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Araştırma Makalesi ● Research Article

Economic Development in Türkiye, The Effects of Financial Development on Environmental Sustainability: The Role of Load Capacity Factor

Türkiye'de Ekonomik Kalkınma, Finansal Gelişimin Çevresel Sürdürülebilirlik Üzerindeki Etkileri: Yük Kapasite Faktörü Rolü

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ÖZ

Bu araştırmanın amacı Türkiye ekonomisi için 1982-2022 arasındaki dönemde ekonomik büyüme ve finansal gelişmenin çevresel sürdürülebilirlik üzerindeki uzun ve kısa dönemli etkilerini incelemektir. Bu çerçevede sosyal ve demografik değişkenlerin etkileri analiz edilmiştir. Araştırmada ekonomik büyüme, finansal gelişme, sosyo-demografik değişkenlerin yük kapasite faktörü (LCF) üzerindeki etkileri gecikmesi dağıtılmış otoregresif (ARDL) sınır testi yaklaşımı kullanılarak tahmin edilmiştir. Sonuçlarımız Türkiye için ekonomik kalkınmanın hem uzun hem de kısa dönemde çevresel sürdürülebilirliğin önemli bir belirleyicisi olduğunu ortaya koymuştur. Özellikle uzun dönemde ekonomik kalkınma çevresel sürdürülebilirliği teşvik etmektedir. Bu bakımdan ekonomik ve çevresel sürdürülebilirliği destekleyecek finansal politikaların özendirilmesi hem çevresel sürdürülebilirliğe hem de Türkiye'nin sürdürülebilir kalkınma çabalarına katkı sağlayacaktır.

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A B S T R A C T

This research examined the long and short-term effects of economic growth and financial development on environmental sustainability for the Turkish economy in the period between 1982 and 2022. In this context, he analyzed the effects of social and demographic variables. In the study, the effects of economic growth, financial development, and socio-demographic variables on the load capacity factor (LCF) were estimated using the distributed autoregressive (ARDL) bounds test approach. Our results revealed that economic development for Türkiye is an important determinant of environmental sustainability in both the long and short term. Especially in the long run, economic development promotes environmental sustainability. In this respect, encouraging financial policies supporting economic and environmental sustainability will contribute both to environmental sustainability and to Turkey's sustainable development efforts.

1. Introduction

The financial sector is one of the important drivers of economic growth. At the global level, the financial sector facilitates the efficient use of funds and improves livelihoods through strategic investments (Javed et al, 2024:

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1590). This is because financial development accelerates economic growth by attracting R&D investments along with foreign investments and thus influences the dynamics of environmental performance. In addition, it represents an important dimension of the relationship between economic growth and the environment (Frankel and Romer, 1999: 380). Financial development is not only a consequence of economic growth, but also a prelude to economic growth, as technological progress and savings stimulate capital accumulation and lead to investments. It also provides motivation and opportunity to increase the sustainability of regional development (Zahoor et al., 2022: 16008; Shahbaz et al., 2020: 10686). There are numerous studies on the positive impact of financial development on economic growth (Schumpeter 1934; 75, Gurley ve Shaw 1955; 517, Davis 1965; 372, Patrick 1966: 176, Sylla 1969:1870, Ghali 1999: 314, Palley 2002: 35, Rousseau 2003: 156, Stockhammer 2004: 45, Harvey 2005: 42, Deidda 2006: 235; Destek ve Aslan 2020: 1299, Shoaib et al, 2020: 12463; Fakher et al, 2021: 61097; Raghutla and Chittedi 2021: 6156; Fengju ve Wubishet 2024: 1178). On the other hand, there is a rich view in the literature that the market complexity caused by financial development will lead to a continuous decline in the rate of economic growth and may lead to the emergence of a crisis. Some of these include Gregorio and Guidotti (1995), Beck et al (2000), Ghirmay (2004), Lee and Chang (2009), Hassan et al (2011), Law and Singh (2014), Cecchetti and Kharroubi (2019), Song et al (2021), etc. Although foreign investment through financial development (Zahoor et al., 2022: 16008; Shahbaz et al., 2020: 10686) stimulates growth, increased energy consumption can lead to increased carbon emissions (Birdsall and Wheeler, 1993: 138; Frankel and Rose, 2002: 436; Baloch et al., 2021: 177) and excess industrial pollution, thus polluting the environment (Ntow-Gyamf et al., 2020: 94). On the other hand, in another aspect, financial development leads to the adoption of advanced technologies in production, thereby increasing energy efficiency and consequently reducing carbon emissions. This proves that energy is largely responsible for environmental degradation (Shahbaz et al., 2020: 10687; Tamazian et al., 2009: 247).

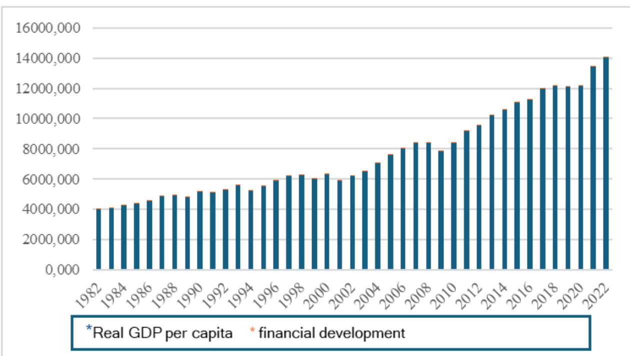
LFC is a measure of environmental quality that expresses the ability of a region or country to use its current lifestyle to sustain its population (Siche et al., 2010: 3183). The LCF presents an inverted environmental Kuznets curve (EKC) and reveals a "U-shaped" relationship between per capita income and environmental well-being (Caglar et al, 2024: 67200). Since the LCF allows environmental assessment from both demand and supply perspectives, it assumes that environmental quality is jeopardized in the early stages of economic development (Pata and Kartal, 2023: 587). An LCF less than 1 indicates that the current system is not sustainable in terms of environmental status, while an LCF greater than 1 indicates that the environmental status is sustainable (Siche et al., 2010: 3183). In the Load Capacity Factor hypothesis (LCF), it is argued that when per capita income reaches a certain milestone, people with increased income consume more environmentally friendly products and thus environmental quality can be improved (Pata and Kartal, 2023: 588).

With the January 24, 1980 decisions, Türkiye transitioned to a free-market economy and increased its economic and financial integration with rest of the world. The globalization process experienced during this period played an important role in the economic and financial development of the country. While economic expansion and the development of financial markets have contributed to raising the level of production, employment and social welfare, they have also increased the demand for energy and natural resources. According to the Energy Institute (2024), total primary energy consumption in 2023 was 2% higher than in 2022, 0.6% higher than its ten-year average, and more than 5% higher than its 2019 preliminary level. According to the organization, Türkiye's primary energy consumption was 5.08 Exajoules in 2013, compared to 7.10 Exajoules in 2022 and 7.00 Exajoules in 2023 (3.44% of the OECD total). During this period, the country's greenhouse gas (GHG) emissions as a share of total global GHG emissions decreased but increased in quantity. The Emissions Database for Global Atmospheric Research (EDGAR, 2024) of the European Commission reported that Türkiye's total GHG emissions to the environment, which was 221.69 million tons of CO2 equivalent in 1990, reached 598.84 million tons ofCO2 equivalent in 2022 and 606.43 million tons of CO2 equivalent in 2023 (1.15% of the world total). On the other hand, Figure 1 shows the periodic change graph of real GDP per capita (USD), financial development and LCF for the period 1982-2022 for the Turkish economy. As seen in the graph, real GDP per capita in Türkiye has increased throughout the period due to economic expansion. As a matter of fact, according to World Bank (2025) data, while GDP per capita was 3977 USD in 1982, it increased to 14055 USD in 2022. Similarly, the financial development ratio (the ratio of broad money supply to GDP), which was 25.596% at the beginning of the period, was 55.496% at the end of the period. On the other hand, there was a rapid increase in the consumption of natural resources in the country during the period in question, thus increasing the pressure on the ecological balance. While the LCF, which can be expressed as the ratio of biocapacity utilization to ecological footprint, was 1.082 in 1982, this ratio has fallen below the critical threshold of environmental sustainability of one since 1984. The LCF recorded a continuous decline until 0.435 in 2022. In this respect, it is of critical importance for the Turkish economy to reveal the effects of economic growth and financial development on environmental sustainability in order to ensure the country's ecological future and long-term sustainable development goals. In line with the goals of combating climate change and sustainable development, Türkiye became a party to the Paris Agreement in 2015 and ratified it by Presidential Decree on October 7, 2021. Moreover, the environmental targets set for the realization of the United Nations 2030 sustainable development goals were included in the Twelfth

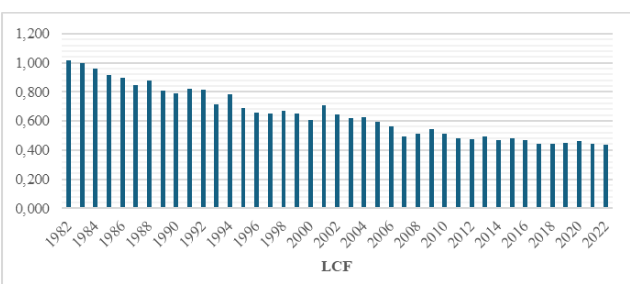
Development Plan (2024-2028) by the Presidency of the Republic of Türkiye Strategy and Budget Directorate (CSBB, 2023). In this plan, it was emphasized that a Long-Term Climate Change Strategy would be prepared by setting interim periods and relevant targets in line with the country's 2053 net zero emission target and that the Second National Contribution Statement, which includes GHG emission reduction and climate change adaptation targets and commitments, would be updated.

Figure 1: Time Graph of Research Series

(a)



(b)



This study analyzed the effects of economic growth and financial development on environmental sustainability in Türkiye. The short and long term effects of economic growth and financial development on the load capacity factor (LCF) for the period between 1982 and 2022 for Türkiye were examined. The research aims to contribute to literature in several ways. First, the long and short term relationship between economic growth and financial development with the environment for the Turkish economy is analyzed in the context of LCF and the effects of these factors on environmental sustainability and the regenerative capacity of the ecological balance are determined. In this context, the validity of the LCC hypothesis in the relationship between economic growth and environment for Türkiye is tested. Third, the role of clean energy policies, urbanization and human capital in the context of the effects of economic growth and financial development on environmental sustainability are revealed. Fourth, the long term and short term relationship between the variables is discussed in the context of sustainable development and important implications are drawn. In this framework, the research is designed in five parts. The first part is the Introduction. The literature review section reviews the empirical literature on the relationship between economic growth and financial development and environmental sustainability. In this respect, the differences and similarities between research and the empirical literature are emphasized. In the third section, Data and Methodology, the data set of the study is introduced and the econometric methods used are explained. In the Results section, the findings obtained as a result of the analyzes are presented. In the Conclusion section, the results of the study are interpreted and policy implications and recommendations are made within this framework.

2. Literature

2.1. The Relationship Between Financial Development and Growth

Early studies in the literature generally focused on the impact of capital, labor and technological development on economic growth. However, recent theoretical developments have shown that financial factors play an important role in economic growth (Li et al, 2015: 9396). This explains why money is one of the most important factors in economic growth and development and is therefore recognized as a determinant of the stage of financial development. Economic historians such as Schumpeter (1911), Gurley and Shaw (1955), Gerschenkron (1962), Goldsmith (1969) and Rostow (1962) have analyzed the process in this context from a broad perspective. Economists such as Greenwood and Jovanovic (1990), King and Levine (1993), Fischer (1993) and Barro (1997) have tried to deepen the subject with different indicators. Beck et al (2000) examined the relationship between economic growth and the sources of financial development. Using GMM and IV estimators, the study found that as the level of financial development increases, economic growth and total factor productivity increase. Fase and Abma (2003) examined the relationship between financial development and economic growth for nine developing countries in Southeast Asia and found that financial development is important for economic growth. Christopoulos and Tsionas (2004) examined the relationship between financial depth and economic growth for 10 developing countries using panel cointegration analysis. They find that there is unidirectional causality from financial depth to growth. Ivanova and Angeles (2006) investigated the relationship between trade and environmental problems for Asia-Pacific countries and found that ecological degradation imposes financial costs on Asia-Pacific countries and globally and leads to various losses in goods and services. Tang and Tang (2006), in their study on the impact of financial development on the economy in APEC countries, found that financial development, capital accumulation and increasing technological innovation promote economic growth. Oruç and Turgut (2014) examined the impact of financial development on economic growth in Türkiye for the period

1990-2010 using the error correction model and concluded that financial deepening affects economic growth. Ak et al. (2016) examined the direction of the causality relationship between growth and financial development in Türkiye for the period 1989-2011. Using the Toda-Yamamoto test, they constructed a development index reflecting the level of financial development of the Turkish economy and found that there is a unidirectional causality relationship running from growth to financial development. Eyüboğlu and Akan (2020) analyzed the relationship between financial development and economic growth in Türkiye for the period 1980-2016 using cointegration tests and concluded that financial development is necessary for growth. Jun et al (2021) examined the effect of globalization, non-renewable energy resource consumption and economic growth on CO2 emissions for the period 1985-2018 in South Asian economies using the ordinary least squares (FMOLS) technique. The study found that non-renewable energy consumption and economic growth increase environmental pollution.

2.2. The Relationship Between Financial Development, Environmental Degradation and Economic Growth

Rjoub et al (2021) examined the regulatory role of financial development on carbon emissions in Türkiye for the period 1960-2016 using ARDL bounds test and Bayer-Hanck cointegration test. The empirical findings reveal that economic growth, capital formation, energy consumption, urbanization and financial development are determinants of environmental degradation. Although financial development deteriorates environmental quality, the literature on the positive relationship between financial development and environmental quality is limited. In this context, Tadesse (2005) found that financial development encourages technological innovation and thus improves environmental quality in his analysis for 38 country industries. Li et al (2015) examined the relationship between financial development, economic growth and environmental quality for 102 countries for the period 1980-2010 using the generalized method of moments estimation. The empirical results show that financial development and environmental quality have a significant impact on economic growth and that there is an "inverted U-shaped" relationship between financial development and economic growth. Tamazian et al (2009) examined the relationship between environmental quality and financial development in Brazil, Russia, India and China for the period 1992-2004. Using panel data analysis, the study found that the higher the level of financial development, the higher the environmental quality. Omri et al (2015) examined the relationship between carbon dioxide emissions, financial development, trade and economic growth for 12 Middle East and North African countries for the period 1990-2011 using panel data. The empirical findings suggest that the decline in environmental quality has negative external effects on economic growth and that high levels of financial development and trade openness help to reduce pollution emissions by stimulating technological innovation. Zhang (2011) analyzed the relationship between China's financial development and carbon emissions using econometric techniques and found that there is a positive relationship between financial development and carbon emissions. Nasreen and Anwar (2015) analyzed the impact of economic and financial development on energy consumption and environmental degradation for the period 1980-2010. Using dynamic panel data models, the study finds that financial development promotes environmental degradation in middle- and low-income countries and reduces environmental degradation in high-income countries. Zeeshan et al. (2021) examined the relationship between financial development and the environment for 20 developed countries for the period 2001-2018 and found that financial development improves the environmental quality in all countries within the scope of the study. Liu et al. (2022) examined the impact of financial development, institutional quality and human capital on ecological quality for developing countries for the period 1990-2018. Using panel data, the study found that financial development increases ecological footprint and decreases ecological quality. Udeagha and Breitenbach (2023), using dynamic autoregressive distributed lag simulation method for the period 1960-2020 in South Africa, found that financial development positively affects environmental sustainability in the short and long run. However, studies such as (Sharma et al, 2021; Musa et al, 2021; Dagar et al, 2022) etc. have obtained results that financial development increases environmental degradation. There are many studies in the literature with different variables in the perspective of growth-environment relationship. Here, only a limited number of studies conducted in the context of growth and environment relationship are included. These are; Phimphanthavong (2013) evaluated the relationship between economic growth and environmental degradation within the scope of the EKC hypothesis using time series data for the period 1980-2010 and found that there is a relationship between economic growth and environmental degradation. Artan et al (20215) investigated the validity of the EKC hypothesis in the triangle of economic growth, openness to foreign trade and environmental pollution for the period 1981-2012 in Türkiye using time series analysis method. The empirical findings indicate that there is an inverted-U shaped relationship between economic growth and environmental pollution in the context of the EKC hypothesis. Kılıç and Akalın (2016) analyzed the relationship between economic growth and environment for the period 1960-2011 in Türkiye using ARDL model and found that there is an inverted-U relationship between per capita income and environmental pollution. Kızılkaya et al (2016) investigated the relationship between carbon dioxide emissions, transportation sector energy consumption, economic growth and openness to international trade for the period 1967-2010 in Türkiye. According to the findings, economic growth, transportation energy consumption and openness to internationalization have a positive effect on carbon dioxide emissions.

2.3. Some Studies on LCF and Environmental Quality Based on Economic Growth and Financial Development

LCF, which is among the factors used to examine environmental quality, is a new concept. When the literature is examined, it is seen that the studies are limited. Some of them; Pata and Isik (2021) found that the load capacity factor decreases as income, energy intensity and resource rent increase, whereas human capital improves environmental quality in the long run. Pata et al. (2023a) found that while human capital supports environmental quality, increased economic development has no effect. Clean energy technologies and urbanization were also found to have no effect on LCF. These results are similar to the results of Pata et al (2023b). In another study, Pata et al (2023c) found that renewable energy improves LCF in the short and long run and that trade openness has a stimulating effect in the long run, while globalization and economic expansion have negative effects. Pata et al (2023d) examined the impact of financial development, biomass energy and economic growth on environmental quality on the load capacity factor using the ARDL method for the US 1965-2018 period. The empirical findings show that while biomass energy improves environmental quality, financial development has no effect on LFC and the increase in per capita income decreases LFC. Pata and Kartal (2023) examined the effects of nuclear energy consumption on environmental quality by considering carbon dioxide (CO2) emissions, ecological footprint and load capacity factor for the period 1977-2018 in South Korea. In the study using the ARDL method, it was found that the LFC and EKC hypotheses are valid and nuclear energy has a positive effect on environmental quality. They also found that renewable energy has no effect on the environment and environmental quality increases as income increases. Guloglu et al (2023) examined the impact of human capital, income, natural resources, urbanization and renewable energy on the load capacity factor for 26 OECD countries for the period 1980-2018 with the quantile common correlated effects mean group (QMG) estimator. The results show that there is an inverted U-shaped link between income and environmental quality and the LFC hypothesis is valid. Güneysu (2023) examined the relationship between economic growth, financial development, globalization and industrialization and freight capacity factor (LCF) for the period 1970-2018 in Türkiye. In their study, they determined that the hypothesis is valid since there is a U-shaped relationship between economic growth and LCF. They also found that while globalization and financial development decrease environmental quality, industrialization increases environmental quality. İçen (2024) examined the effect of gross domestic product, trade openness, renewable and non-renewable energy consumption variables on load capacity factor for the period between 1980 and 2021 in Türkiye. Using the Extended Autoregressive Distributed Lagged Model (AARDL) approach, the study discovered that there is a long-run relationship between the relevant variables and the load capacity factor. (2024) examined the impact of economic complexity, foreign direct investment and renewable electricity on LCF for the BRICS-T countries for the period 1990-2018 using the Panel nonlinear autoregressive distributed lag (NARDL) method. The results show that a positive improvement in economic complexity has a positive impact on LCF in the long run. In addition, they stated that a negative development in FDI has a positive impact on LCF and renewable electricity improves environmental quality in the short and long run.

3. Data and Econometric Method

This section first introduces the dataset and the databases used in the study. The next section of the study explains the econometric methods and analyses used in the study.

3.1. Data

This study analyzes the effects of economic growth and financial development on environmental sustainability in Türkiye for the period 1982-2022. In this framework, the effects of selected variables on load capacity factor (LCF) are estimated using time series estimators. Research variables are presented in Table 1. The LCF, which measures the environmental sustainability of a country or region, reflects the regeneration capacity of natural resources in a country. For LCF, calculated as biocapacity utilization divided by ecological footprint;

LCF<1 means that for an economy, excessive use of natural resources puts pressure on the ecological balance, so that consumption exceeds the regenerative capacity of nature,

LCF>1, the use of biocapacity for an economy can be said to meet the ecological demand and the ecological balance is sustainable.

The data used to calculate the LCF in the study are taken from the Global Footprint Network (GFN) database. The ratios of real GDP per capita (USD) and broad money supply to GDP were used to represent economic growth and financial development. The empirical literature was reviewed and urbanization (annual percentage change), renewable energy consumption (Terawatt-hour) and population (annual percentage change) were taken as control variables.

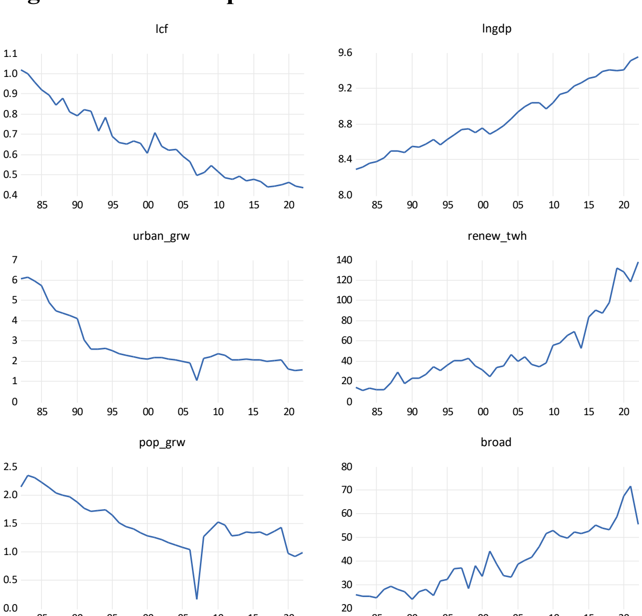
Table 1: Research Variables

Dependent Variable	Explanation	Type	Data Source
LCF	Load capacity factor	The ratio of ITO capacity usage to ecological footprint was taken	GFN
Core Explanatory Variable			
LnGDP	Real GDP per capital	The natural logarithm was taken	World Bank

FN	Financial development	The ratio of broad money supply to GDP is taken	World Bank
Control Variable			
URB	Urbanization	Annual growth rate of urbanization is taken	World Bank
REN	Renewable energy consumption	The production amount per terawatt-hour was taken	World Bank
POP	Population	Annual percentage growth rate is taken	World Bank

The core explanatory variables and control variables used in the study were obtained from the World Bank's official database. Renewable energy consumption data from the Statistical Review of World Energy of the Energy Institute (2024) were obtained from Our World in Datas database. The natural logarithm of per capita income is used in this study. In order to analyze the linear relationship between economic growth and LCF and to test the LCC hypothesis in this context, the square of the natural logarithm of per capita income is included in the estimated model. Figure 2 shows the periodic change graph of the research series. While LCF, population and urbanization rates generally exhibited a downward trend throughout the period, other series showed an upward trend throughout the period.

Figure 2: Time Graph of Research Series



3.2. Econometric Method

The empirical literature was followed in analyzing the econometric relationship between the variables (Li et al, 2015; Akalın, 2016; Güneysu, 2023; Pata et al, 2023c; Udeagha and Breitenbach, 2023). The econometric representation of the model established in this framework and showing the relationship between the variables is as follows:

$$LCF_t = \beta_0 + \beta_1 LnGDP_t + \beta_2 LnGDP^2_t + \beta_3 FD_t + \beta_4 URB_t + \beta_5 REN_t + \beta_6 POP_t + \mu_t \quad (1)$$

Here, "β0" represents the constant term parameter and "β" represents the coefficient slope parameters. "μ" represents the error term and 't' represents the time dimension. In the framework of the research, the relationship between the variables is estimated using the Autoregressive Distributed Lag (ARDL) model procedure proposed by Pesaran et al. (2001). The ARDL approach allows for the joint estimation of level and first difference stationary series, provided that the dependent variable is stationary at first difference. The conditional ARDL model equation estimated in this study is defined as follows:

$$\Delta LCF = \alpha 0 + \beta 1 LnGDPt\text{-}1 + \beta 2 LnGDP^2 t\text{-}1 + \beta 3 FDt\text{-}1 + \beta 4 URBt\text{-}1 + \beta 5 RENt\text{-}1 + \beta 6 POPt\text{-}1 + + \sum_{i=1}^{p} \alpha_{i \Delta LCFt-1} + \sum_{i=1}^{p} \lambda_{i \Delta LnGDPt-1} + \sum_{i=1}^{p} \delta i_{\Delta LnGDP^2 t-1} + \sum_{i=1}^{p} \theta_{i \Delta FDt-1} + \sum_{i=1}^{p} \phi\, i_{\Delta URBt-1} + \sum_{i=1}^{p} \zeta\, i_{\Delta RENt-1} + \sum_{i=1}^{p} \eta\, i_{\delta POPt-1} + \varepsilon t \quad (2)$$

In the next stage of the study, the causality relationship between the variables is estimated using the Toda-Yamamoto (1995) Granger causality test. Unlike the classic Granger (1969) causality test, the Toda-Yamamoto (1995) test allows for the joint estimation of series that are stationary at level (I[0]) or in their first and second differences (I[1] and I[2]), without depending on cointegration and stationary conditions. Moreover, it is widely used in the empirical literature as an extremely flexible and practical method in terms of application. Therefore, the Toda-Yamamoto (1995) causality test was applied within the scope of this research. This approach is based on the classic VAR (Vector Autoregressive) model. After determining the appropriate lag length of the estimated VAR model, the estimation is made by adding a lag equal to the maximum degree of integration of the series to the number of lags (dmax+k).

4. Findings

Descriptive statistics of the series used in this study are presented in Table 2. The average LCF value of Türkiye for the 1982-2022 period is calculated as 0.647. In this respect, it is observed that natural resource consumption for Türkiye exceeds the renewal capacity of the ecological balance. In this period, the maximum value of LCF was found as 1.019 and the minimum value as 0.435. The average value of the natural logarithm of GDP per capita, represented by LnGDP, was calculated as 8.863, while the maximum and minimum values were calculated as 9.550 and 8.288. The average value of financial development represented by FD is calculated as 40.162. The maximum and minimum values are 71.605 and 23.740. The average values of urbanization, renewable energy consumption and population series represented by URB, REN and POP are calculated as 2.780, 48.826 and 1.480 respectively. The maximum values of these series are 6.139, 137.842 and 2.350, while the minimum values are 1.037, 11.342 and 0.160. The research sample consists of 41 years of observations (T=41).

In the context of the research, the stationarity of the series was analyzed first. Considering the structural breaks and shocks experienced in the period in question, the stationarity of the series was examined using the Minimized Dickey-Fuller t-Statistics unit root test with structural breaks. In addition, as shown in Figure 1, it is observed that the series exhibit an upward or downward trend throughout the period. For this reason, in addition to the constant assumption, the constant + trend condition was also taken into account when applying the unit root tests. The unit root test results are presented in Table 2. Accordingly, LCF, LnGDP and LnGDP2, URB and REN series contain unit root problem at the level. On the other hand, FD and POP series are stationary at level under the assumption of constant and trended. In general, all series are stationary in their first differences (I [1]).

Table 2: Descriptive Statistics

	LCF	LnGDP	FD	URB	REN	POP
Mean	0.647	8.863	40.162	2.780	48.826	1.480
Median	0.624	8.752	38.074	2.171	36.456	1.380
Max.	1.019	9.550	71.605	6.139	137.84	2.350
Min.	0.435	8.288	23.740	1.037	11.342	0.160
Std.D.	0.174	0.368	12.890	1.348	34.400	0.438
Jarque-Bera	3.257	2.751	2.693	14.847	11.671	0.879
Prob.	0.196	0.252	0.260	0.000	0.002	0.644
Obs	41	41	41	41	41	41

Table 3: Minimized Dickey-Fuller t-Statistics Unit Root Test

	Fixed				Stable and Trendy			
	Level	Breaking	Difference	Breaking	Level	Breaking	Difference	Breaking
LCF	-3.408	2003	-10.146***	1993	-4.419	1992	-10.194***	1993
LnGDP	-1.633	2002	-7.401***	2009	-3.291	1993	-7.261***	2009
$LnGDP^2$	-1.463	2002	-7.363***	2009	-3.109	2010	-7.229***	2009
FD	-3.046	2004	-7.774***	2021	-4.937**	2007	-7.895***	2021
URB	-4.041	1985	-7.433***	1993	-3.672	2007	-7.328***	1993
REN	-2.044	2014	-8.798***	2019	-3.669	2014	-7.747***	1988
POP	-3.430	1995	-10.981***	2007	-12.712***	2007	-9.278***	2009

***, ** and * p≤0.01, p≤0.05 and p≤0.10 represented significance at the level.

Akaike, Schwarz and Hannan-Quinn information criteria were used to estimate the appropriate ARDL model (Table 4). The information criteria are also based on whether there are any structural breaks, model building, normality, variance and autocorrelation problems at the lags in question. It appeared that the second lag has the lowest information criteria for the three lags. The normality, autocorrelation, heteroscedasticity and model building test results for the estimated ARDL (2, 2, 1, 2, 0, 2, 2, 2) model are presented in Table 5. The test results show that there is no diagnostic problem in the estimated ARDL model.

Table 4: Determination of Appropriate Lag Length in ARDL Model

Delay (Lag)	Akaike	Schwarz	Hannan-Quinn
1	-4.508	-4.128	-4.371
2*	-4.795	-4.027	-4.519
3	-4.795	-4.027	-4.519

*. Showed appropriate delay length.

Table 5: ARDL (2, 2, 1, 2, 0, 2, 2) Model Diagnostic Tests

	Test Statistics	Prob.
Jarque-Bera	2.377	0.304
Breusch-Godfrey	0.703	0.492
Breusch-Pagan-Godfrey	0.475	0.411
Ramsey-Reset [1]	0.088 (1, 20)	0.769

In the next stage of the study, the ARDL model that shows the long-run relationship between the variables was estimated. The representation of the model showing the long-run relationship between dependent variables and explanatory variables is as follows:

$$\Delta LCF=\alpha_0+\sum_{i=1}^{p}\alpha_i\Delta LCF_{t-1}+\sum_{i=1}^{p}\lambda_i\Delta LnGDP_{t-1}+\sum_{i=1}^{p}\delta i\ \Delta LnGDP^2_{t-1}+\sum_{i=1}^{p}\theta_i\Delta FD_{t-1}+\sum_{i=1}^{p}\phi i\ \Delta URB_{t-1}+\sum_{i=1}^{p}\zeta i\ \Delta REN_{t-1}+\sum_{i=1}^{p}\eta i\ \delta POP_{t-1}+\varepsilon_t \quad (3)$$

Table 6 shows the results of the F bounds test for the ARDL (2, 2, 1, 2, 0, 2, 2) model. The F statistic value is above the Pesaran (2001) critical values calculated for 1% and 5% significance levels (5.683). In this respect, the existence of long-run cointegration between LCF and explanatory variables is confirmed for Türkiye. Table 7 presents the long-run coefficients of the ARDL model. The estimation results show that the long-run effect of economic growth on LCF is negative, while the square of economic growth is positive. In this respect, the results of the study reveal that the Load Capacity Factor Curve (LCC) hypothesis is valid for Türkiye. Accordingly, economic growth for the Turkish economy initially created a pressure on the ecological balance as it required excessive consumption of natural resources, leading to overexploitation of resources. However, after a certain phase, economic growth contributed to the improvement of environmental quality due to increasing welfare and environmental sensitivities (U relationship). The findings reveal economic growth has the potential to support environmental sustainability in the long run for Türkiye. In order to sustain the contribution of growth to environmental sustainability and to achieve long-term sustainable development goals, environmental improvement should be supported by other policies besides growth. Indeed, ARDL results indicate urbanization and renewable energy consumption positively affect environmental sustainability in the long run. In this context, energy policies that will accelerate the transition to clean energy sources and the implementation of smart, sustainable urbanization policies are critical for environmental sustainability in Türkiye. In this context, investments in renewable energy sources have recently increased significantly in the country. As a matter of fact, in 2024, 35.2% of the country's current electricity generation was generated from coal, 18.9% from natural gas, 21.5% from hydraulic energy, 10.5% from wind, 7.5% from solar, 3.2% from geothermal energy and 3.2% from other sources (Republic of Türkiye Ministry of Energy and Natural Resources, 2025). In this respect, it can be said that Türkiye is above the world average and ahead of many countries with a renewable energy utilization rate of 42.7% (EMBER, 2024). Statistics show that the country's clean energy policies are in line with the UN 2030 sustainable development goals and the Twelfth Development Plan (2024-2028). According to the international energy think tank Ember (2024), Türkiye aims to increase its use of renewable energy sources to 47% by 2030. The Twelfth Development Plan (2024-2028) aims to achieve an average annual growth rate of 5.0 percent during the plan period, with a per capita income of $17,554 and a national income per capita in PPP terms exceeding $58,000 by the end of the plan period (CSBB, 2023:65). In this regard, the implementation of sustainable and low-carbon growth policies centered on clean resources will contribute to reducing the pressure on ecological balance and ensuring environmental sustainability for Türkiye. After the 1950s, Türkiye entered into a process of rapid urbanization in many developing countries. During this period, the increasing population and uncontrolled migration flow from rural areas to urban areas have, on the one hand, created the problem of squatting and, on the other hand, encouraged the transformation of cities into apartment cities. This has led to some socio-economic and environmental problems. In addition to being responsible for the majority of energy consumption, cities also play an important role in the sustainability of ecological balance. For this reason, urbanization policies are nowadays given great importance in combating climate change. However, when the World Bank (2025) data are examined, it is observed that the urbanization rate, which was 6.061% in 1982, decreased to 4.099% in 1990, 2.086% in 2000 and 1.574% in 2022. Implementation of smart and planned urbanization policies supporting economic growth and are compatible with clean energy policies in Türkiye has a key role in combating climate change as well as supporting ecological sustainability.

Our results demonstrate the effects of financial development and population on environmental sustainability are negative. The analysis reveals that population growth encourages more resource consumption, increasing the pressure on the ecological balance. Moreover, the development of financial markets poses serious risks to environmental sustainability in the long run. Therefore, it is important to adopt policies to encourage green financing practices and environmentally friendly technologies and practices in the financial sector in Türkiye.

Table 6: ARDL (2, 2, 1, 2, 0, 2, 2) Model F Bounds Test

F Statistics	5.683			
	Pesaran (2001) Critical Values			
%5 At the Significance Level			%1 At the Significance Level	
Sample	I (0)	I (1)	I (0)	I (1)
35	2.685	3.960	3.713	5.326
40	2.618	3.863	3.505	5.121
Asymptotic	2.270	3.280	2.880	3.990

Table 7: ARDL (2, 2, 1, 2, 0, 2, 2) Model Long-Term Coefficients

Variable	Coefficient	Std. Error	t-Statistics	Prob.
$LnGDP_{t-1}$	-4.715	1.188	-3.968	0.000***
$LnGDP^2_{t-1}$	0.242	0.066	3.624	0.001***
FD_{t-1}	-0.002	0.000	-2.767	0.009***
URB_{t-1}	0.030	0.008	3.650	0.000***
REN	0.0007	0.000	2.331	0.026**
POP_{t-1}	-0.035	0.016	-2.106	0.043**
C	23.390	5.294	4.418	0.000**

***, ** and* p≤0.01, p≤0.05 and p≤0.10 represented significance at the level of.

In the next stage of the research, the short-run error correction model, which shows the long-run stabilization rates of short-run shocks, was estimated. The estimation of the ARDL method short-run error correction model is as follows:

$$\Delta LCF=\alpha_0+ \sum_{i=1}^{p} \alpha_i \Delta LCF_{t-1}+ \sum_{i=1}^{p} \lambda_i \Delta LnGDP_{t-1}+ \sum_{i=1}^{p} \delta i\ \Delta LGDP^2_{t-1}+ \sum_{i=1}^{p} \theta_i \Delta FD_{t-1}+ \sum_{i=1}^{p} \phi i\ \Delta URB_{t-}$$

$_{1}+\ \sum_{i=1}^{p}\zeta i\ \ \Delta REN_{t-1}+\ \ \sum_{i=1}^{p}\eta i\ \ \delta POP_{t-1}+\ \ \upsilon i\psi_{t-1}+\varepsilon_t$ *(4)*

ARDL (2, 2, 1, 2, 0, 2, 2, 2) The results of the short-run error correction model are presented in Table 8. As expected, the short-run error correction parameter (Ψ) is negative and significant. In the short run, one lagged value of LCF, one lagged value of the square of economic growth and one lagged value of population change are found to increase environmental sustainability. On the other hand, the effects of one lagged value of economic growth and urbanization on LCF are negative. The effects of urbanization and financial development on LCF are statistically insignificant. The results established that the explanatory variables explain 87% of the variation in the dependent variable and the model as a whole is significant.

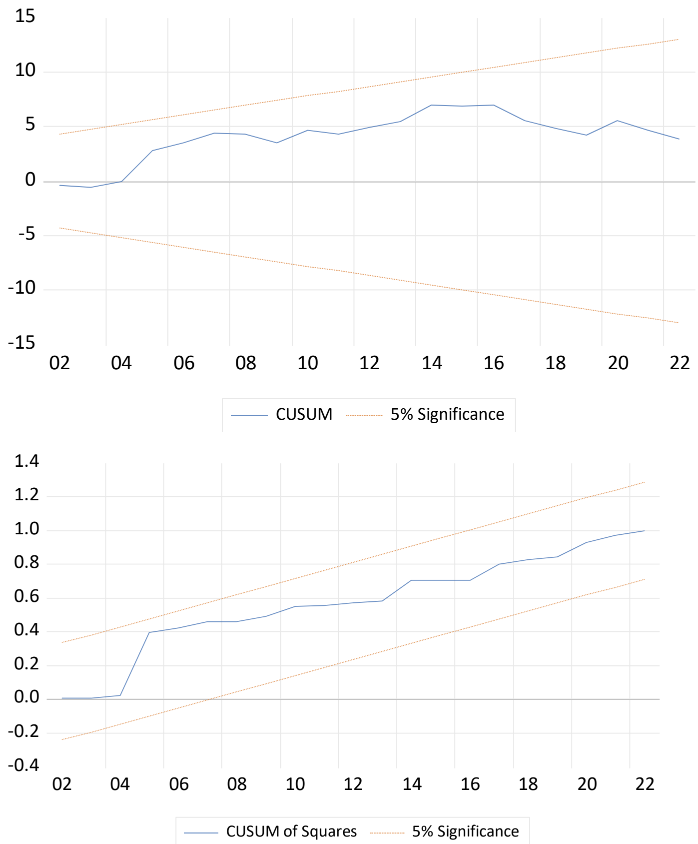
Table 8: ARDL (2, 2, 1, 2, 0, 2, 2) Short-Term Error Correction Model

ΔLCF is the dependent variable.				
Variable.	Coefficient	Std. Error	t-Statistics	Prob.
Ψ	-1.477	0.189	-7.785	0.000***
ΔLCF_{t-1}	0.265	0.121	2.184	0.037**
ΔLnGDP	-14.474	1.909	-7.580	0.000***
$\Delta LnGDP_{t-1}$	0.222	0.089	2.470	0.019**
$\Delta LnGDP^2_{t-1}$	0.792	0.108	7.330	0.000***
ΔURB	0.012	0.015	0.844	0.405
ΔURB_{t-1}	-0.075	0.018	-4.129	0.000***
ΔPOP	0.0005	0.020	0.024	0.980
ΔPOP_{t-1}	0.100	0.023	4.277	0.000***
ΔFD	-0.0004	0.000	-0.711	0.482
ΔFD_{t-1}	0.001	0.000	1.746	0.091
R^2	0.875			
Adj R^2	0.831			
F- Statistics	19.775			
Prob	0.000***			

***, ** and * p≤0.01, p≤0.05 and p≤0.10 represented significance at the level of.

In the next stage of the study, the stability structure of the long-run coefficient parameters was analyzed using CUSUM and CUSUMSQ graphs. As shown in Figure 2, CUSUM and CUSUMSQ plots show that there were no structural breaks during the research period and the long-run coefficient parameters maintained their stability. Finally, the causality relationship between the variables within the framework of the study was estimated using the Granger-based causality test proposed by Toda-Yamamoto (1995). The estimation results are shown in Table 9.

Figure 3: CUSUM and CUSUMSQ Graphs



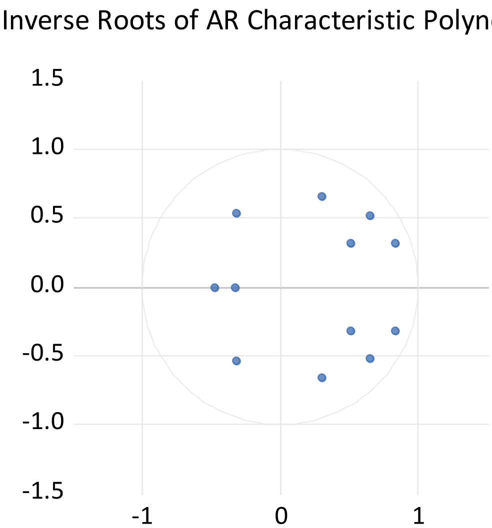
The causality relationship between LCF and explanatory variables was examined using the Granger-based causality test proposed by Toda and Yamamoto (1995). While applying the analyses, the maximum integration was determined as 1 (dmax), and according to the Akaike, Schwarz, and Hannan-Quinn information criteria, the lag length was determined as 1 (k). However, upon detecting the autocorrelation and stability problems in the degree of delay and integration (k+dmax), the analyses were applied to two delays. The autocorrelation and varying variance results for the estimated model are presented in Table 9, and the VAR model stability conditions are presented in Figure 4. In the third delay in the VAR model, as estimated in Table 1, there is an autocorrelation problem at the 90% confidence interval. For this reason, the autocorrelation-resistant HAC (Newey-West) option was applied to the predicted Toda-Yamamoto test.

Table 9: Toda-Yamamoto-VAR Model Autocorrelation and Varying Variance Tests

	Lag	LRE-statistic	Prob
LM Test	1	37.061	0.419
	2	46.682	0.109
	3	49.228	0.069
White kikare (χ^2)		773.016	0.325

The stability chart for the estimated VAR model is shown in Figure 1. As seen in the chart, all residuals are within the circle diagram.

Figures 4: VAR Model Stability Condition



The results of the applied causality analysis are shown in Table 10. The results of the analysis showed that there is a one-way Granger causality from economic growth to LCF. The findings revealed LCF is an important determinant of economic growth in the short run. There is a two-way Granger causality between financial development and LCF in the short run. For Türkiye, the development of financial markets and the environmental policies implemented in the short term are compatible with each other. It was observed that there was no statistically significant causality towards LCF among other variables. According to the results of the analysis, there is a one-way Granger causality from financial development to economic growth, from urbanization to renewable energy consumption, and from population density to urbanization. The findings revealed that there is a bidirectional Granger causality between renewable energy consumption and population density. In this respect, the increasing population and the clean energy policies implemented in the short term are integrated with each other in Türkiye.

Table 10: Toda-Yamamoto Causality Analysis

	LFC	LnGDP	FD	URB	REN	POP
	Wald-F statistic	Wald-F statistic	Wald-F statistic	Wald-F statistic	Wald-F statistic	Wald-F statistic
LCF	1.000	2.077	11.866***	0.452	1.318	0.064
LnGDP	6.549***	1.000	3.295*	0.598	0.871	0.466
FD	7.795***	10.121***	1.000	0.226	0.274	0.169
URB	0.216	0.500	2.102	1.000	5.583**	1.292
REN	0.998	0.599	3.691**	1.396	1.000	3.370*
POP	0.693	0.027	0.078	4.223**	7.480***	1.000

***, ** and * p≤0.01, p≤0.05 and p≤0.10 represented significance at the level of.

5. Conclusion Discussion and Policy Recommendations

For governments, the goal of sustainable economic growth is at the center of key macroeconomic policies. After the January 24, 1980 Decisions, the Turkish economy underwent a rapid structural transformation process and increased its economic, trade and financial relations with the rest of the world. In the 1982-2022 period, the country's economic expansion and financial development accelerated with the impact of globalization. However, the intensive use of energy and natural resources required by the rapid growth process in this period increased the pressure on the environment and ecological balance. Especially since 1984, there has been a significant decline in the country's LCF, which indicates the country's environmental sustainability. Similarly, although the country's share in total global GHG emissions decreased in terms of ratio, it continued to increase in terms of quantity. Therefore, the country's 2030 Sustainable Development Goals and the Twelfth Development Plan (2024-2028) attach great importance to environmental targets. This study examines the long-run and short-run effects of economic growth and financial development on environmental sustainability for Türkiye over the period 1982-2022. In this framework, the validity of the LCC hypothesis is tested for Türkiye. Since increased economic activity in this period encourages migration from rural areas to urban areas and population growth, urbanization, population and renewable energy use are used as control variables in the estimated models. ARDL results confirm that the variables are cointegrated in the long run for Türkiye. In the long run, Türkiye's economic growth and financial development are associated with environmental sustainability. The results show that economic growth is inversely and the square of economic growth is positively related to LCF in the long run. In this respect, the findings reveal that the LCC hypothesis is valid for Türkiye. These results support the results of İçen (2024), Güneysu (2023), Pata et al (2023c) and Ullah et al (2024). Accordingly, environmental sensitivities have taken a backseat to growth-oriented policies, as the initially increasing level of production requires the intensive use of fossil fuels and other natural resources. In this respect, the results of Ivanova and Angeles (2006), Phimphanthavong (2013) and Jun et al

(2021) are similar to the results of studies that fossil fuel use increases environmental pollution while creating economic growth. However, after a certain stage, the prosperity brought by economic expansion has positively affected environmental improvement by increasing the importance given to the environment and environmental sensitivities in the country. Therefore, economic growth for the Turkish economy can be said to take into account environmental sustainability in the long run. The findings suggest that growth policies centered on productivity and environmentally friendly green investments are crucial for the Turkish economy in terms of alleviating ecological pressure and promoting environmental sustainability. Indeed, our results show that urbanization and renewable energy consumption positively affect environmental sustainability in the long run. However, the claim of Pata and Kartal (2023) that renewable energy has no impact on the environment does not coincide with our results. In this context, the implementation of practices that will accelerate the transition to clean energy sources and the implementation of smart, sustainable urbanization policies in Türkiye are critical for environmental sustainability. Today, the 42.2% utilization rate of renewable energy sources in the country is important in terms of showing that the clean energy policies implemented support the UN 2030 sustainable development goals and the Twelfth Development Plan (2024-2028). On the other hand, as stated by the Republic of Türkiye CSBB (2023), an average annual growth rate of 5.0 percent is targeted for the Turkish economy in the 2024-2028 period. In this respect, the implementation of sustainable and low-carbon growth policies centered on clean resources will contribute to reducing the pressure on ecological balance and ensuring environmental sustainability in Türkiye. In addition, although the rate of urbanization has been declining in Türkiye recently, cities continue to have a dominant impact on ecological balance and the environment as they are responsible for the majority of energy consumption and are at the center of economic activity and social life. For this reason, sustainable urbanization target constitutes one of the important topics in the UN 2030 Sustainable Development Goals (2015-2030). At the same time, in the Twelfth Development Plan (2024-2028) prepared by the Republic of Türkiye CSBB (2023), it is emphasized that it is aimed to create smart, safe, sustainable cities and settlements that are resilient to climate change and disasters, have qualified residential areas in harmony with their historical and cultural background, provide accessible urban services for everyone, have high quality of life, and are based on green and digital technologies. The ARDL bounds test results indicate urbanization policies positively affect LCF in the long run and support ecological recovery and environmental sustainability. In this respect, our results suggest that urbanization policies have a key role in Türkiye's long-run sustainable development goals. On the other hand, the effects of financial development and population on environmental sustainability are found to be negative. The results of the analysis reveal that population growth increases the pressure on ecological balance by encouraging more resource consumption. Population is not only an important component of economic processes but also an important indicator of the development of human capital in a country. In this respect, our findings indicate that it is necessary to implement policies that consider the balance between population growth and environmental sustainability. In this context, policies that encourage resource efficiency and sustainable consumption can be given more weight. Here, it is of key importance to disseminate quality education that prioritizes environmental sensitivities throughout the country. Population policies that support economic growth and center on environmental protection will also support the development of the country's economic competitiveness muscles. Our results provide evidence that for the Turkish economy, financial development in the long run poses serious risks to environmental sustainability. This result is similar to the results of Zhang (2011), Omri et al (2015), Nasreen and Anwar (2015), Liu et al (2022), Sharma et al (2021), Musa et al (2021), Dagar et al (2022), etc. in the literature. However, Tadesse (2005), Tamazian et al (2009), Kızılkaya et al (2016), Zeeshan et al (2021), Udeagha and Breitenbach (2023) provide evidence that financial development does not cause environmental pollution, on the contrary, it positively affects it. The results of Ivanova and Angeles (2006) and Jun et al (2021), Phimphanthavong (2013) claim the opposite. Therefore, it is important to emphasize policies to encourage green financing practices in Türkiye and to adopt environmentally friendly technologies and practices in the financial sector. Economic theory suggests that financial development has a key role in sustaining economic growth. Moreover, the financial sector can play an important role in the development of environmentally friendly sectors, the transformation of carbon-intensive sectors and increasing renewable energy investments. Therefore, for Türkiye, emphasizing policies that promote green practices and clean energy use in the financial sector will contribute to both environmental and economic sustainability. Indeed, Toda-Yamamoto (1995) causality test results support the conclusions of the study. The results of the analysis have shown that there is mutual granger causality between financial development and LCF, and that one -way Granger causality is from financial development to economic growth. In the context of the causality relationship, Beck et al (2000), Fase and Abma (2003), Christopoulos and Tsionas (2004), Tang and Tang (2006), Oruç and Turgut (2014) and Eyüboğlu and Akan (2020) studies show that financial development increases growth. The results of the analysis revealed that LCF is an important determinant of economic growth in the short term. The results showed that there is a one-way Granger causality from urbanization to renewable energy consumption and from population density to urbanization. In addition, the findings revealed that there is a bidirectional Granger causality between renewable energy consumption and population density. In this respect, it has been shown that the increasing population and the clean energy policies implemented for Türkiye in the short term are integrated with each other. The following inferences can be made from the research results in general and suggestions can be made for future research:

- Our results revealed that economic development for Türkiye is an important determinant of environmental sustainability in both the long and short term. Especially in the long run, economic development promotes environmental sustainability.
- On the other hand, it has been determined that financial development is to the detriment of environmental sustainability in the long run. In this respect, encouraging financial policies that will support economic and environmental sustainability will contribute to both environmental sustainability and Turkey's sustainable development efforts.
- As a matter of fact, our results show that clean energy policies implemented in the short term are an important determinant of financial development. For this reason, it is important to expand green financing practices that will encourage clean energy policies.
- The results of the research analyzed the role of financial, social and demographic factors in the relationship between economic growth and environmental sustainability for Turkey.
- In this respect, future studies are important to reveal the impact of these factors on the relationship between economic development and environmental sustainability for Türkiye more clearly.
- Our results showed that the clean energy policies implemented support Turkey's environmental sustainability in the long term and are closely related to urbanization and population policies in the short term.

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