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Financial stability and environment degradation in Turkey: evidence from fourier ARDL approach

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This study investigates the impact of financial stability on environmental degradation in Turkey, controlling for economic growth, renewable energy consumption, and primary energy consumption between 1990 and 2019. The study employs various statistical methodologies, including LS Unit Root, Fourier ARDL, DOLS, and FMOLS tests. The findings reveal an inverse relationship between financial stability and environmental degradation. Both economic growth and primary energy consumption are found to exacerbate environmental degradation. This study recommends that policymakers incorporate financial stability into policies aimed at reducing CO₂ emissions. Furthermore, it emphasizes the importance of investing in renewable energy infrastructure and the transportation sector to effectively mitigate environmental degradation.

KEYWORDS

financial stability, environmental degradation, economic growth, trade, Turkey

1 Introduction

Energy is a vital resource necessary for heating, lighting, transportation, and the use of modern technological products. As technology progresses, the demand for energy keeps rising. The increase in environmental degradation has become a significant issue for countries within both underdeveloped and developing regions. Particularly due to the adverse effects on the global economy, numerous theories and policies have been developed to mitigate this damage. It has been identified that the primary cause of environmental degradation is the rise in greenhouse gases (Pata, 2018). Among these gases, carbon emissions (CO₂) hold the highest share (Pata, 2018). CO₂ emissions result from the combination of carbon, released through the combustion of fossil fuels, with oxygen, forming carbon dioxide. The increase in environmental pollution due to CO₂ emissions

Abbreviations: ADF, Augmented Dickey-Fuller; ARDL, Autoregressive Distributed Lag; CO₂, Carbon dioxide; DOLS, Dynamic Ordinary Least Square; LGDP, Economic Growth; LFR1, Financial Stability; FMOLS, Fully Modified Ordinary Least Square; IMF, International Monetary Fund; LNG, Liquefied Natural Gas; NO₂, Nitrogen Dioxide; NARDL, Nonlinear Autoregressive Distributed Lag; PM10, Particulate Matter; LENERGY, Primary Energy Consumption; LREC, Renewable Energy Consumption; PP, Phillips-Perron; SO₂, Sulfur Dioxide; SDGs, Sustainable Development Goals; UN, United Nations; WLMC, Wavelet Local Multiple Correlation.

occurs when carbon dioxide emissions exceed the world's emission capacity (Çetin and Yüksel, 2018). The nexus between financial stability, primary energy consumption, and the correlation between energy utilization and CO₂ emissions constitutes a pivotal domain of inquiry within environmental economics. The theoretical underpinnings of these interconnections are frequently grounded in the principles of sustainable development and the Environmental Kuznets Curve (EKC) hypothesis (Çetin and Yüksel, 2018). Financial stability, characterized by the resilience and robustness of financial institutions and markets, is indispensable in facilitating investments in renewable energy technologies and efficient energy systems (Nwani et al., 2023). These investments are crucial for the diminution of primary energy consumption and the mitigation of CO₂ emissions. Healthy financial markets enable the allocation of capital towards green technologies and infrastructure, which are imperative for the transition to a sustainable energy future (Farooq et al., 2022). The EKC hypothesis postulates an inverted U-shaped relationship between economic growth and environmental degradation (Farooq et al., 2022). According to this hypothesis, CO₂ emissions tend to escalate during the initial stages of economic growth (Kirikkaleli and Adebayo, 2024). However, as an economy continues to develop and mature, emissions eventually decline due to the adoption of cleaner technologies and the implementation of stringent environmental regulations (Kirikkaleli and Adebayo, 2024). This perspective underscores the dynamic interplay between economic development and environmental quality (Adekunle et al., 2024). In this context, financial mechanisms and policies are paramount in the pursuit of energy efficiency and sustainability. Effective financial policies and incentives can support the adoption of green technologies and research and development in sustainable practices, and ensure that economic growth is congruent with environmental preservation (Nwani et al., 2023).

This study aims to explain the impact of financial stability on environmental degradation while controlling economic growth, renewable energy, and energy consumption in Turkey. The study analyzes data between 1990-Q1 and 2019-Q4. Unlike other research that spans multiple countries, this study focuses solely on Turkey, differentiating itself by the current period analyzed and the unique methodologies employed. Research on the connection between renewable energy, financial stability, and environmental degradation in Turkey is sparse. The methods used are prevalent in the literature and their combined use enables comparative analysis. Additionally, the study separately assesses the relationships between financial stability and environmental degradation, economic growth, renewable energy, and energy consumption. The use of such sophisticated analytical techniques makes this study unique, as it addresses a gap in the existing literature by applying these specific methodologies to Turkey. The study's findings contribute to a deeper understanding of the complex dynamics between financial stability and environmental outcomes in Turkey. Turkey is increasingly focusing on boosting its energy production to decrease dependence on fossil fuels and imports.

The paper is structured as follows: Section 2 explains the evolution of environmental regulations in Turkey. Section 3

provides a review of related literature. Section 4 describes the data and methodology, while Section 5 provides empirical findings. Finally, Section 6 concludes the study.

2 Evolution of environmental regulations in Turkey

In the 1970s, Turkey began prioritizing environmental concerns due to increased awareness and the 1973 oil crisis that underscored the importance of diversifying energy sources. Initially, development plans centered on economic growth with little focus on environmental protection. The Third Five-Year Development Plan (1973–1977) marked the first significant attention to environmental issues (Isik and Kilic, 2014). The 1982 constitution included environmental protection clauses, and the Ministry of Environment was created in 1991. Turkey's international environmental involvement expanded in the 1990s, adopting sustainable development after the 1992 Rio Conference (Isik and Kilic, 2014). In 2015, Turkey committed to global sustainability by ratifying “The 2030 Agenda for Sustainable Development.” (Newell et al., 2015). The United Nations in Turkey works on the Sustainable Development Goals (SDGs) to address global challenges like poverty, inequality, and climate change. The SDGs aim to enhance human development, eliminate poverty, ensure health, promote education, and achieve gender equality, with a strong focus on environmental sustainability (Gultekin et al., 2017). The UN supports sustainable agriculture, food security, proper water management, resilient infrastructure, sustainable industrialization, innovation, and responsible consumption (Gultekin et al., 2017). Collaborating with the government, civil society, the private sector, and international organizations, the UN seeks to mobilize resources and implement sustainable strategies to achieve these objectives by 2030 (Gultekin et al., 2017).

Turkey's environmental regulation has been significantly influenced by European Union treaties and agreements, such as the Single European Act, Maastricht Treaty, Treaty of Amsterdam, and Treaty of Nice, along with the EU's environmental action plans since 1973 (Suleymanoglu-Kurum, 2018). This influence is reflected in Turkey's constitutional framework, with the 1961 Constitution addressing the environment in terms of health and the 1982 Constitution explicitly recognizing the right to a healthy environment, imposing duties on both the state and citizens (Suleymanoglu-Kurum, 2018). Since the 20th century, efforts have focused on understanding and mitigating greenhouse gas emissions, particularly carbon dioxide from fossil fuels, which drive global warming and climate change (Saboori and Sulaiman, 2013). This has led to a shift towards renewable energy sources like solar, wind, and hydroelectric power due to the depletion and environmental impact of fossil fuels. Governments and organizations have promoted this transition through policies emphasizing energy efficiency, carbon pricing, and green technologies (Artan et al., 2015). The move towards renewable energy and sustainable policies demonstrates a commitment to fostering economic growth without harming the planet, addressing climate change, and reducing the carbon footprint (Artan et al., 2015).

During the 1950–1974 period, known as the Golden Age, economic prosperity came at the cost of significant environmental degradation (Pamuk and Bektas, 2014). This period's economic growth often overlooked the environmental damage caused by manufacturing processes that relied on non-renewable energy sources (Kolsuz and Yeldan, 2017). Environmental degradation from fossil fuels led to global warming, air pollution, and climate change. As a result, there has been a shift towards examining macroeconomic parameters to create a more livable environment, emphasizing the importance of qualitative growth alongside quantitative growth for sustainability. Environmental quality has become a key concern, measured through parameters such as CO₂, NO₂, SO₂, PM₁₀ emissions, heavy metals in water, pathogen levels, ecological footprints, and deforestation (Artan et al., 2015). Despite the increasing prevalence of renewable energy sources, Turkey continues to import significant amounts of natural gas, primarily through pipelines and liquefied natural gas (LNG), highlighting an ongoing reliance on fossil fuels.

According to the IMF's latest report, Turkey, one of the world's top 20 largest economies, experienced strong economic growth in 2023, with a 4.5% increase in GDP and a *per capita* income of USD 11,939 (World Bank, 2024). Turkish banks are increasingly integrating sustainability into their operations by assessing the environmental impact of their credit and investment portfolios, including CO₂ emissions. They consider environmental and social risks in their lending processes, with renewable energy projects now comprising 50% of their energy generation financing. Notably, Turkey Garanti Bank, Turkey Halk Bank, and Sinai Kalkınma Bank conduct extensive environmental analyses, with Halk Bank focusing on CO₂ emissions and Sinai Kalkınma Bank prioritizing high-risk sectors to support the transition to a "Green Economy" (Borsaistanbul, 2017). The trend of reporting on financing for high CO₂ emission sectors, which began in 2017, highlights the growing commitment to integrating environmental sustainability into financial practices (Borsaistanbul, 2017).

The transportation sector is vital for economic growth but significantly increases carbon emissions, especially from road transport, which accounts for over 70% of global transport emissions. In Turkey, this sector contributes 22.2% of the energy sector's emissions and 15% of national emissions (Isik and Kilic, 2014). While countries like Germany and the UK have reduced their emissions, Turkey's have doubled since 1990, with a 181% increase in its carbon footprint from 1990 to 2015. This rise is largely due to increased use of diesel and LPG (Isik and Kilic, 2014). The need for Turkey to implement effective measures to reduce transportation-related emissions is crucial, given the stark contrast with European countries' achievements in emission reductions.

3 Review of the related literature

While Meo et al. (2023) focused on the asymmetric impact of temperature, energy use, population, economic growth, and water scarcity on CO₂ emissions in Pakistan, utilizing the NARDL model to analyze data from 1960 to 2016, Tuncsiper's (2023) study examined the relationship between Turkey's GDP, CO₂ emissions, and renewable energy consumption from 2003 to

2020, using Granger causality analysis and a deep learning network to model these dependencies. Both studies highlight the significant negative effects of economic growth on the environment. Kirikkaleli et al. (2023); Kalmaz and Kirikkaleli (2019) highlighted the connections between financial stability, economic growth, and environmental impact. Kirikkaleli et al. (2023) argue that financial stability can deter environmental degradation and note a positive correlation between economic growth and carbon emissions, while also emphasizing the beneficial role of renewable energy in reducing emissions, particularly in Norway. Kalmaz and Kirikkaleli (2019) focus on Turkey, employing modern econometric techniques to explore the long-term effects and causal relationships between CO₂ emissions and factors like energy consumption, economic growth, urbanization, and trade openness. Their findings offer valuable insights for policymakers aiming to mitigate carbon emissions and foster sustainable development in Turkey. Akbar et al. (2021) examine the connections between healthcare spending, CO₂ emissions and the Human Development Index (HDI) in OECD countries using a panel Vector Autoregression (VAR) model. The study is based on the Environmental Kuznets Curve (EKC) hypothesis, which suggests that environmental degradation initially worsens with economic growth but improves after a certain income level is reached. Additionally, the research incorporates the theory of sustainable development, highlighting the need to balance economic growth, social inclusion, and environmental protection. Based on these outcomes, we constructed the following hypothesis:

H1: There is a positive relationship between economic growth and environmental degradation.

Wang et al. (2023) assert that the relationship between various renewable energy sources and economic growth in ten selected Asian countries. It utilizes panel data analysis and advanced econometric techniques to investigate how hydropower, wind, solar, biomass, and geothermal energy, along with factors like trade openness and capital investment, influence economic expansion. The findings reveal a positive and significant impact of these renewable energy sources on the economic growth of Asian economies, offering valuable insights for stakeholders. Pata (2018), Jebli et al. (2016), and Ohlan (2015) each provide nuanced examinations of the relationship between CO₂ emissions, economic factors, and renewable energy within different contexts. Pata and Yurtkuran focus on Turkey from 1981 to 2014, finding that while population density, financial development, and economic growth increase CO₂ emissions, renewable energy consumption improves environmental quality. Ben Jebli et al., analyzing OECD countries from 1980 to 2010, support the environmental Kuznets curve (EKC) hypothesis, indicating that CO₂ emissions initially rise with economic growth before eventually declining as renewable energy adoption increases. Ohlan's study, spanning 1970 to 2013, also confirms that higher population density leads to greater CO₂ emissions, employing advanced statistical methods to explore both short- and long-term dynamics and validate the EKC hypothesis. Collectively, these studies underscore the critical role of renewable energy in mitigating environmental degradation amidst economic growth and urbanization. Chang et al. (2022); Ali and Meo (2024) also argued the role of renewable energy in reducing CO₂ emissions. Based on these arguments, we constructed the following hypothesis;

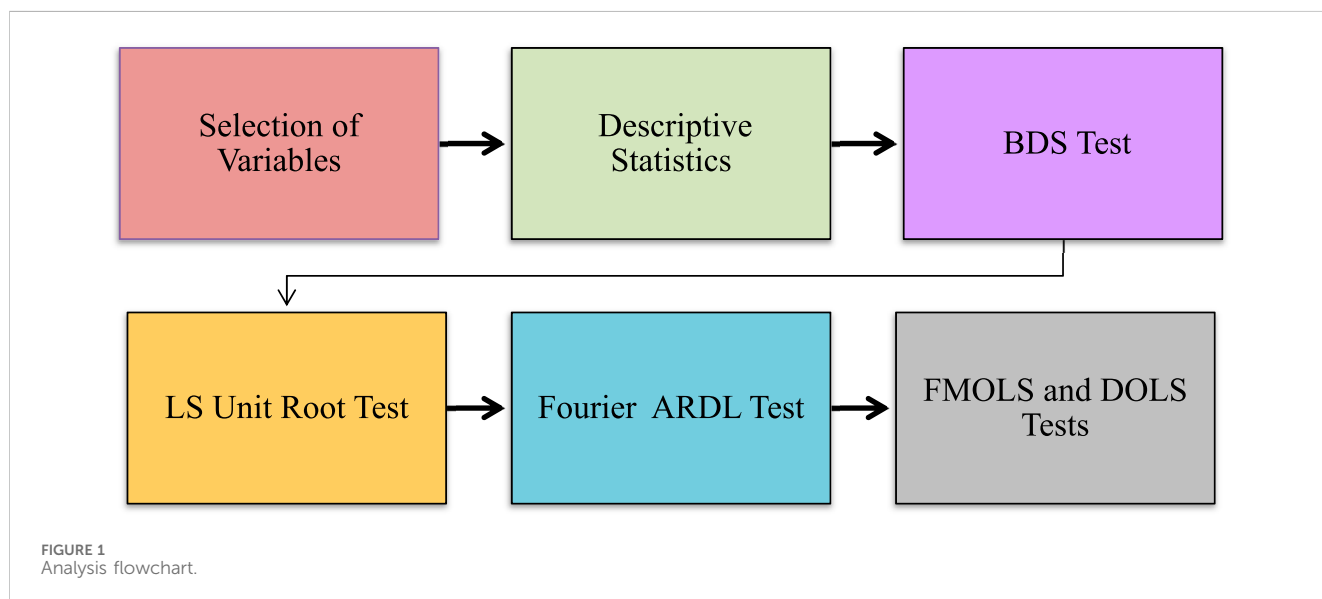


TABLE 1 Descriptive statistics.

Code	LCO ₂	LFRI	LGDP	LREC	LENERGY
Variable	Carbon dioxide (CO ₂) emissions from fossil fuels and industry	Financial Risk Index	Gross Domestic Product (constant 2015 US\$)	Renewable Energy Consumption	Primary Energy Consumption
Measure	Tonnes	Index	US\$	Terawatt-hours	Terawatt-hours
Source	Global Carbon Budget	Political Risk Services	World Bank	Energy Institute - Statistical Review of World Energy	Energy Institute - Statistical Review of World Energy
Mean	2.408306	3.442121	3.877707	1.218393	2.996429
Median	2.387612	3.481240	3.857103	1.210772	2.984842
Maximum	2.631356	3.650658	4.079997	1.392958	3.250790
Minimum	2.173152	3.106080	3.723227	1.050802	2.745766
Std. Dev	0.136823	0.133363	0.111866	0.113468	0.151267
Skewness	-0.019297	-1.046312	0.343863	0.195016	0.048914
Kurtosis	1.757485	3.335843	1.824637	1.564972	1.859441
Jarque-Bera	279.3636	399.2860	449.8140	141.3336	347.5857
Probability	2.152860	2.045361	1.439105	1.480636	2.631398

H2: There is a negative relationship between renewable energy consumption and environmental degradation.

Gov and Kaya (2022), Kızılkaya and Dag (2021), and Katircioglu (2014) present varied perspectives on the factors influencing CO₂ emissions in Turkey. Kosaroglu and Kaya (2022) study, covering 1998–2019, highlights that foreign direct investments, economic growth, motor vehicles, financial development, primary energy consumption, and advanced technology exports increase CO₂ emissions, whereas environmental tax reduces them. Kızılkaya and Dag (2021), analyzing 1975–2019, reveal a complex relationship where higher CO₂ emissions correlate with increased healthcare spending and potentially hinder economic growth, using

Fourier cointegration and causality tests. Katircioglu’s (2014) research, focusing on the tourism sector, demonstrates that tourism and energy consumption are significantly linked to CO₂ emissions, emphasizing the need for sustainable practices in these sectors. Together, these studies underscore the multifaceted drivers of CO₂ emissions in Turkey and the importance of integrating environmental considerations into economic and sectoral policies. The following hypothesis is constructed based on these arguments:

H3: There is a positive relationship between primary energy consumption and environmental degradation.

Khan and Yoon (2021) explore the theoretical linkages suggested by economic theory between financial instability

TABLE 2 LS unit root test.

LS unit root test						
At Level						
		LCO ₂	LFRI	LGDP	LREC	LENERGY
LS	t-Statistic	-4.214157	-6.326943	-4.945872	-5.880643	-5.512685
	Break Points	2000Q4 2005Q1	1996Q1 2004Q2	1994Q4 2001Q4	2006Q1 2013Q4	1995Q3 2001Q4
Test critical values	1% level	-5.848000	-6.063613	-5.746420	-5.918607	-5.746420
	5% level	-5.416327	-5.413133	-5.245273	-5.434260	-5.245273
	10% level	-5.090667	-5.069193	-4.983920	-5.145273	-4.983920
At First Difference						
		LCO ₂	LFRI	LGDP	LREC	LENERGY
LS	t-Statistic	-5.702039		-6.302054		
	Break Points	1999Q3 2003Q3		1999Q3 2009Q4		
Test critical values	1% level	-6.002600		-6.026000		
	5% level	-5.360067		-5.478800		
	10% level	-5.048133		-5.233600		

Note: *, **, and *** denote statistically significant at the 10%, 5%, and 1% levels, respectively.

TABLE 3 BDS probability test.

Dimension	LCO ₂	LFRI	LGDP	LREC	LENERGY
2	0.0000	0.0000	0.0000	0.0000	0.0000
3	0.0000	0.0000	0.0000	0.0000	0.0000
4	0.0000	0.0000	0.0000	0.0000	0.0000
5	0.0000	0.0000	0.0000	0.0000	0.0000
6	0.0000	0.0000	0.0000	0.0000	0.0000

and environmental quality. The findings indicate that income, trade openness, investment, and financial instability contribute to increased carbon dioxide (CO₂) emissions, whereas financial instability has a mitigating effect. Akbar et al. (2021) highlight that environmental protection investments positively impact the accounting and market performance of financially non-constrained Chinese listed firms. In contrast, these investments negatively affect the performance of financially constrained firms. Nasreen et al. (2017) estimate the relationship between financial stability, economic growth, energy consumption, and carbon dioxide (CO₂) emissions in South Asian countries from 1980 to 2012. The analysis employs the bounds test for cointegration and the Granger causality approach. Financial stability is found to improve environmental quality, whereas increases in economic growth, energy consumption, and population density harm environmental quality in the long run. The results also

support the environmental Kuznets curve (EKC) hypothesis. Serener et al. (2022) study indicates that renewable energy consumption reduces environmental degradation while economic growth increases it, and renewable energy lowers carbon dioxide emissions in Sweden. The above literature leads to the development of the following hypothesis:

H4: There is a negative relationship between financial stability and environmental degradation.

4 Methodology

Economic growth, primary energy consumption, energy consumption and financial stability were chosen as the explanatory variables. This selection is grounded in both theoretical frameworks and empirical studies that highlight their significant roles in generating and exacerbating carbon dioxide emissions (Kalayci and Hayaloglu, 2019). To ensure consistency and comparability across the variables, all data were transformed into their logarithmic forms. This approach helps to normalize the data and mitigate issues related to different scales of measurement (Kalayci and Hayaloglu, 2019).

The study employed a variety of advanced econometric methods, including the LS unit root test, Fourier ARDL, DOLS, and FMOLS tests. As an initial test, the present study employed the LS unit root test with two structural breaks to capture the integration order of the variables. As a main estimator, the Fourier ARDL test is employed to capture the

TABLE 4 Fourier ARDL long run form.

Variable	Coefficient	Std. Error	t-Statistic	Prob
LFRI	-0.052389	0.025422	-2.060774	0.0423
LGDP	0.132864	0.110519	1.202183	0.2325
LREC	-0.280265	0.051874	-5.402794	0.0000
LENERGY	0.619683	0.102187	6.064209	0.0000

effect of financial stability, primary energy consumption, economic growth, and renewable energy consumption on environmental degradation in Turkey between 1990Q1 and 2019Q4. In Fourier ARDL, structural changes are identified by using Fourier functions. Therefore, there is no need to run an additional structural change test or modify the estimated model. In the study, we also applied DOLS and FMOLS tests to support the outcomes of the Fourier ARDL. This study stands out due to its use of advanced analytical techniques, filling a gap in the current literature by applying these particular methodologies to Turkey. This study aims to explain financial stability’s impact on environmental degradation while controlling economic growth, renewable energy, and energy

consumption in Turkey. Based on this aim, the following the Eq. 1 is constructed;

$$CO_2 = f(LGDP, LFRI, LREC, LENERGY) \tag{1}$$

To eliminate the multicollinearity and heteroscedasticity issues in the estimated model, all parameters are used in their natural logarithms;

$$LCO2_{it} = \alpha_i + \beta_1 LGDP_{it} + \beta_2 LFRI_{it} + \beta_3 LREC_{it} + \beta_4 LENERGY_{it} + \varepsilon_{it} \tag{2}$$

Where in Eq. 2 t shows time which is between 1990-Q1 and 2019-Q4, i indicates Turkey, while α and β are measured as the coefficients and ε_{it} is the error term.

5 Empirical findings and discussion

5.1 Data and sources

As shown in Figure 1, this study focuses on the asymmetric effects of economic growth, renewable energy consumption, energy

TABLE 5 Robust test.

FMOLS				
Variable	Coefficient	Std. Error	t-Statistic	Prob
LFRI	-0.019488	0.00861	-2.263397	0.0256
LGDP	0.015005	0.053168	0.282217	0.7783
LREC	-0.221999	0.025562	-8.68457	0.0000
LENERGY	0.743487	0.047632	15.60887	0.0000
C	0.460663	0.107426	4.288202	0.0000
R-squared	0.998245	Mean dependent var		2.410351
Adjusted R-squared	-0.998181	S.D. dependent var		0.13563
S.E. of regression	0.005784	Sum squared resid		0.003681
Long-run variance	0.0000922			
DOLS				
Variable	Coefficient	Std. Error	t-Statistic	Prob
LFRI	-0.019267	0.009167	-2.101895	0.0379
LGDP	0.015732	0.052644	0.298844	0.7656
LREC	-0.223486	0.025806	-8.660241	0.0000
LENERGY	0.740595	0.047484	15.59677	0.0000
C	0.467982	0.107442	4.355686	0.0000
R-squared	0.998467	Mean dependent var		2.410351
AdjustedR-squared	0.998351	S.D. dependent var		0.13563
S.E. of regression	0.005508	Sum squared resid		0.003216
Long-run variance	0.0000892			

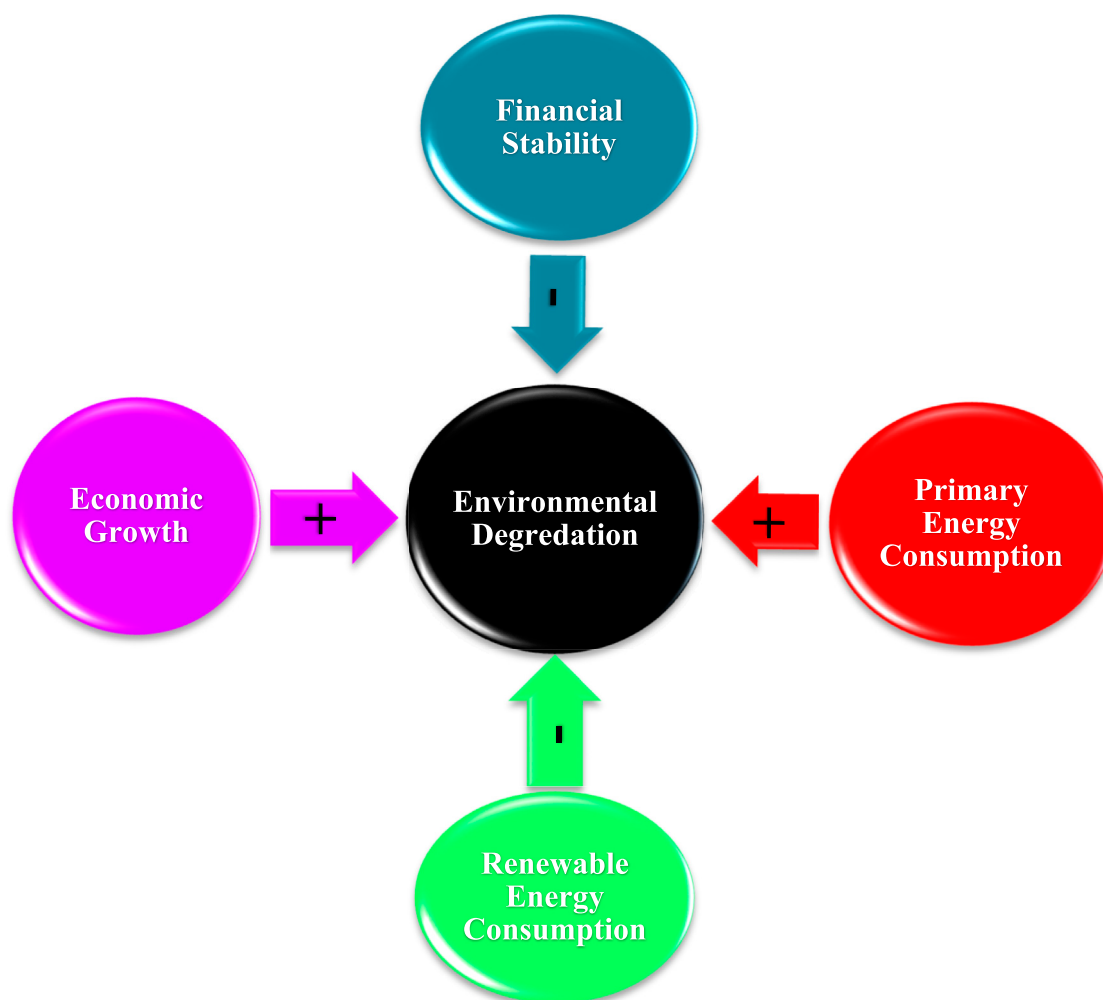


FIGURE 2
Summary of empirical findings with methods.

consumption, and financial stability on CO₂ emissions between 1990Q1 and 2019Q4. All variables are shown in log form. In other words, this study aims to capture the effect of financial stability on environmental degradation in Turkey while controlling economic growth, energy consumption, and renewable energy in Turkey 1990Q1 and 2019Q4 analyzes with LS unit root test, DOLS, FMOLS, and Fourier ARDL.

Based on the empirical model, Table 1 shows a descriptive statistical analysis of the parameters. Table 1 shows that the mean values of LCO₂, LFRI, LGDP LREC, and LENERGY are 2.408306, 3.442121, 3.877707, 1.218393, and 2.996429, respectively. In this study, the time series variables are used in their natural logarithmic form.

Table 2 displays the results of the LS unit root test. The LS unit root tests with breakpoints are used to analyze the series' integration order. LS unit root test results presented in Table 2 clearly show that LFRI, LREC, and LENERGY are not stationary at levels. LCO₂ and LGDP, however, become stationary after taking the first difference. The breakpoints of the time series variables are: CO₂ (1999Q3; 2003Q3) and LGDP (1999Q3; 2009Q4).

As shown in Table 3, the BDS nonlinearity test examines the hypothesis that all research variables are not uniformly distributed. Therefore, dynamic asymmetric skeletons are crucial to constraining nonlinear interactions. As clearly seen in Table 3, the time series variables have a nonlinearity behavior. After confirming the structural breakdowns and asymmetry in the series, the authors estimate the coefficients using the Fourier ARDL model. BDS test has many advantages over the alternatives.

The analysis detailed in Table 4 shows that the Fourier ARDL long-run estimates for all coefficients are statistically significant. For LREC and LFRI, the coefficients are negative, indicating that a unit increase in these variables leads to a decrease in CO₂ emissions by 0.28% and 0.05%, respectively. This suggests that LREC and LFRI play significant roles in reducing CO₂ emissions in Turkey. Conversely, the coefficients for LGDP and LENERGY are positive, meaning that a unit increase in these factors results in a 0.13% and 0.62% increase in CO₂ emissions, respectively.

The outcomes of the FMOLS and DOLS estimates (Table 5) for model robustness indicate that the independent variables

cumulatively (i.e., LFRI, LGDP, LREC, and LENERGY) can explain the dependent variable, CO₂ emissions, by 98% using FMOLS and 99% using DOLS estimators respectively. As previously demonstrated by the Fourier ARDL results, the estimated model is statistically significant and has the expected signs. In other words, the effect of LFRI and LREC on carbon dioxide emissions in Turkey is negative and significant, while primary energy consumption and economic growth are positive and have a positive effect on environmental degradation. The main findings of the present study are illustrated in [Figure 2](#).

6 Conclusion

The objective of this study is to explore the effects of economic growth, renewable energy consumption, energy consumption, and financial stability on CO₂ emissions between 1990Q1 and 2019Q4. Unlike studies that cover multiple countries, this research is exclusively focused on Turkey, distinguishing itself through its analysis of a recent period and the unique methodologies it employs. There is a scarcity of research examining the relationship between renewable energy, financial stability, and environmental degradation in Turkey. The use of advanced analytical techniques makes this study unique, addressing a gap in the current literature by applying these specific methodologies to Turkey. According to the Fourier ARDL long-run analysis results for Turkey, financial stability and renewable energy resources have a negative impact, while economic growth and primary energy consumption have a positive impact on environmental degradation. These findings align with the work of [Raza and Shah \(2018\)](#), which indicates that economic growth contributes to higher CO₂ emissions in the long run, while renewable energy consumption reduces them. This pattern is also observed in other studies. For instance, research on Thailand from 1980 to 2018 shows that renewable energy consumption has a negative and statistically significant impact on CO₂ emissions ([Boontome et al., 2017](#)). Similarly, a study in Ireland found that primary energy consumption increases environmental degradation, reinforcing the conclusions of this study ([Kirikkaleli and Sofuoğlu, 2023](#)). Comparative analysis shows that the variables and outcomes are consistent across different contexts. Renewable energy consumption improves environmental quality due to its zero emissions. This conclusion is further validated by [Safi et al. \(2021\)](#), who indicate that financial stability and renewable energy consumption both decrease CO₂ emissions in their study. According to [Serener et al. \(2022\)](#), the Fourier ARDL long-run estimation shows that renewable energy negatively affects environmental degradation. However, financial development and economic growth positively affect Sweden's environmental degradation. [Cetin and Yuksel \(2018\)](#) identify a positive link between energy consumption and carbon emissions in Turkey, indicating a significant reliance on fossil fuels. This finding supports hypotheses two and 3, underscoring the critical need to promote and utilize renewable energy sources such as biofuel, solar, wind, hydroelectric, and geothermal energy, which are cleaner alternatives. [Kirikkaleli et al. \(2023\)](#) found that financial stability is beneficial for the environment in Norway. The results align with our expectations and Hypotheses 1 and 4, particularly because a stable financial system ensures efficient resource allocation,

effective risk management, maintenance of employment levels close to the natural rate of unemployment, and stabilization of real or financial asset prices to support monetary stability and employment levels. Financial stability refers to the financial system's capacity to mitigate imbalances caused by adverse and unexpected events. This stability helps prevent disruptions to the real economy and other financial systems by absorbing shocks through self-correcting mechanisms ([Khan and Yoon, 2021](#)). This finding aligns with the traditional understanding that as economies grow, industrial production, transportation, and energy consumption increase, leading to higher CO₂ emissions. Economic growth often entails a rise in manufacturing and industrial activities, which are typically associated with significant carbon emissions due to the reliance on fossil fuels ([Wang et al., 2023](#)). The expansion of economic activities, while beneficial for development, poses a challenge for environmental sustainability, highlighting the need for a balanced approach to growth that incorporates environmental considerations. In contrast, the study found that renewable energy consumption negatively impacts environmental degradation. Renewable energy sources such as wind, solar, and hydroelectric power do not produce CO₂ emissions during their operation, making them a cleaner alternative to traditional fossil fuels. The increased utilization of renewable energy in Turkey has contributed to a reduction in CO₂ emissions, underscoring the importance of transitioning to a more sustainable energy mix. This shift towards renewable energy not only helps in mitigating environmental degradation but also promotes energy security and reduces dependence on imported fossil fuels ([Wang et al., 2023](#)). Primary energy consumption, which encompasses the total energy used by the economy, was found to have a positive influence on environmental degradation. Higher energy consumption generally correlates with increased CO₂ emissions, particularly when the energy mix is heavily reliant on fossil fuels. This finding suggests that while energy consumption is essential for economic development, it also poses significant environmental challenges. Managing energy consumption through enhanced energy efficiency measures and promoting the use of cleaner energy sources are crucial steps to mitigate the environmental impact. Conversely, the study highlighted that financial stability negatively impacts environmental degradation. Financial stability can facilitate better investment in clean technologies and infrastructure that reduce emissions. Stable financial systems are more likely to support long-term investments in environmental projects and renewable energy, providing the necessary funding for sustainable development initiatives. This relationship indicates that strengthening financial institutions and mechanisms can play a pivotal role in promoting environmental sustainability.

6.1 Policy recommendation and future research

Drawing from these findings, the study presents several actionable policy suggestions to address environmental degradation in Turkey. The study underscores the importance of implementing targeted policy measures, particularly in the transportation sector, to curb emissions effectively. It proposes the adoption of a multifaceted approach encompassing carbon taxation, biofuel quotas, and incentives for zero and low-emission technologies. By incentivizing

cleaner energy sources and technologies, such policies aim to mitigate the adverse environmental impact associated with transportation activities. The study advocates for the establishment of investment support schemes to accelerate the transition towards renewable energy and clean technologies. Government-backed initiatives and financial incentives can play a pivotal role in fostering the adoption of sustainable energy solutions, thereby reducing reliance on fossil fuels and mitigating environmental degradation. By broadening the geographical focus, future studies can provide a more comprehensive understanding of environmental degradation patterns and identify common trends and policy implications across diverse regions. This study relies on macroeconomic data and future research could complement this by incorporating microeconomic data.

6.2 Limitations

This study provides valuable insights into the relationship between financial stability and environmental degradation in Turkey through the use of Fourier ARDL approaches. However, several limitations need to be acknowledged. The focus on Turkey may restrict the general applicability of the findings to other nations with varying economic, social and environmental conditions. Time series data utilized in this study from 1990Q1 to 2019Q4. Incorporating more recent and detailed datasets as they become accessible could strengthen the credibility of future research.

Data availability statement

The raw data supporting the conclusion of this article will be made available by the authors, without undue reservation.

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Conflict of interest

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