, a common language, and common terminology have been addressed in a range of academic studies. A. Bican Ercilasun, one of the prominent scholars in this field, argues that differences among Turkic language varieties stem from distinct historical processes and that these differences may occasionally create challenges in communication (Ercilasun, 2013: 45–52). Mustafa Aydın emphasizes that, in parallel with the development of cooperation within the Turkic world, the need for common concepts and terminology in the field of communication has become increasingly important (Aydın, 2016: 120-125). From this perspective, terminology has emerged not merely as a linguistic issue but also as a strategic factor directly affecting processes of cooperation.

İbrahim Şahin, in turn, identifies the "issue of common terminology" as one of the most important and pressing challenges facing the Turkish language. He argues that, owing to the complexity of the issue, it has remained overshadowed by debates over a common alphabet and a common language of communication, while the shared linguistic heritage preserved in Old Turkic texts has not been sufficiently utilized in efforts to develop solutions. In this context, the resolution of the problem may be possible by drawing upon the common linguistic heritage of the Turkic world. Works dating from the emergence of the Turkish language through the thirteenth century are regarded by Turkic communities as a shared heritage and provide a lexical repertoire of approximately 10,000 words. Among these sources, particularly *Dīwān Lughāt al-Turk* by Mahmud al-Kashgari, with approximately 7,500 lexical items, represents a significant linguistic resource capable of contributing to greater linguistic cohesion across the contemporary Turkic world. It has been argued that terminology developed on the basis of this lexical heritage and approximately 140 suffixes found in Old Turkic could contribute to resolving the problem of common terminology while also strengthening unity, cooperation, and a shared understanding of the future among the various Turkic language varieties (Şahin, 2023: 124-134).

These studies demonstrate that, despite considerable linguistic affinity among the Turkic peoples, terminological inconsistencies persist and may create significant challenges, particularly in media and academic communication.

3.2. International Examples: Terminology Policies

At the international level, one of the most comprehensive examples of terminology standardization is provided by the European Union. Owing to its multilingual structure, the European Union addresses terminology management within an institutional framework and has developed various databases for this purpose. IATE (Interactive Terminology for Europe), established within the European Union, constitutes an important instrument for harmonizing concepts across different languages. IATE is used within EU institutions and agencies for the collection, dissemination, and management of the terminology employed by these institutions and bodies (European Commission, 2018: 10-15).

Such practices demonstrate the critical role of terminology standardization in enhancing the effectiveness of communication within multilingual and multicultural structures. In addition, terminology standards developed by the International Organization for Standardization contribute to achieving conceptual harmonization at the international level (ISO, 2009: 1-3).

Given the broad geographical scope of the Turkic world, preserving common linguistic elements and establishing terminological unity are of vital importance for the modernization and sustainability of Turkic languages. In this context, the experience of Arab language academies, which have provided a significant institutional model for language preservation and standardization, may offer a relevant reference. In the late nineteenth century, increasing pressure on the Arabic language in Arab countries under British and French colonial rule, particularly as educational systems increasingly shifted toward foreign languages, generated a need for institutional mechanisms to preserve the integrity of Arabic and adapt it to modern requirements. The establishment of Arabic Language Academies subsequently assumed important functions, including lexicographic development, the study of dialects, the creation of new terminology, and the promotion of scholarly research.

Drawing upon this institutional experience, a “Turkish Language Institute” could potentially be established within the framework of the Turkic Academy. Such an institution could assume responsibility for the systematic development, coordination, and standardization of terminology across the Turkic world.

3.3. Research Gap Analysis

Although the literature contains substantial research on linguistic unity, alphabet reforms, and cultural convergence in the Turkic world, studies addressing communication terminology systematically and at the institutional level remain limited. Existing research has predominantly focused on linguistic or cultural perspectives, while the dimensions of communication and public diplomacy have received comparatively insufficient attention.

In particular, the assessment of communication terminology within the context of public diplomacy and the development of an applicable model in this field constitute a significant gap in the existing literature. Addressing this gap, the present study seeks to contribute to scholarly debate by

proposing a comprehensive and strategic approach to the standardization of communication terminology among the Turkic states.

4. METHODOLOGY

This study was designed within a qualitative research approach to examine the standardization of communication terminology among the Turkic states. The qualitative method was selected because it enables the contextual and multidimensional examination of social phenomena. This approach provides a particularly appropriate research framework for analyzing complex processes involving language, communication, and intercultural interaction (Creswell, 2014: 4-6).

4.1. Qualitative Research Approach

Qualitative research is an approach aimed at interpreting the meaning systems, experiences, and perceptions of individuals and societies. In this study, particular attention was given to understanding not only the technical dimensions of differences in communication terminology but also their cultural and institutional dimensions. Accordingly, an interpretivist approach was adopted (Denzin & Lincoln, 2011: 12-15).

Data collection in qualitative research generally relies on techniques such as observation, interviews, document analysis, and discourse analysis. Within this approach, human behavior and perceptions are examined in depth within their natural and social contexts, while a holistic perspective that brings together insights from different disciplines is also adopted. Qualitative research approaches the research problem interpretively within its contextual setting and focuses on the meanings individuals attribute to events and phenomena. In this process, the researcher's exploratory reasoning plays a significant role and facilitates a deeper understanding of the relationships among phenomena. Although exploration constitutes an element of all research approaches, it is particularly important in qualitative research for developing an in-depth understanding of phenomena and events. At the same time, because qualitative research involves a researcher-centered interpretive process, it is subject to a certain degree of subjectivity and may be influenced by the researcher's interpretations and perspective (Baltacı, 2019: 370).

4.2. Document Analysis

Document analysis was employed as the primary data collection method in this study. Document analysis involves the systematic examination of written, visual, and digital materials. Within this framework, the following types of materials produced by the Turkic states, particularly Türkiye and Uzbekistan, were examined:

- Official institutional statements;

- Press releases;

- Media content; and

- Public diplomacy texts.

4.3. Document Analysis and Terminological Comparison

Document analysis was considered appropriate for the study because it enables a systematic and comprehensive assessment based on existing data (Bowen, 2009: 27-29). As a qualitative research technique, document analysis involves the systematic examination of written, visual, and digital materials. In this study, a comparative analysis approach was employed to identify terminological differences. In particular, drawing on the cases of Türkiye and Uzbekistan, different forms of usage of equivalent concepts were examined, and the implications of these differences for communication processes were assessed. The comparative approach enhances the analytical depth of the study by enabling similarities and differences to be identified systematically (Ragin, 2014: 15-18).

Accordingly, a total of 14 documents (see Appendix 1), consisting of official institutional statements, press releases, media content, and public diplomacy texts, were analyzed to comparatively examine the use of public diplomacy and communication terminology in the Turkic states, with particular emphasis on Türkiye and Uzbekistan. The selection of documents was based on four criteria: the level of official status, relevance to public diplomacy, publication between 2018 and 2025, and accessibility.

For the Türkiye sample, strategy documents published by the Presidency of the Republic of Türkiye Directorate of Communications, TİKA activity reports, cultural diplomacy texts produced by the Yunus Emre Institute, and Anadolu Agency content were examined. For the Uzbekistan sample, texts published by the Administration of the President of Uzbekistan, the Ministry of Foreign Affairs of the Republic of Uzbekistan, and the Agency for Information and Mass Communications were included in the analysis, together with content produced by UzA (Uzbekistan National News Agency) and Daryo.uz.

The documents were examined using thematic analysis, concept mapping, and frequency analysis techniques. A terminology coding scheme was developed around key concepts such as “public diplomacy,” “strategic communication,” “soft power,” and “media diplomacy.” The coding table developed within this framework identified the equivalents of Turkish and Uzbek terms and documented their respective contexts of use.

The analysis revealed that the concepts of “public diplomacy” and “strategic communication” are institutionalized and widely used in Türkiye, whereas in Uzbekistan, similar substantive meanings are more frequently articulated through concepts such as *axborot siyosati* (“information policy”) and *xalqaro hamkorlik* (“international cooperation”). The corresponding terms in other Turkic language varieties are presented as follows:

Table 1. Equivalents of Selected Communication-Related Concepts across Different Turkic Language Varieties

Concept (English)	Turkish	Uzbek	Kazakh	Kyrgyz	Azerbaijani
Public diplomacy	Kamu diplomasisi	Jamoat diplomatiyasi	Қоғамдық дипломатия (Qogamdyq diplomatiya)	Коомдук дипломатия (Koomduk diplomatiya)	İctimai diplomatiya
Soft power	Yumuşak güç	Yumshoq kuch	Жұмсақ күш (Jumsaq küsh)	Жумшак күч (Jumshak küch)	Yumşaq güc
Strategic communication	Stratejik iletişim	Strategik kommunikatsiya	Стратегиялық коммуникация (Strategiyalyq kommunikatsiya)	Стратегиялык коммуникация (Strategiyalyk kommunikatsiya)	Strateji kommunikasiya
Information policy	Enformasyon politikası	Axborot siyosati	Ақпарат саясаты (Aqparat sayasaty)	Маалымат саясаты Maalymat sayasaty)	İnformasiya siyasəti
International cooperation	Uluslararası iş birliği	Xalqaro hamkorlik	Халықаралық ынтымақтастық (Halyqaralyq yntymaqtastyq)	Эл аралык кызматташтык El aralyk kyzmattashtyk)	Beynəlxalq əməkdaşlıq

Source: Compiled by the authors.

Although these concepts exhibit similarities, they differ significantly in terms of their content, intended purposes, and institutional contexts. While the concepts of “public diplomacy” and “strategic communication” used in Türkiye primarily refer to planned, multi-actor, and long-term communication strategies aimed at influencing foreign publics, the concepts of “axborot siyosati” and “xalqaro hamkorlik” that are more prominent in Uzbekistan largely reflect state-centered information management and diplomatic cooperation processes. This situation points to a structural difference between the two countries not only in terms of terminology but also with regard to their underlying approaches to communication and public diplomacy.

Based on the findings obtained, this study proposes a “Common Communication Terminology Model” for the standardization of communication terminology across the Turkic world. The first component of the model is the establishment of a “common terminology pool” based on the heritage of Old Turkic and contemporary usage. Second, institutional coordination is proposed through the establishment of a “Terminology Commission” within the Organization of Turkic States. The third component involves the creation of a digital terminology platform operating on a model similar to the European Union’s IATE system. Fourth, the model aims to facilitate both the development and dissemination of terminology through coordination among academia, the media, and public institutions. Finally, the integration of terminology into public diplomacy is proposed to strengthen the development of common narratives and greater coherence in perceptions.

In conclusion, the model approaches the standardization of communication terminology in the Turkic world not merely as a process of linguistic harmonization but also as a strategic instrument for public diplomacy, soft-power generation, and regional cooperation. Accordingly, common terminology

can become a fundamental element in enhancing communication effectiveness among the Turkic states, fostering trust and predictability, and strengthening their capacity for representation and visibility at the global level.

5. FINDINGS

5.1. Terminological Differences

As part of this study, a document analysis of a total of 14 documents from Türkiye and Uzbekistan identified significant similarities and differences in the use of public diplomacy and communication terminology. The concepts identified during the analysis were thematically classified, while their frequencies of use and contextual meanings were comparatively assessed.

The findings indicate that concepts such as "public diplomacy," "strategic communication," and "soft power" are widely and institutionally used in both official institutional documents and media content in Türkiye. In particular, public diplomacy appears to be systematically addressed as one of the instruments of the state's foreign policy, with a coordinated terminological framework established across different institutions. This suggests that communication terminology in Türkiye has developed within an institutional framework that is broadly aligned with the international literature.

By contrast, in the Uzbekistan sample, similar substantive meanings were found to be articulated predominantly around the concepts of axborot siyosati ("information policy") and xalqaro hamkorlik ("international cooperation"). The use of these concepts reflects a predominantly state-centered approach, with communication processes being addressed primarily in the context of information management and formal diplomatic relations. Accordingly, it may be argued that communication terminology in Uzbekistan has not yet become fully institutionalized around conceptual frameworks such as public diplomacy and strategic communication.

The comparative analysis reveals a degree of terminological divergence between the two countries. While a more multi-actor, interaction-oriented, and strategic communication perspective is prominent in Türkiye, a more centralized and information-management-oriented approach appears to prevail in Uzbekistan. This difference reflects not merely a linguistic divergence but also a differentiation in the conceptual and practical understanding of public diplomacy.

At the same time, both countries have experienced increasing institutionalization of communication and foreign policy processes, accompanied by growing terminological diversity. This development points to the potential for establishing a common communication terminology among the Turkic states. However, the existing differences demonstrate that such a process is unlikely to emerge spontaneously and would instead require systematic and institutionalized efforts.

In conclusion, the findings clearly demonstrate the need for a model aimed at standardizing communication terminology among the Turkic states. The development of common conceptual

frameworks may enhance the effectiveness of public diplomacy activities while contributing to regional cooperation and greater international visibility.

5.2. Communication Challenges

The analysis indicates that terminological differences generate a range of challenges in communication processes. The most prominent include:

- Shifts in meaning during translation processes;

- Conceptual inconsistencies in official statements; and

- Divergent interpretations in media content.

These challenges make it more difficult for messages to reach target audiences accurately and effectively and consequently reduce communication efficiency. Furthermore, the use of different terminology to describe the same issue may generate divergent perceptions among the public.

Communication challenges arising from terminological differences clearly demonstrate the need for the proposed "*Common Communication Terminology Model for the Turkic World*." Meaning shifts, conceptual inconsistencies, and differences in interpretation observed in communication processes point to the absence of a common terminological infrastructure. The literature emphasizes that public diplomacy is directly associated with processes of meaning-making and perception management (Melissen, 2005: 3-27; Cull, 2009: 12-25). From this perspective, differences in terminology should be regarded not merely as linguistic diversity but also as a structural challenge that may undermine communication effectiveness.

The components of the proposed model, including a common terminology pool, an institutional coordination mechanism, and a digital terminology platform, offer a comprehensive approach to addressing these challenges. In particular, the establishment of a common set of concepts can contribute to greater coherence in public diplomacy messaging and facilitate greater consistency in audience perceptions. This is also consistent with Joseph S. Nye's conceptualization of soft power as the capacity to generate influence through attraction and persuasion rather than coercive instruments (Nye, 2004: 5–11). Accordingly, by proposing a multi-actor and sustainable framework capable of minimizing communication challenges arising from terminological differences, the model may contribute to strengthening strategic communication capacity among the Turkic states.

5.3. Implications for Public Diplomacy

Terminological inconsistencies appear to have a direct impact on the effectiveness of public diplomacy activities. Since public diplomacy is a field that requires the production of accurate and coherent messages, conceptual differences may adversely affect this process.

In particular:

- The incomplete or inaccurate transmission of messages to target audiences;

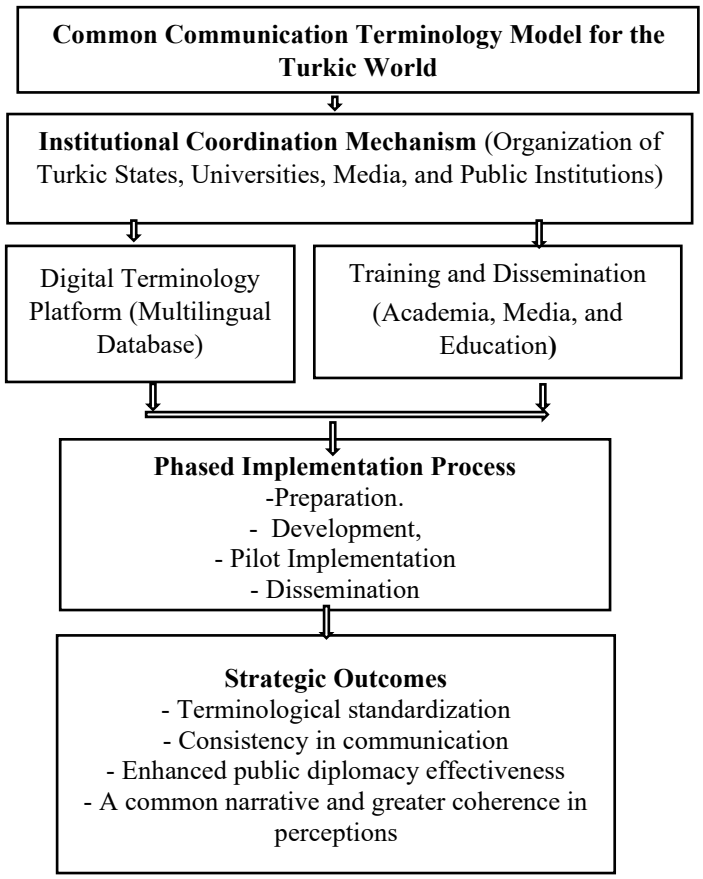
- Inconsistency in institutional discourse; and

- A weakening of the common narrative at the international level

are among the resulting consequences.

These findings demonstrate that the standardization of communication terminology is not merely a linguistic necessity but also a strategic imperative. Establishing a common terminology among the Turkic states would enhance the effectiveness of public diplomacy and contribute to the development of a stronger, more coherent, and more consistent communication framework.

Figure 1. Proposed Model for the Organization of Turkic States (OTS)



Source: Developed by the authors.

6. PROPOSED MODEL

Based on the findings obtained within the scope of this study, a multi-stakeholder, sustainable, and feasible model is proposed to facilitate the standardization of communication terminology among the Turkic states. Designed from a public diplomacy perspective, the proposed model consists of four

principal components: institutional structure, digital infrastructure, training and dissemination, and an implementation process.

6.1. Institutional Structure and Coordination

The first stage of the model envisages the establishment of a common coordination mechanism to conduct and coordinate terminology-related activities among the Turkic states. This structure should be designed as a multi-stakeholder platform involving universities, public institutions, media organizations, and relevant international organizations.

Within this framework, the establishment of a "Communication Terminology Working Group" under the Organization of Turkic States (OTS) is proposed. This body would be responsible for coordinating the processes of terminology development, updating, and standardization.

6.2. Digital Terminology Platform

The second component of the model involves establishing a digital platform to ensure the accessibility and sustainability of the common terminology. The platform should incorporate the following features:

- A multilingual terminology database;

- Concept definitions and examples of usage; and

- An open-access and continuously updateable structure.

Similar to the European Union's IATE database, this system would enable users to identify terminological equivalents quickly and accurately.

6.3. Training and Dissemination

Beyond the development of terminology itself, its effective adoption and use are equally important. Accordingly, the model proposes the development of:

- Integration into academic programs;

- Training programs for media professionals; and

- Guidelines for translators and communication specialists.

This process would enhance the practical applicability of the terminology and contribute to the sustainability of standardization efforts.

6.4. Phased Implementation Process

To enhance the feasibility of the proposed model, a phased implementation roadmap is recommended:

- Preparation Phase: Identification and analysis of existing terminology;

- Development Phase: Identification and definition of common concepts;

- Pilot Implementation: Testing in selected institutions and countries; and

- Dissemination: Implementation across all Turkic states.

This phased approach would enable the model to be implemented in a flexible and sustainable manner.

The proposed model represents not merely a technical approach to terminology standardization but a comprehensive framework aimed at establishing strategic alignment in communication and fostering a common narrative among the Turkic states. In this respect, the model has the potential to enhance the effectiveness of public diplomacy and establish a sustainable foundation for long-term cooperation in the field of communication across the Turkic world.

7. CONCLUSION AND RECOMMENDATIONS

This study has demonstrated that the standardization of communication terminology among the Turkic states constitutes a strategic imperative from the perspective of public diplomacy. The analyses conducted indicate that terminological differences may lead to shifts in meaning, inconsistencies in messaging, and a decline in the effectiveness of public diplomacy processes.

The model proposed in this study offers a comprehensive approach encompassing institutional coordination, digital infrastructure, training, and phased implementation. The implementation of this model would contribute to establishing greater conceptual coherence in communication among the Turkic states and, consequently, to the conduct of more effective and consistent public diplomacy.

Within the scope of the study, the following recommendations are put forward:

- An institutional mechanism should be established to coordinate common terminology initiatives among the Turkic states. In this context, a **"***Turkish Language Institute***"** should be established within the Turkic Academy.

- A multilingual and continuously updateable terminology database should be established.

- Terminology studies should be integrated into academic and professional education and training programs.

- Guidelines encouraging the use of common terminology should be developed for media organizations and public institutions.

In conclusion, the standardization of communication terminology should be regarded not merely as a process of linguistic harmonization in the Turkic world, but also as an important area of transformation in terms of strategic communication and public diplomacy. Such a process would

contribute to the development of a stronger communication network and the construction of a common narrative among the Turkic states.

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OVERCOMING FISCAL CONSTRAINTS THROUGH FORMAL EDUCATION: INSTITUTIONAL STRATEGIES, INTERNATIONAL SCHOLARSHIPS, AND SOCIAL WELFARE IMPROVEMENT IN BONDOWOSO REGENCY, INDONESIA

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ABSTRACT

Interregional development disparities in Indonesia are often rooted in low fiscal capacity and dependence on central government transfers, as seen in Bondowoso Regency. This situation creates a structural poverty trap in which limited fiscal space hinders productive public investment, particularly in education. This study aims to develop a policy model that links fiscal constraints, institutional strategies, and aspiration transformation to improve human capital without burdening regional budgets. Using a Mixed-Methods Embedded Case Study design, this research integrates econometric analysis with an in-depth qualitative approach. Quantitative analysis using the Vector Autoregression (VAR) method was applied to examine the structural pattern of the relationship between education level and economic growth based on secondary data. Meanwhile, qualitative analysis through observation, semi-structured interviews, and data triangulation was conducted to explore informational and sociocultural barriers, such as low educational aspirations and norms of early marriage that hinder the improvement of human capital quality. Initial findings indicate that information interventions regarding access to international scholarships can significantly increase interest in education. Theoretically, this research offers a novel approach by positioning international scholarships not merely as an instrument for individual mobility but as an externally financed regional development policy that triggers spillover effects on local productivity and fiscal capacity. The findings are expected to offer a replicable policy model for regions with similar fiscal characteristics, as they attempt to escape the poverty trap through globally oriented education strategies with tangible local impact.

Keywords: *Fiscal Capacity, Economic Education, Human Capital, International Scholarships, Transformation of Aspirations, Regional Development.*

JEL Codes: *A12, I21, I23, I25, I28, O11, O23.*

1. INTRODUCTION

Regional development disparities remain a fundamental challenge in the context of fiscal decentralization in Indonesia (Mahi, 2016). Although regional autonomy confers broad authority over resource management and development planning, limited fiscal capacity often constrains the

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effectiveness of public policy at the local level (Supriyadi et al., 2021). Bondowoso Regency is one example of a region facing this structural problem. This regency, characterized by a low Human Development Index and significant reliance on central government transfers, exemplifies the persistent fiscal dependence observed across many Indonesian regions despite regulatory reforms aimed at enhancing local revenue generation (Suryawati et al., 2018; Zainuri et al., 2025).

Previous thesis research shows that Bondowoso Regency's local revenue is low and tends to be stagnant in the long term. This condition runs parallel to social welfare achievements that consistently fall below the provincial average and poverty rates that are always above the provincial average (Sumual et al., 2021, p. 1752). This phenomenon indicates a low fiscal capacity trap, a condition in which limited fiscal capacity constrains productive public investment, ultimately hindering economic growth and narrowing the regional tax base.

Further analysis identified two main structural factors contributing to this condition: limited infrastructure and low quality of formal education. The average length of schooling for the people of Bondowoso Regency is only 6.3 years (BPS, 2025), which means that most of the population only completes primary education. This low level of educational attainment has an impact on the quality of human capital, labor productivity, technology adoption capabilities, and the region's competitiveness in attracting investment. (Alesina et al., 2021, p. 5; Angrist et al., 2021, p. 410).

However, the education problem in Bondowoso is not only structural, but also informational and cultural. A simple field experiment conducted on 50 high school students showed that initially, only 4 students expressed interest in continuing their studies abroad. The majority considered higher education abroad to be difficult and expensive, making it seem unattainable. After being provided with information and understanding about access to international scholarships based on empirical experiences of master's studies in Turkey, the number of interested students increased to 42. These findings show that aspirational and informational constraints play an important role in limiting the educational choices of the younger generation.

In addition to information constraints, cultural factors and social norms also have a significant impact. Interviews with the community revealed a perception that higher education is irrelevant because most of the population works in the agricultural sector. Early marriage is still practiced, driven by certain social norms, which ultimately contribute to low levels of education among women, high rates of teenage pregnancy, and the risk of stunting in children. The combination of low education, early marriage, and suboptimal health creates an intergenerational cycle of poverty and low human resource quality. (Affairs, 2024, p. 22)

In development economics literature, formal education is positioned as an investment in human capital that has long-term effects on economic growth (human capital theory and endogenous growth theory) (Bhattacharjee et al., 2024, p. 2089). However, improving the quality of education often requires

significant public budget allocations, while regions with low local revenues have limited fiscal space. Therefore, a crucial research question arises: how can regions with fiscal constraints improve the quality of human capital without burdening their budgets? (Vedechkina & Borgonovi, 2021, p. 611160)

This study offers conceptual and empirical novelty by developing an analytical framework that links fiscal constraints, institutional strategies, and aspirational transformation in a unified model of regional development. Rather than viewing international scholarships solely as an instrument of individual mobility, this study positions them as an externally financed regional development policy with the potential to generate long-term spillover effects on productivity, economic base expansion, and local fiscal capacity. Using the case study of Bondowoso Regency, this research aims to produce a policy model that not only explains the causal relationship between education and welfare but also identifies institutional mechanisms that enable regions with low fiscal capacity to escape the trap of structural poverty through formal education strategies that are globally oriented but have a local impact.

2. LITERATURE REVIEW

Fiscal decentralization shows that central government transfers to local governments often do not have an optimal impact due to weak planning and the dominance of routine spending (Arief, 2025). Income inequality between regions remains persistent (Dick-Sagoe et al., 2022), and dependence on regional revenue and expenditure budgets, especially in regions with low local revenue such as Bondowoso, makes it very difficult to increase regional growth (Wahyudi & Kurniawati, 2022).

Investment in human capital, especially through education, is widely recognized as the main foundation for sustainable economic growth and poverty alleviation (Natalia et al., 2023). Human capital theory (Schultz, 1961; Becker, 1964) emphasizes that education is the foundation of economic growth. A study conducted by Fauzan and Arif (2023) proves that an increase in the average length of schooling reduces poverty (Fauzan & Arif, 2023). However, investment in education faces cultural barriers in the form of aspiration failure, where poor communities do not dare to dream due to limited information and the absence of role models. This phenomenon manifests itself in the practice of early marriage, which leads to stunting, perpetuating the cycle of intergenerational poverty (Taufikurrahman et al., 2023).

Amid fiscal constraints, international scholarships are a strategic instrument because they do not burden local revenue (Suharsih & Rahayu, 2023). Scholarship programs enable regions to send their best students to pursue higher education with external funding (Campbell & Neff, 2020; Kosasih et al., 2023). The author's experience indicates that simple information interventions can significantly alter students' aspirations, demonstrating that knowledge transfer can overcome cultural barriers. This integrated strategy offers a solution by overcoming fiscal constraints, improving the quality of human resources, changing mindsets, and breaking the cycle of poverty (Hoff & Demeritt, 2023).

3. DATA AND METHODOLOGY

This study uses a Mixed-Methods Embedded Case Study Design, with a sequential explanatory mixed-methods design approach, in which quantitative analysis is performed first to identify causal relationships and structural patterns, followed by in-depth qualitative analysis to explain the mechanisms, institutional context, and cultural factors that cannot be fully captured by econometric models (Luyt, 2011). This design choice facilitates a more nuanced interpretation of complex phenomena by allowing the qualitative strand to refine and contextualize the findings from the quantitative data, thereby optimizing the depth and utility of the analysis (Venkatesh et al., 2023). Bondowoso Regency is positioned as a single instrumental case study, which is a case used to develop a theoretical model that can be replicated in regions with low fiscal characteristics.

The quantitative or econometric data consists of secondary data obtained from the World Bank and Statistics Indonesia (BPS), whereas the qualitative data comprises primary data gathered through observations and interviews with various stakeholders, such as the regent, the head of the Regional Development Planning Agency, the head of the Education Office, teachers, and students (Aminuddin et al., 2026).

First, quantitative analysis was conducted to examine the relationship between education levels and economic growth. Eviews was used as the software to analyze the relationship between these variables, using secondary data obtained from the Indonesian Central Statistics Agency and the World Bank (Cipta, 2023, p. 70; Edwards et al., 2021, p. 128). The data were tested for stationarity using Root Tests, including ADF, PP, KPPS, and NG Peron. Then, if the data were declared stationary, the relationship between variables was tested using the VAR method. The steps in the VAR method are testing the VAR lag Order Selection Criteria, VAR Residual Serial Correlation LM Tests, VAR Residual Heteroskedasticity Tests, testing the Inverse Roots of AR Characteristic Polynomial to see if the data is consistent, and VAR Granger Causality/Block Exogeneity Wald Tests to see if the variable has a relationship with other variables. And finally, Response to Cholesky One S.D. (d.f. adjusted) Innovations to see how long the relationship between variables lasts.

Second, qualitative analysis was conducted to explain the mechanisms, institutional context, and cultural factors that could not be fully captured by econometric models. This began with requesting permission from the Bondowoso Regency Government, because, according to John W. Creswell, the most important thing in qualitative research is research ethics (Creswell, 1994). Once permission was granted, observations were conducted at the research site. Semi-structured interviews were then conducted with stakeholders relevant to the research topic, including the mayor, regional secretary, head of the education office, head of the regional development planning, research, and development agency, teachers, students, and the community in Bondowoso Regency, using the snowball sampling method. Once the data has been collected, data validation will be carried out using the triangulation method. Then, after data validation, the data will be analyzed using NVIVO software, starting from data coding, data analysis, and visualization of the research results. (Calandra et al., 2023, p. 674).

4. DATA ANALYSIS

4.1. Quantitative Method

Testing variable data for stationarity needs to be done in quantitative research methods, as a first step to find out whether the data in this variable is stationary or not. The following is the root test of the two variables in my research:

Table 1. ADF, Phillips-Perron, KPSS, and Ng-Perron Tests' Results

Variable	Level, 1.st difference/2.st diffrence	ADF	PP	KPSS	NG PERON			
					Mza	MZt	MSt	MPt
Economic Growth	1. st difference	-2,354973	-5,923272	0.098374	-1,32659	-2,76538	0.76338	1,67635
Education	2. st difference	-7,597421	-32,07195	0,600091	-8,45372	-1,87636	0,23827	3,76357

Information: Both variables (economic growth and education) are stationary according to the Augmented Dickey-Fuller (ADF), Phillips-Perron, KPSS, and Ng-Perron tests; thus, the data are stationary and considered to have passed the initial step of the quantitative method.

Figure 1. VAR Lag Order Selection Criteria

VAR Lag Order Selection Criteria
Endogenous variables: EDUCATION GDP
Exogenous variables: C
Date: 06/08/26 Time: 17:23
Sample: 1995 2025
Included observations: 29

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-130.9092	NA	32.80071	9.166150	9.260446	9.195682
1	-103.0472	49.95945*	6.335862*	7.520494*	7.803383*	7.609092*
2	-101.9144	1.874857	7.763563	7.718237	8.189719	7.865899

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

To see the lag length criteria, I refer to the Hannan-Quinn Information Criterion (HQIC). Based on this criterion, the optimal number of lags for the VAR model is 4 because the lowest value in HQIC is located at lag 1.

Figure 2. LM Tests' Results

VAR Residual Serial Correlation LM Tests
Date: 06/08/26 Time: 17:25
Sample: 1995 2025
Included observations: 29

Null hypothesis: No serial correlation at lag h

Lag	LRE* stat	df	Prob.	Rao F-stat	df	Prob.
1	4.492137...	4	0.343...	1.156262...	(4, 42.0)	0.343...

Null hypothesis: No serial correlation at lags 1 to h

Lag	LRE* stat	df	Prob.	Rao F-stat	df	Prob.
1	4.492137...	4	0.343...	1.156262...	(4, 42.0)	0.343...

*Edgeworth expansion corrected likelihood ratio statistic.

The results of the VAR residual serial correlation test using the LM test indicate that the probability value (p-value) is greater than 0.05; thus, the data show no residual serial autocorrelation in the model, meaning the assumption of no correlation between residuals is acceptable.

Figure 3. Heteroskedasticity Tests' Results

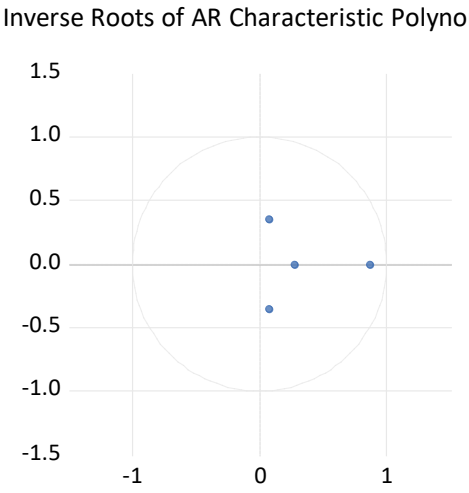
VAR Residual Heteroskedasticity Tests (Levels and Squares)
Date: 06/08/26 Time: 17:25
Sample: 1995 2025
Included observations: 29

Joint test:

Chi-sq	df	Prob.
26.7210603...	24	0.317622225555532

As with the previous LM test, the test for heteroskedasticity in the VAR residuals yielded a probability (p-value) of 0.317622225555532; since this value exceeds the established significance level (0.05), it can be concluded that there is no heteroskedasticity in the residuals.

Figure 4. Inverse Roots of the AR Characteristic Polynomial



This section shows that all points lie within the circle or do not exceed the value of 1. Therefore, the data is deemed suitable and stable for further analysis.

Figure 5. VAR Granger Causality/Block Exogeneity Wald Test Results

VAR Granger Causality/Block Exogeneity Wald Tests
Date: 06/08/26 Time: 18:29
Sample: 1995 2025
Included observations: 29

Dependent variable: EDUCATION

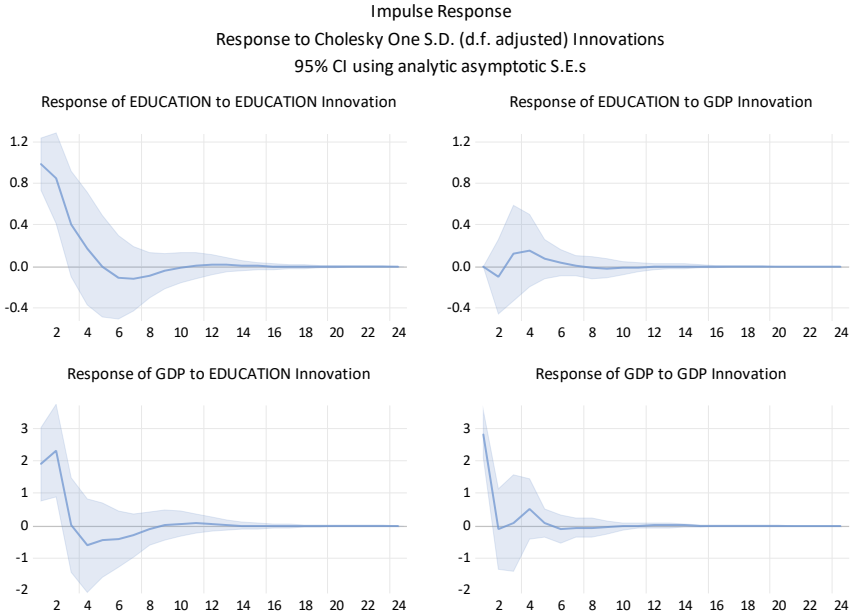
Excluded	Chi-sq	df	Prob.
GDP	1.50219608...	2	0.47184815...
All	1.50219608...	2	0.47184815...

Dependent variable: GDP

Excluded	Chi-sq	df	Prob.
EDUCATION	9.87905993...	2	0.00715796...
All	9.87905993...	2	0.00715796...

Based on the results of the VAR Granger causality test, a unidirectional relationship was found between education and economic growth. Education, acting as the independent variable, influences economic growth (the dependent variable)—as evidenced by a probability value of less than 0.05—indicating that education has an impact on economic growth. Conversely, the probability value for economic growth as the independent variable and education as the dependent variable exceeded 0.05, indicating that economic growth does not influence education.

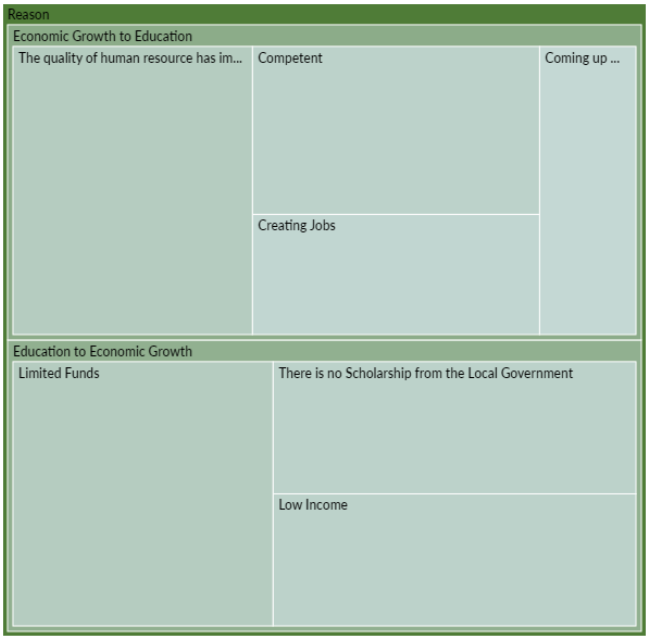
Figure 6. Impulse Response Functions of EDUCATION and GDP



The graph illustrates the relationship between education and economic growth. The findings of this study indicate that education has a negative impact on economic growth in the first and second years; from the second to the fourth year, the impact is positive; and it becomes negative again from the fifth to the tenth year.

4.2 Qualitative Method

Figure 7. Hierarchy Chart Visualization



The results visualized in this diagram indicate that the positive impact of education on economic growth is primarily driven by improvements in the quality of human resources, which enhance their competence in their respective fields. Furthermore, this is driven by the creation of new job opportunities through innovative ideas. Conversely, the absence of a positive impact of economic growth on education is attributed to funding constraints, low regional revenue, and a lack of scholarship support from local governments.

Figure 8. Government Responses to International Scholarships for Improving Education and Social Welfare

This diagram shows that the government views international scholarships as a positive solution and a sound concept overall. The government also supports the program and intends to implement it as part of efforts to boost the local economy through outreach, training, and experience-sharing activities.

5. CONCLUSION

Education levels influence economic growth in Bondowoso Regency, Indonesia; results from the VAR Granger causality test indicate a probability value of less than 0.05. This finding aligns with previous studies demonstrating the impact of education on economic growth—paralleling the situation in Northern Europe, where economic growth rates exceed those of Southern Europe due to higher educational attainment in the north.

The influence of education levels on economic growth in Bondowoso Regency stems from improvements in the quality of human resources. Higher levels of education among the population lead to enhanced human resource quality; consequently, formal sector roles are filled by individuals who are competent in their respective fields. Furthermore, a well-educated population with high-quality human resources can generate new employment opportunities through creative and innovative ideas, thereby reducing unemployment and boosting local economic growth.

The Bondowoso Regency government highly appreciates and supports the International Scholarship program as a solution for boosting the local economy and fostering regional development. Furthermore, the local government intends to implement the program through collaboration among the administration, the Education Office, schools, and relevant stakeholders. This involves organizing the initiative and providing necessary access and facilities—including outreach and training for teachers,

students, and parents—to prepare students for higher education. This initiative is expected to enhance local economic competitiveness.

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THE PREVALENCE OF PSYCHOLOGICAL DISTRESS TO EMPLOYEES IN TÜRKİYE

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ABSTRACT

Psychological distress is all employees and remains largely untreated. Also that is losses in employee productivity in absenteeism. Identified to potential work related risk factors is playing an important role to determining to path map of prevention studies to both employees and employers. In this study data was collected with cross section study in Turkey via online with web based form. In study 470 employees (48.70% male; mean age 32.17-years ± SD 10.59-years) responded to the SCL-90-R which contained a nine measure of psychological distress. Global Severity Index (GSI), T-score using nonpatient norm, greater than or equal to a of 63 or if any two primary dimension T-score are greater than or equal to a 63 then the individual was considered at high risk for a psychiatric diagnosis. According to the results, 11.5% of the employees (n = 54) according to the Global Severity Index, 10.6% (n = 50) according to the Somatization sub-dimension, 10.9% (n = 51) according to the Obsessive-Compulsive sub-dimension, 10.6% (n = 50) according to the Interpersonal Sensitivity sub-dimension, 12.8% (n = 60) according to the Depression sub-dimension, 11.7% (n = 55) according to the Anxiety sub-dimension, 13.6% (n = 64) according to the Hostility sub-dimension, 14.3% (n = 67) according to the Phobic Anxiety sub-dimension, 14.0% (n = 66) according to the Paranoid Ideation sub-dimension and 13.4% (n = 63) according to the Psychoticism sub-dimension were evaluated as high risk for psychiatric diagnosis. As a whole, 32.3% of the employees (n = 152) were in this group. High psychological distress is largely untreated at employee. These risk factors will guide to identify the targeting of mental health prevention programs.

Keywords: *Employee, Mental Health, Psychiatric Diagnosis.*

JEL Codes: *I1, I12, I18.*

1. INTRODUCTION

Psychological distress is all employees and remains largely untreated. Also that is losses in employee productivity in absenteeism. Identified to potential work related risk factors is playing an

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important role to determining to path map of prevention studies to both employees and employers (Hilton et al., 2008; Hilton & Whiteford, 2010).

2. METHOD

2.1. Participants

This study included 470 participants aged 18-75 (mean = 32.17; s = 10.59), comprising 241 women (51.30%) and 229 men (48.7%). Of the participants, 15 had completed primary school (3.2%), 23 had completed middle school (4.90%), 96 had completed high school (20.40%), and 336 had completed associate's or bachelor's degrees (71.50%). Regarding income level, 49 participants (10.40%) reported low income, 323 (68.70%) reported medium income, and 92 (19.60%) reported high income (6 participants did not specify their income level (1.3%)).

2.2. Materials

In the study, participants were given a socio-demographic questionnaire consisting of several questions, along with the Symptom Checklist-90-Revised (SCL-90-R), which includes nine different measures of psychological distress. This inventory measures psychological symptoms and distress in terms of nine primary symptom dimensions. The dimensions of the SCL-90-R are Somatization, Obsessive-Compulsive Disorder, Interpersonal Sensitivity, Depression, Anxiety, Hostility, Phobic Anxiety, Paranoid Thoughts, and Psychoticism (Dağ, 1991; Derogatis & Fitzpatrick, 2004).

In addition to nine primary dimensions, the SCL-90-R is assessed using three additional first-level global scores (the sums of sub-dimensions) to evaluate overall psychological distress. These three global scores are the Global Severity Index (GSI), the Positive Symptom Distress Index (PSDI), and the Positive Symptom Total (PST). In this study, only the Global Severity Index (GSI), which is a general indicator of the current level of distress, was used (Derogatis & Fitzpatrick, 2004).

2.3. Procedure

The study was implemented using a web-based form during the 2025-2026 fall semester. The form's link was shared on social media, and individuals reached through this method voluntarily participated in the study. The form first explained the purpose of the study and requested "voluntary consent," followed by the questions and items of the form.

2.4. Data Analysis

In the study, Cronbach's Alpha internal consistency reliability coefficients of the scales used were calculated first, and then Pearson correlation analysis was performed between the total scores. Subsequently, using the total scores of the sub-dimensions obtained in the study, the number of employees considered to be at high risk for psychiatric diagnosis was determined.

3. FINDINGS

In this study, the Cronbach's Alpha internal consistency reliability coefficients of the SCL-90-R were first calculated. According to the results, the Cronbach's Alpha coefficients of the scales ranged from .760 to .880 for the nine primary symptom dimensions. The internal consistency coefficient of the Global Severity Index (GSI) was determined as .974. Subsequently, correlations were calculated between the total scores of the nine core symptom dimensions, and coefficients ranging from .582 ($p < .001$) (between Paranoid Ideation (PAR) and Somatization (SOM)) to .812 ($p < .001$) (between Depression (DEP) and Anxiety (ANX)) were determined. The Global Severity Index showed the lowest correlation with the Hostility (HOS) subscale ($r = .802$) and the highest correlation with the Anxiety (ANX) subscale ($r = .927$) (Table 1).

Table 1. Cronbach's Alpha internal consistency reliability coefficients and Interdimensional Correlations of SCL-90-R

Dimension / Symptom (n = 470)	n of item	GSI	SOM	O_C	INT	DEP	ANX	HOS	PHOB	PAR	PSY
Global Severity Index (GSI)	90	(.974)									
Somatization (SOM)	12	.831***	(.873)								
Obsessive-Compulsive (O-C)	10	.823***	.641***	(.817)							
Interpersonal Sensitivity (INT)	9	.884***	.666***	.721***	(.818)						
Depression (DEP)	13	.903***	.669***	.752***	.805***	(.880)					
Anxiety (ANX)	10	.927***	.777***	.711***	.780***	.812***	(.858)				
Hostility (HOS)	6	.802***	.615***	.562***	.657***	.681***	.758***	(.811)			
Phobic Anxiety (PHOB)	7	.816***	.668***	.610***	.729***	.679***	.779***	.645***	(.814)		
Paranoid Ideation (PAR)	6	.819***	.582***	.637***	.734***	.726***	.704***	.719***	.611***	(.760)	
Psychoticism (PSY)	10	.873***	.656***	.647***	.776***	.740***	.804***	.682***	.722***	.733***	(.839)

Note: ***$p < .001$; Cronbach's Alpha is given diagonally (in parentheses).

Subsequently, as Derogatis and Fitzpatrick (2004) stated, using the Global Severity Index (GSI) non-patient norm, an employed individual was considered at high risk for a psychiatric diagnosis if their T-score was 63 or higher, or if any two baseline dimensions had a T-score of 63 or higher. According to the calculations made in this context, 11.5% (n = 54) of the employees were evaluated as being at high risk for psychiatric diagnosis according to the Global Severity Index, 10.6% (n = 50) according to the Somatization subscale, 10.9% (n = 51) according to the Obsessive-Compulsive subscale, 10.6% (n = 50) according to the Interpersonal Sensitivity subscale, 12.8% (n = 60) according to the Depression subscale, 11.7% (n = 55) according to the Anxiety subscale, 13.6% (n = 64) according to the Hostility subscale, 14.3% (n = 67) according to the Phobic Anxiety subscale, 14.0% (n = 66) according to the

Paranoid Ideation subscale, and 13.4% (n = 63) according to the Psychoticism subscale. Overall, 32.3% (n = 152) of employees belonged to this group (Table 2).

Table 2. Percentages of Employees Assessed As High-Risk for Psychiatric Diagnoses

Dimension/Symptom	Non risk group for a psychiatric diagnosis		High risk group for a psychiatric diagnosis	
	n	%	n	%
Global Severity Index (GSI)	416	88,5	54	11,5
Somatization (SOM)	420	89,4	50	10,6
Obsessive-Compulsive (O-C)	419	89,1	51	10,9
Interpersonal Sensitivity (INT)	420	89,4	50	10,6
Depression (DEP)	410	87,2	60	12,8
Anxiety (ANX)	415	88,3	55	11,7
Hostility (HOS)	406	86,4	64	13,6
Phobic Anxiety (PHOB)	403	85,7	67	14,3
Paranoid Ideation (PAR)	404	86,0	66	14,0
Psychoticism (PSY)	407	86,6	63	13,4
Total	318	67,7	152	32,3

According to these results, 32.3% of the employees examined in this study are considered to be at high risk for psychiatric diagnosis and are therefore evaluated as a case (Derogatis, 2000; Derogatis & Cleary, 1977; Derogatis & Fitzpatrick, 2004; Derogatis, Rickels & Rock, 1976).

4. DISCUSSION

High psychological distress is largely untreated at employee. These risk factors will guide to identify the targeting of mental health prevention programs.

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SELF-REWARD BEHAVIOR IN CONSUMPTION: A MULTIDIMENSIONAL REVIEW OF HEDONIC AND COMPENSATORY CONSUMPTION

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ABSTRACT

This study examines self-reward behavior from a multidimensional perspective by integrating insights from hedonic and compensatory consumption literature. As consumption increasingly functions as a tool for emotional regulation and self-expression, self-reward behavior has become a key concept in understanding contemporary consumer behavior. Grounded in self-regulation theory, self-reward is conceptualized as a self-administered reinforcement mechanism in which individuals reward themselves upon achieving self-defined standards. The study highlights the dual role of self-reward behavior in both pleasure-oriented (hedonic) and coping-oriented (compensatory) consumption processes. Findings indicate that self-reward is shaped by emotional states, psychological needs, and contextual influences, and is driven by mechanisms such as self-licensing and perceived deservingness. Despite its theoretical richness, the literature remains fragmented, with limited empirical evidence and methodological diversity. The study also underscores ethical concerns related to the use of self-reward appeals in marketing strategies. By synthesizing prior research, this study clarifies conceptual boundaries and offers directions for more integrative, empirical, and culturally diverse future research.

Keywords: *Self-Reward Behavior, Hedonic Consumption, Compensatory Consumption, Consumer Behavior, Emotional Regulation.*

JEL Codes: *M31, D91, D12.*

1. INTRODUCTION

In contemporary consumer research, consumption is no longer viewed solely as a functional activity aimed at meeting basic needs; rather, it is considered a complex field of behavior closely linked to individuals' emotional, psychological, and symbolic lives. One of the most striking reflections of this transformation is self-reward behavior, which refers to individuals' tendency to reward themselves through consumption after perceived effort, success, or emotional experiences. With consumption increasingly becoming a means of self-expression and emotional regulation, understanding self-reward behavior has gained significant importance in the consumer behavior literature (Khan & Dhar, 2006;

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Kivetz & Simonson, 2002; Kemp & Kopp, 2011). Self-reward behavior is generally defined as a form of self-regulated appreciation and incentive where individuals reinforce their own behavior by linking rewards to achieving self-defined performance standards. This definition is based on the theory of self-regulation, where individuals monitor and evaluate their own performance and consequently receive internal reinforcement (Bandura, 1976). Unlike externally presented rewards, self-reward behavior stands out as a highly personal and psychologically based form of consumption, with the individual having complete control over the selection and application of the reward (Tirrell et al., 1977).

The conceptualization of self-reward behavior shows remarkable consistency across different disciplines. This behavior is considered as an expression of appreciation for one's own efforts, a behavioral self-regulation mechanism, and a self-regulated reward system that encourages personal achievements (Bandura, 1976; Kivetz & Simonson, 2002). This interdisciplinary overlap indicates that self-reward behavior is not merely a phenomenon limited to consumption; it is also a broader psychological construct closely related to motivation, behavior regulation, and identity processes.

Historically, self-reward behavior has undergone a significant developmental process. Early studies primarily addressed this concept from an emotion regulation perspective, emphasizing its role in regulating emotional states through consumption (Luomala, 1998; Kemp & Kopp, 2011). Subsequent research has expanded the literature by revealing the underlying mechanisms of this behavior. For example, Johar and Mukhopadhyay (2009) introduced the concept of "justified pleasure" to the literature by showing that previous consumption restrictions trigger subsequent pleasure-oriented consumption expressed as self-reward. This finding is supported by Atalay and Meloy (2006), revealing that individuals psychologically justify their self-reward behaviors. The field has further matured with the development of measurement tools and the creation of holistic theoretical frameworks. Mortimer et al. (2015) consider self-reward behavior as a symbolic and context-dependent form of consumption; while Mandel et al. (2017) and Brown et al. (2017) placed self-reward behavior within a broader model of compensatory consumer behavior, associating it with coping strategies developed against ego dysregulation. These developments reveal that self-reward behavior should be considered not merely a simple emotional response, but a complex and multidimensional consumption structure.

However, despite the increasing theoretical advancements, empirical findings on self-reward behavior appear to be limited and fragmented. A systematic review by Brown et al. (2017) revealed that studies directly addressing self-reward in this area are quite limited, and self-motivation mechanisms have only a very small effect size. Parallel to these theoretical developments, broader socio-cultural transformations have also contributed to the spread of self-reward-based consumption. Modern consumer societies prioritize individualization, self-actualization, and identity construction; making consumption a fundamental tool in expressing individual values and achievements (Kennedy, 2020; Pettigrew, 2002). In this context, self-reward behavior is often culturally legitimized by being presented

as a reward earned in return for self-care or effort (Johar & Mukhopadhyay, 2009; Atalay & Meloy, 2006).

Another important point is that self-reward behavior is located at the intersection of hedonic consumption and compensatory consumption concepts. On the one hand, it carries the characteristics of pleasure-seeking and enjoyment-oriented consumption (Holbrook & Hirschman, 1982), while on the other hand, it overlaps with the framework of compensatory consumption by serving to alleviate emotional stress and ego dissonance (Mandel et al., 2017). This dual structure makes self-reward behavior a critical concept in understanding contemporary consumption patterns.

2. CONCEPTUAL FRAMEWORK

2.1. Self-Reward Behavior

Self-reward behavior has been conceptualized primarily in the behavioral psychology and consumer behavior literature, and its integration with broader interdisciplinary perspectives has remained limited. In its most basic form, self-reward refers to the process by which individuals reward themselves based on achieving certain behavioral or performance standards. This behavior is considered, particularly in consumer research, as self-directed consumption actions undertaken by individuals to appreciate their own efforts (Mick & DeMoss, 1990; Brown et al., 2017).

From a sociocognitive perspective, self-reward behavior is based on self-regulation processes. In this process, individuals monitor their own behavior and evaluate the results according to their own internally defined standards. Bandura (1976) considers this mechanism as part of a broader self-reinforcement system and states that individuals regulate their behavior by rewarding themselves when they meet the performance criteria they have set for themselves. This approach emphasizes the autonomous nature of self-reward behavior, distinguishing it from external reward systems and positioning it as one of the fundamental determinants of self-directed behavior (Bandura, 1985). Despite these conceptual foundations, a significant problem stands out in the literature: interdisciplinary terminological inconsistency. The different definitions and uses of similar concepts in different studies make theoretical integration difficult and lead to a fragmented structure in the literature (Bagozzi, 2007). This situation limits the development of a holistic framework for self-reward behavior.

The theoretical foundations of self-reward behavior are based on various complementary approaches such as social cognitive theory, self-determination theory, and self-regulation models. While social cognitive theory emphasizes the role of self-efficacy and internal standards in directing behavior (Bandura, 1985), self-determination theory posits that individuals maintain their behaviors through intrinsic motivation and autonomy (Deci & Ryan, 2002). Furthermore, the self-regulation literature

highlights the dynamic relationship between motivation and self-control, demonstrating that individuals utilize reward mechanisms to maintain goal-oriented behaviors (Baumeister & Vohs, 2007).

Recent approaches have enriched this conceptual framework with a neuroscience perspective. Studies examining reward processing processes show that dopamine-based neurobiological mechanisms play a significant role in determining how individuals perceive and respond to rewards (Mirenowicz & Schultz, 1994; Apicella et al., 1997). These findings reveal that self-reward behavior is based not only on psychological but also biological foundations. Motivational dynamics also play a significant role in self-reward behavior. The literature shows a critical distinction between intrinsic and extrinsic motivation in reward-based behaviors. While extrinsic rewards can weaken intrinsic motivation over time (Deci et al., 1999), self-reward behavior appears to support intrinsic motivation by preserving the individual's sense of autonomy and control. This reveals that self-reward is a unique mechanism that combines extrinsic reinforcement with intrinsic motivation.

Another important aspect of self-reward behavior is its manifestation in different forms. The distinction between tangible and experiential rewards is particularly noteworthy. Tangible rewards involve the acquisition of concrete products, while experiential rewards focus on life experiences and activities. Research shows that experiential rewards are more strongly associated with individuals' self-perception and identity and are considered more significant compared to tangible rewards (Carter & Gilovich, 2012; Van Boven & Gilovich, 2003). However, it is also noted that these effects may vary depending on contextual factors (Nicolao et al., 2009). Despite all these theoretical developments, empirical findings regarding self-reward behavior appear to be limited. Brown et al. (2017) emphasize that there are very few studies directly addressing self-reward in this area, and most existing studies focus on related concepts. Furthermore, current studies do not provide sufficient evidence on how this behavior differs among demographic groups. In conclusion, the literature reveals that self-reward behavior is a theoretically rich but empirically underdeveloped construct. This situation highlights the need for more holistic and systematic research in the context of consumer behavior.

2.2. Hedonic Consumption

Hedonic consumption represents one of the fundamental dimensions of consumer behavior, emphasizing the experiential, emotional, and sensory dimensions of consumption instead of solely focusing on its functional or utilitarian aspects. This concept was first systematically addressed by Holbrook and Hirschman (1982), who defined hedonic consumption as a process involving multisensory, imaginative, and emotional aspects of product use. This approach represents a significant departure from the traditional economic understanding that explains consumption solely through rational decision-making and utility maximization.

At the heart of hedonic consumption lies the pursuit of pleasure, enjoyment, and emotional satisfaction. In this context, hedonic consumption encompasses a wide range of activities such as entertainment, leisure activities, luxury consumption, and aesthetic experiences. Unlike utilitarian consumption, hedonic consumption is more emotional and experiential, reflecting consumers' search for arousal, excitement, and emotional intensity (Holbrook & Hirschman, 1982; Lacher, 1989). These types of consumption experiences often include elements of daydreaming and a temporary detachment from reality.

The distinction between hedonic and utilitarian consumption is widely supported in the literature. Hedonic consumption is associated with emotional processes, spontaneous behaviors, and low cognitive effort, while utilitarian consumption is explained more by cognitive evaluation, planning, and goal-oriented behaviors (Babin, Darden, & Griffin, 1994). Empirical findings show that hedonic decisions are more intuitive and emotionally based, which can lead to higher impulsivity and risk-taking tendencies in the context of consumption (Hoch & Loewenstein, 1991; Shiv & Fedorikhin, 1999).

Emotions play a central role in shaping hedonic consumption decisions. Consumers' expectations of how they will feel after consumption, and the emotions they experience during or after consumption, significantly influence their purchase intentions and satisfaction. Research shows that positive emotional responses to hedonic stimuli reinforce consumer attitudes (Kemp & Kopp, 2011). It has also been shown that emotions experienced during consumption can affect satisfaction independently of product performance (Phillips & Baumgartner, 2002).

One of the fundamental mechanisms of hedonic consumption is the concept of indulgence. This concept refers to individuals allowing themselves to engage in consumption behaviors that give them pleasure, despite the potential for conflict with long-term goals. The literature shows that indulgence is closely related to self-licensing. Accordingly, individuals justify their hedonic choices by citing their previous effort or self-control (Khan & Dhar, 2006; Johar & Mukhopadhyay, 2009). This process allows individuals to balance the internal conflict between self-control and the pursuit of pleasure. However, hedonic consumption often includes complex emotions such as guilt and pleasure (Ramanathan & Williams, 2006).

Hedonic consumption becomes more pronounced, especially in the context of experiential consumption. The experience economy approach emphasizes that consumers value experiences more than products (Pine & Gilmore, 1999). In this context, hedonic consumption plays a significant role in individuals' identity construction and self-expression processes. Situational factors are also critical in shaping hedonic consumption behavior. Store atmosphere, physical environment, and environmental stimuli can influence consumers' emotional states and direct their consumption behavior (Bitner, 1992; Donovan & Rossiter, 1982). This shows that hedonic consumption is a context-sensitive structure influenced by environmental factors.

In conclusion, hedonic consumption is a multidimensional structure characterized by emotional involvement, experiential value, and the pursuit of pleasure. Its strong relationship with emotional processes and sensitivity to situational factors distinguishes it from utilitarian consumption and makes it one of the fundamental components of modern consumer behavior. Furthermore, its close relationship with self-indulgence and emotional regulation mechanisms makes hedonic consumption an important theoretical framework for understanding self-reward behavior.

2.3. Compensatory Consumption

Compensatory consumption refers to a form of consumption behavior where individuals acquire goods and services to compensate for perceived psychological deficiencies, emotional distress, or threats to their self-concept. Unlike hedonic consumption, compensatory consumption, which is not based on pleasure seeking, is fundamentally focused on repair and aims to reduce the individual's internal discomfort and restore psychological balance (Mandel et al., 2017).

The literature reveals several key psychological antecedents that trigger compensatory consumption. The most prominent among these are threats to self-esteem, feelings of powerlessness, and a lack of social belonging. These mechanisms are particularly related to individuals' efforts to restructure their identities (Dittmar, 2005; Mandel et al., 2017). Empirical studies support these mechanisms. For example, Rucker and Galinsky (2008) showed that individuals with a low perception of power tend to engage in more status-oriented consumption behaviors and show a greater willingness to pay for products with high symbolic value in order to regain a sense of control.

One of the fundamental theoretical explanations for compensatory consumption is based on the theory of self-discrepancy. Developed by Higgins (1987), this theory posits that individuals experience psychological distress when they experience a discrepancy between their real and ideal selves. To alleviate this, consumers attempt to resolve this discrepancy and reconstruct their selves through symbolic consumption (Mandel et al., 2017). This process reveals that consumption functions as a tool for identity regulation.

Emotional states play a critical role in the emergence of compensatory consumption behavior. Negative emotions such as stress, anxiety, loneliness, and depression are among the strongest triggers of this behavior (Yurchisin et al., 2008). These emotional states lead individuals to seek relief through consumption, making it a coping mechanism. It is also noted that different emotional states can lead to different compensatory strategies (Chen & Pham, 2018). This demonstrates that compensatory consumption is a dynamic structure that varies depending on the context and type of emotion. It is also important to distinguish compensatory consumption from impulsive buying behavior. While impulsive buying is characterized by sudden and unplanned purchases, compensatory consumption is a more conscious and psychologically grounded process. In this process, individuals aim to address identity-based deficiencies (Faber, 2010; Dittmar, 2005). This distinction shows that compensatory consumption

is based on deeper cognitive and psychological processes. One of the important factors affecting compensatory consumption is self-esteem. Research shows that individuals with low self-esteem are more prone to compensatory consumption behavior.

However, a high level of self-acceptance reduces the tendency towards compensatory consumption and encourages the adoption of healthier coping strategies (Kim & Gal, 2014). Consumers also justify compensatory consumption behaviors through various cognitive processes. These processes include rationalization and narrative construction. Individuals construct personal narratives to align their consumption behaviors with their self-perception, framing these behaviors as “deserved” or “necessary” (Woodruffe-Burton & Elliott, 2005). Furthermore, individuals re-evaluate perceived deficiencies, transforming them from threatening to more manageable, thus facilitating compensatory consumption (Kim & Gal, 2014).

In conclusion, compensatory consumption is a multidimensional construct based on complex interactions between psychological needs, emotional states, and identity processes. While it may provide relief and self-repair in the short term, it does not always offer a sustainable solution in the long term. With these characteristics, compensatory consumption provides a critical theoretical framework for understanding self-reward behavior, especially when consumption functions both as a coping mechanism and a tool for self-reinforcement.

3. LITERATURE REVIEW

3.1. Self-Reward and Hedonic Consumption

Self-reward behavior encourages hedonic consumption by allowing consumers to psychologically justify their pleasure-oriented consumption. In this context, individuals perceive their pleasurable consumption as "deserved" and can therefore reward themselves more easily (Kivetz & Simonson, 2002; Khan & Dhar, 2006). One of the main mechanisms explaining this relationship in the literature is the licensing effect. According to this effect, individuals use positive or virtuous behaviors they have previously performed to legitimize their subsequent pleasure-oriented consumption. Khan and Dhar (2006) showed that the licensing effect temporarily strengthens individuals' self-perception and that this leads to more hedonic consumption. This finding is also supported by the relationship between self-control and hedonic preference put forward by Dhar and Wertenbroch (2000). Prior effort and self-control also significantly influence hedonic consumption decisions. Kivetz and Simonson (2002) showed that individuals tend to prefer luxury and pleasure-oriented rewards in situations requiring more effort. Similarly, Johar and Mukhopadhyay (2009) revealed that prior restraint or effort psychologically justifies subsequent pleasure-oriented consumption. However, some studies suggest that although individuals may perceive effort as justifying hedonic consumption, this effect may be limited at the level of actual experience (Xu & Schwarz, 2009).

The literature also shows that hedonic consumption behaviors associated with self-reward exhibit certain patterns. These behaviors are generally associated with a sense of "deservingness," and individuals tend to engage in more hedonic consumption to reward themselves (Mick & DeMoss, 1990; Kivetz & Simonson, 2002). However, it is also noted that this can lead to overconsumption and a weakened self-control (Hoch & Loewenstein, 1991). On the other hand, some studies show that self-rewarding behavior can increase an individual's motivation and support positive behaviors (Bandura, 1976).

3.2. Self-Reward and Compensatory Consumption

Self-reward behavior is considered a strategy that plays a significant role, especially in coping with negative emotional states. This behavior helps individuals cope with situations such as stress and anxiety and provides emotional relief through consumption (Kemp & Kopp, 2011; Mandel et al., 2017).

The most important triggers of compensatory self-reward behavior include negative emotions such as sadness, stress, anxiety, and depression. Yurchisin et al. (2008) showed that negative emotional states are positively related to compensatory consumption behavior. In addition, Dubé and Black (2005) stated that consumers turn to "comforting consumption" behavior in the face of negative emotions, and although this consumption provides relief in the short term, it can create feelings of guilt.

Consumers justify self-reward behavior in negative situations with various cognitive processes. In this process, individuals tend to reframe the difficulties they experience and see themselves as deserving of the reward (Khan & Dhar, 2006). Similarly, as the intensity of self-threats and negative life experiences increases, individuals' tendencies toward compensatory consumption and self-reward increase (Mandel et al., 2017). Furthermore, situations such as physical pain or perceptions of injustice have been found to legitimize pleasure-oriented consumption (Bastian, Jetten, & Ferris, 2013).

However, repeated compensatory consumption behaviors have some negative consequences. Research shows that this type of consumption, when repeated, can increase the tendency towards rumination (constant thinking) and weaken self-regulation processes (Lisjak, Bonezzi, Kim, & Rucker, 2015). This can lead individuals into a cycle where they constantly try to compensate themselves through consumption. However, it is also noted that long-term empirical evidence regarding this cycle is limited (Mandel et al., 2017).

3.3. Emotional Regulation in Consumption

Consumption emerges as an important tool that individuals use to regulate their emotional states. In this context, individuals turn to hedonic products and services to alleviate, manage, or change their negative emotions (Kemp & Kopp, 2011; Rick, Pereira, & Burson, 2014). Self-reward-based consumption appears to provide significant emotional benefits in the short term. Research shows that this type of consumption improves individuals' mood and often does not create feelings of guilt (Atalay

& Meloy, 2006). However, some studies reveal that hedonic consumption can cause both positive and negative emotions to be experienced simultaneously (Ramanathan & Williams, 2006).

On the other hand, it is also stated that emotional consumption carries various risks in the long term. These risks include habit formation, unhealthy consumption patterns, and behavioral addiction (O'Guinn & Faber, 1989; Faber & Vohs, 2004). Studies, particularly those related to emotional eating behavior, show that this type of consumption can become chronic over time and have negative effects on individuals' health (Macht, 2008).

It is also observed that emotional regulation processes differ according to the context of consumption and the type of emotion. Different emotions require different regulation strategies, and cultural factors can also influence these processes. For example, consumption-based emotional regulation is more common in individualistic societies, while different coping strategies may come to the forefront in collectivist societies (Markus & Kitayama, 1991; Lee & Aaker, 2004).

4. DISCUSSION

Considering self-reward behavior alongside hedonic and compensatory consumption allows for a more comprehensive and theoretically richer understanding of contemporary consumer behavior. The integration of these concepts contributes to the development of theoretical frameworks with a higher level of abstraction and stronger explanatory power by bringing together different but related structures. Previous studies have shown that conceptual integration expands the scope of explanation while maintaining theoretical integrity (MacInnis, 2011; Bagozzi, 2007). In this context, self-reward behavior stands out as an important concept that serves as a bridge between pleasure-seeking and coping-based consumption. However, there are also significant contradictions in the literature.

One of the most striking problems is the inconsistent findings regarding the effectiveness of self-reward behavior. While early studies emphasized the reinforcing effect of this behavior, empirical findings show that the effects are often limited and inconsistent. For example, Tirrell et al. (1977) showed that self-reward had only a limited effect compared to control groups, while external rewards had stronger effects. Similarly, Deci, Koestner, and Ryan (1999) demonstrated that the effects of extrinsic rewards on motivation vary depending on the context and are limited in some cases. Another significant contradiction arises in the comparison between self-reward and extrinsic reward systems. While some studies argue that extrinsic rewards are more effective in maintaining behavior (Deci et al., 1999), others suggest that extrinsic rewards may weaken intrinsic motivation in the long run and that self-reward is a more sustainable alternative (Ryan & Deci, 2000).

This indicates that there is still no consensus in the literature regarding the mechanisms and effectiveness of self-reward behavior. From a critical perspective, it is seen that self-reward behavior does not always function as expected. In particular, critical self-evaluation processes can weaken the effect of this behavior by leading individuals to question their own motivations. Batson et al. (1987)

showed that the motivational effect of self-reward decreases when individuals question their own intentions. It is also stated that some reward systems can reduce intrinsic motivation, especially when perceived as external control by individuals (Deci et al., 1999). These findings reveal that self-reward behavior is a context-sensitive and multidimensional structure. The integration of self-reward behavior with hedonic and compensatory consumption also raises important ethical debates in terms of marketing practices. Marketing strategies that exploit consumers' self-reward tendencies can lead to manipulative effects, especially on individuals experiencing stress, low self-esteem, or emotional difficulties. The literature draws attention to issues such as consumer vulnerability, deceptive practices, and unethical marketing strategies (Brenkert, 2008; Mick, Pettigrew, Pechmann, & Ozanne, 2012). Therefore, businesses need to adopt a balanced approach between profit-oriented goals and social responsibility.

In conclusion, while self-reward behavior is an important concept in understanding consumer behavior, it contains conceptual ambiguities, empirical inconsistencies, and ethical problems in the literature. Addressing these issues is of great importance both in terms of theoretical development and application.

5. CONCLUSION

This study presents a multidimensional examination of self-reward behavior within the framework of hedonic and compensatory consumption literature. The findings show that this behavior is a complex structure shaped by the interaction of psychological, emotional, and contextual factors. Self-reward behavior is important in understanding consumer behavior because it functions both as a pleasure-seeking and a coping mechanism (Mandel et al., 2017; Mick & DeMoss, 1990).

The literature review reveals that existing studies have several limitations. Firstly, the majority of studies have been conducted in Western societies, which limits the generalizability of the findings (Henrich, Heine, & Norenzayan, 2010). In addition, the lack of methodological diversity and the inadequacy of longitudinal studies are noteworthy (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003). Furthermore, the insufficient integration of different theoretical approaches leads to a fragmented structure in the literature (MacInnis, 2011). Finally, the limited number of empirical applications leads to most existing studies remaining at the exploratory level (Mick et al., 2012).

Future research needs to adopt more innovative and interdisciplinary methodological approaches to overcome these limitations. In particular, it is recommended to increase studies involving qualitative research methods, mixed methods designs, and different cultural contexts. In addition, clearly stating theoretical frameworks in research and considering different perspectives together will make significant contributions to the development of the literature (MacInnis, 2011; Mick et al., 2012).

Furthermore, expanding empirical findings on self-reward behavior is of great importance. The limited number of existing studies and their small effect sizes highlight the need for more comprehensive and robust research. In this context, neuroscience-based approaches and experimental research can

contribute to a better understanding of the mechanisms underlying self-reward behavior (Knutson & Greer, 2008). In conclusion, while self-reward behavior holds significant potential for consumer research, it remains an underdeveloped area. Addressing this concept within a more holistic, empirically supported, and ethically sensitive framework will make significant contributions to the literature.

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EVALUATION OF BANKING SECTOR STOCK PERFORMANCE IN BORSA ISTANBUL USING AN ENTROPY-BASED ARAS APPROACH

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ABSTRACT

The banking sector occupies a pivotal position in financial markets owing to its substantial market value, liquidity structure, and influence on economic stability. In this context, assessing the financial performance of banking sector equities is highly significant for both investors and policy-oriented decision-makers. This study seeks to evaluate the financial performance of leading banking sector stocks traded on Borsa Istanbul through an integrated Entropy-based ARAS multi-criteria decision-making framework.

In the analysis, five banking stocks—AKBNK, GARAN, ISCTR, VAKBN, and HALKB—were identified as the decision alternatives. The evaluation was carried out based on five financial indicators: Return, Sharpe Ratio, Liquidity, Standard Deviation, and Maximum Drawdown. While Return, Sharpe Ratio, and Liquidity were classified as benefit-oriented criteria, Standard Deviation and Maximum Drawdown were defined as cost-oriented criteria. The Entropy method was applied to calculate objective criterion weights, whereas the ARAS method was employed to rank the alternatives according to their overall financial performance levels.

The empirical findings indicated that Maximum Drawdown and Liquidity constituted the most influential evaluation criteria. Based on the ARAS ranking results, GARAN achieved the highest financial performance score, followed respectively by AKBNK and ISCTR. Conversely, HALKB recorded the lowest performance level among the alternatives. Overall, the findings suggest that private sector banks exhibit comparatively stronger financial performance than public banks with respect to liquidity, risk-adjusted returns, and market stability.

The study further reveals that the integrated Entropy-based ARAS methodology offers a robust analytical framework for assessing stock performance under multiple financial criteria. Accordingly, the proposed approach may provide practical guidance for investors, portfolio managers, and financial analysts in investment decision-making processes.

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JEL Classification: *G21, G11, C44.*

1. INTRODUCTION

With the development of financial markets, not only the level of return but also multidimensional indicators such as risk, liquidity, and price volatility have become important in stock selection for investors. The banking sector, in particular, is regarded as one of the fundamental sectors in terms of capital market depth, economic expectations, and financial stability. Therefore, examining the performance of banking sector stocks through a multi-criteria approach provides important insights for both investors and decision-makers.

Banking sector stocks traded on Borsa Istanbul are closely monitored by investors due to their high trading volume and market influence. However, evaluating the financial performance of banks solely based on return is not sufficient. This is because a stock that provides high returns may also carry high volatility or a high maximum drawdown risk. Therefore, considering return, risk, liquidity, and downside loss indicators together in performance evaluation enables a more comprehensive assessment.

The evaluation of financial asset performance has been a central theme in the finance literature. Although traditional models such as the Capital Asset Pricing Model (CAPM) (Sharpe, 1964) and Modern Portfolio Theory (Markowitz, 1952) provide the foundation for understanding the risk-return trade-off, they are generally limited to two dimensions. In recent years, researchers have increasingly turned to Multi-Criteria Decision-Making (MCDM) methods to address the multidimensional nature of investment decisions.

Wang and Lee (2009) incorporated Shannon entropy-based objective weights into a fuzzy TOPSIS framework by combining subjective and objective weighting approaches. Wu et al. (2011) employed Shannon entropy to determine weights in the cross-efficiency evaluation framework of Data Envelopment Analysis (DEA). Yıldırım (2015) demonstrated the applicability of the ARAS method in the Turkish MCDM literature, including the banking sector. Akbulut (2020) combined the ARAS method with Entropy to evaluate the financial performance of Turkish banks and found that ARAS produces consistent and reliable rankings.

This study aims to evaluate the financial performance of the stocks of the five selected banks traded on Borsa Istanbul by using an integrated multi-criteria decision-making methodology. In the study, the Entropy method was employed to determine the criterion weights objectively, while the ARAS (Additive Ratio Assessment) method was used to rank the alternatives.

2. MATERIALS AND METHODOLOGY

2.1. Entropy Method

Nowadays, the concept of Entropy, which is widely used in mathematics and engineering sciences, particularly in physics, was adapted to information theory by Shannon (1948). The concept of entropy was first introduced into the literature by Rudolph Clausius in 1865 as a measure of disorder and uncertainty in a system. The Entropy method is used to measure the amount of useful information provided by the available data (Wu, Sun, Liang, & Zha, 2011, p. 5163). When weighting criteria using the Entropy method in multi-criteria decision-making methods, the following steps are followed (Karami & Johansson, 2014, p. 524):

Step 1: In the first stage of the Entropy method, the alternatives and evaluation criteria related to the decision problem are identified, and the decision matrix is constructed. The decision matrix presents the performance values of each alternative under each criterion. In this method, a multi-criteria decision-making problem consisting of m alternatives and n criteria is represented in matrix form.

Step 2: Since the criteria have different units of measurement, the data are normalized. This enables the criteria to be compared on a common scale.

Step 3: At this stage, the entropy value of each criterion is calculated. The entropy value indicates the amount of information contained in the criterion and its degree of discrimination.

Step 4: After obtaining the entropy values, the degree of uncertainty or diversification for each criterion is calculated. Criteria that create greater differentiation among the alternatives are considered more important.

Step 5: In the final stage, the criterion weights are calculated. Thus, the relative importance of the criteria in the decision-making process is determined objectively.

2.2. ARAS Method

The Additive Ratio Assessment (ARAS) method was introduced into the literature by Zavadskas and Turskis in 2010 through their article entitled “A New Additive Ratio Assessment (ARAS) Method in Multi-Criteria Decision-Making.” Unlike approaches that consider the relative distances to the positive and negative ideal solutions, the ARAS method is based on comparing the utility function values of the alternatives with the utility function value of the optimal alternative added to the decision problem by the researcher. Due to its ease of application and the absence of a requirement for specialized software, ARAS is a method that can be easily applied by decision-makers (Yıldırım, 2015). The implementation of the ARAS method consists of four steps (Zavadskas & Turskis, 2010).

Step 1: In the first stage of the ARAS method, the alternatives and evaluation criteria are identified, and the decision matrix is constructed. At this stage, the optimal value for each criterion is also determined and added to the decision matrix.

Step 2: The data in the decision matrix are normalized so that the criteria become comparable on a common scale. Different normalization procedures are applied for benefit-oriented and cost-oriented criteria.

Step 3: At this stage, the criterion weights are multiplied by the normalized decision matrix to obtain the weighted normalized decision matrix. Thus, the importance levels of the criteria are incorporated into the analysis.

Step 4: The optimality function values are calculated for each alternative. Subsequently, the utility degree of each alternative is determined, and the alternatives are ranked according to these values. The alternative with the highest utility value is accepted as the best option. The Entropy and ARAS analyses were conducted using Microsoft Excel.

3. RESULTS AND DISCUSSION

In this study, the stocks of AKBNK, GARAN, ISCTR, VAKBN, and HALKB, which are traded in the Borsa Istanbul banking sector, were evaluated as the alternatives. These banks were included in the study based on their representative strength within the sector and their trading volume. The data used in the study cover the period from January 1, 2025, to December 31, 2025. Daily closing prices, trading volumes, and other financial indicators of the stocks were obtained from Yahoo Finance and the official website of Borsa Istanbul (BIST).

The financial performance of the banks was evaluated using the criteria of Return, Sharpe Ratio, Liquidity, Std_Dev, and Max_Drawdown. Return represents the average return generated by an investment over a specific period. Since a higher Return value indicates greater profit potential for investors, it was considered a benefit criterion.

The Sharpe Ratio measures the return generated per unit of risk undertaken by the investment. A higher Sharpe Ratio indicates more efficient investment performance.

Liquidity reflects the ease of buying and selling a stock in the market as well as its trading volume. Since stocks with higher liquidity are considered more advantageous for investors, Liquidity was treated as a benefit criterion.

Std_Dev represents the volatility and risk level of stock returns. Since a higher standard deviation indicates greater risk, it was evaluated as a cost criterion.

Max_Drawdown represents the largest decline in the value of an investment during a given period. Since a higher maximum drawdown indicates greater risk for investors, it was treated as a cost criterion.

Accordingly, Return, Sharpe Ratio, and Liquidity were evaluated as benefit criteria, whereas Std_Dev and Max_Drawdown were evaluated as cost criteria. Thus, the performance of the bank stocks was analyzed by considering both their return potential and risk factors.

The decision matrix presents the performance values of the alternatives under the selected criteria. In this study, the decision matrix was constructed using the Return, Sharpe Ratio, Liquidity, Std_Dev, and Max_Drawdown criteria for the AKBNK, GARAN, ISCTR, VAKBN, and HALKB stocks and is presented in Table 1.

Table 1. Decision Matrix

Bank	Return	Sharpe Ratio	Liquidity	Std_Dev	Max_Drawdown
AKBNK	0.0022	0.88	4,200,000,000	0.027	0.17
GARAN	0.0020	0.85	4,500,000,000	0.026	0.16
ISCTR	0.0018	0.80	3,200,000,000	0.025	0.15
VAKBN	0.0016	0.72	2,800,000,000	0.030	0.21
HALKB	0.0014	0.68	2,500,000,000	0.032	0.24

Since the criteria included in the decision matrix have different units of measurement, a normalization procedure was applied to make them comparable. At this stage, each criterion value was divided by the sum of its respective column to obtain the normalized decision matrix. The results are presented in Table 2.

Table 2. Normalized Decision Matrix

Bank	Return	Sharpe Ratio	Liquidity	Std_Dev	Max_Drawdown
AKBNK	0.244	0.232	0.238	0.192	0.190
GARAN	0.222	0.224	0.255	0.185	0.179
ISCTR	0.200	0.211	0.181	0.178	0.168
VAKBN	0.178	0.190	0.158	0.213	0.235
HALKB	0.156	0.179	0.141	0.227	0.268

Following the normalization of the decision matrix, the entropy values, diversification values, and criterion weights were calculated for each criterion. As a result of the Entropy method, the amount of information contained in each criterion and its degree of discrimination were determined, and accordingly, the criterion weights were obtained objectively. The calculated entropy values, diversification values, and criterion weights are presented in Table 3.

Table 3. Entropy Results, Diversification Values, and Criterion Weights

Criterion	Entropy (Ej)	Diversification (dj)	Weight (wj)
Return	0.982	0.018	0.168
Sharpe Ratio	0.984	0.016	0.150
Liquidity	0.975	0.025	0.234
Std_Dev	0.979	0.021	0.196
Max_Drawdown	0.973	0.027	0.252

The decision matrix and the normalized decision matrix are presented in Table 1 and Table 2, respectively. Using the criterion weights obtained through the Entropy method, the ARAS method was applied to determine the financial performance rankings of the alternative banks. In this context, the weighted normalized decision matrix was first constructed, and then the optimality function values and utility degrees of the alternatives were calculated to obtain the performance rankings of the banks. The weighted normalized decision matrix, constructed using the criterion weights obtained through the Entropy method, is presented in Table 4.

Table 4. Weighted Normalized Decision Matrix

Banks	Return	Sharpe Ratio	Liquidity	Std_Dev	Max_Drawdown
Optimal Value	0.033	0.027	0.049	0.036	0.049
AKBNK	0.033	0.027	0.045	0.033	0.043
GARAN	0.030	0.027	0.049	0.034	0.046
ISCTR	0.027	0.025	0.035	0.036	0.049
VAKBN	0.024	0.022	0.030	0.030	0.035
HALKB	0.021	0.021	0.027	0.028	0.031

Using the weighted normalized decision matrix, the optimality function values (S_i) and utility degrees (K_i)) of the alternatives were calculated. The alternatives were then ranked according to the calculated utility degrees, and the results are presented in Table 5.

Table 5. Optimality Function Values and Ranking of Alternatives

Banks	(S_i)	(K_i)	K_i(%)	Rank
AKBNK	0.182	0.940	93.999	2
GARAN	0.185	0.957	95.679	1
ISCTR	0.171	0.884	88.361	3
VAKBN	0.141	0.730	73.010	4
HALKB	0.128	0.659	65.925	5

4. CONCLUSION

In this study, the financial performance of five major banking sector stocks traded on Borsa Istanbul was evaluated using the integrated Entropy-based ARAS method. Within the scope of the analysis, the stocks of AKBNK, GARAN, ISCTR, VAKBN, and HALKB were evaluated based on five criteria: Return, Sharpe Ratio, Liquidity, Standard Deviation, and Maximum Drawdown. Return, Sharpe Ratio, and Liquidity were considered benefit criteria, whereas Standard Deviation and Maximum Drawdown were evaluated as cost criteria.

The Entropy method was used to determine the objective weights of the criteria. According to the findings, Maximum Drawdown and Liquidity were identified as the most important criteria affecting

financial performance. This result indicates that downside risk and market depth play a significant role in investors' decision-making processes within the banking sector. In contrast, the Sharpe Ratio and Return criteria were found to have relatively lower weights due to the similarity of the performance values among the alternatives.

Using the criterion weights obtained from the Entropy method, the ARAS method was applied to rank the banking stocks. According to the results, GARAN achieved the highest financial performance score among the alternatives, followed by AKBNK and ISCTR, respectively. On the other hand, HALKB exhibited the lowest performance value among the evaluated alternatives. Overall, the findings reveal that private banks demonstrate stronger performance than public banks in terms of liquidity, risk-adjusted return, and overall market stability.

The study demonstrates that integrated multi-criteria decision-making methods can provide effective and systematic results in evaluating stock market performance. In particular, the Entropy-based ARAS approach enables both the objective weighting and the comprehensive ranking of financial alternatives. Therefore, the proposed methodology can serve as a useful decision support tool for investors, portfolio managers, and financial analysts.

For future research, the analysis can be extended by including additional banking stocks, different financial indicators, or alternative multi-criteria decision-making techniques such as TOPSIS, VIKOR, or WASPAS. Furthermore, sector-based comparative analyses may provide a broader perspective on investment decision-making processes.

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