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Revisiting the Environmental Kuznets Curve Hypothesis in Türkiye: Evidence from the Period 1970–2024

Türkiye'de Çevresel Kuznets Eğrisini Yeniden Düşünmek: 1970-2024 Döneminden Kanıtlar

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ABSTRACT

This study examines the validity of the Environmental Kuznets Curve (EKC) hypothesis for Türkiye over the period 1970–2024 by analyzing the relationship between per capita income and greenhouse gas emissions. Annual data are employed within the Autoregressive Distributed Lag (ARDL) bounds testing framework, which allows for the estimation of both short- and long-run dynamics among variables integrated at different orders. The empirical findings confirm the existence of a long-run relationship among greenhouse gas emissions, per capita income, and the share of renewable energy in total energy consumption. The estimated coefficients indicate a concave association between income and emissions, providing partial support for the EKC hypothesis. However, the calculated turning point lies beyond the observed income range, suggesting that a fully realized inverted U-shaped trajectory has not yet materialized during the sample period. Instead, the results imply that the positive linkage between income and emissions diminishes as income levels rise. Overall, the findings underscore the critical role of sustainable growth strategies in mitigating environmental degradation.

Keywords: Environmental Kuznets Curve, Economic Development, Greenhouse Emissions, ARDL Bounds Test

JEL Codes: O44, Q42, Q53, C22

ÖZET

Bu çalışma, 1970–2024 dönemi için Türkiye'de kişi başına gelir ile sera gazı emisyonları arasındaki ilişkiyi analiz ederek Çevresel Kuznets Eğrisi (ÇKE) hipotezinin geçerliliğini incelemektedir. Çalışmada, farklı bütünleşme derecelerine sahip değişkenler arasındaki kısa ve uzun dönem dinamiklerin tahmin edilmesine olanak sağlayan Otoregresif Dağıtılmış Gecikme (ARDL) sınır testi yaklaşımı kapsamında yıllık veriler kullanılmıştır. Ampirik bulgular, sera gazı emisyonları, kişi başına gelir ve yenilenebilir enerjinin toplam enerji tüketimi içindeki payı arasında uzun dönemli bir ilişkinin varlığını doğrulamaktadır. Tahmin edilen katsayılar, gelir ile emisyonlar arasında konkav bir ilişkiye işaret ederek ÇKE hipotezine kısmi destek sağlamaktadır. Bununla birlikte, hesaplanan dönüm noktasının gözlenen gelir aralığının ötesinde yer alması, örneklem dönemi boyunca tam anlamıyla gerçekleşmiş ters U şeklinde bir patikanın henüz ortaya çıkmadığını göstermektedir. Bunun yerine sonuçlar, gelir ile emisyonlar arasındaki pozitif ilişkinin gelir düzeyi arttıkça zayıfladığını ima etmektedir. Genel olarak bulgular, çevresel bozulmanın azaltılmasında sürdürülebilir büyüme stratejilerinin kritik rolünü vurgulamaktadır.

Anahtar Kelimeler: Çevresel Kuznets Eğrisi, Ekonomik Kalkınma, Sera Gazı Emisyonları, ARDL Sınır Testi

JEL Kodları: O44, Q42, Q53, C22

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1. INTRODUCTION

The relationship between economic growth and environmental sustainability has been a significant topic of debate among both policymakers and academics. Industrialization has led to increased production and consumption, which, in turn, has resulted in environmental degradation. Many empirical studies based on the Environmental Kuznets Curve (EKC) hypothesis have shown that the relationship between economic development and environmental degradation may not be linear (Al-Mulali et al., 2014; Maneejuk & Yamaka, 2022; Barak et al., 2024). Generally, the Environmental Kuznets Curve represents an inverted U-shaped relationship, suggesting that environmental degradation increases during the early stages of development and decreases in later stages (Shahbaz et al., 2014).

While the inverted U-shaped relationship between economic development and environmental degradation has attracted considerable attention, some studies provide evidence that this nonlinear relationship may instead be N-shaped or inverted N-shaped. An N-shaped relationship implies that environmental degradation initially increases, then decreases, and subsequently increases again with economic development (Abdallah et al., 2013). By contrast, an inverted N-shaped relationship suggests that environmental degradation first decreases, then increases, and finally decreases again as economic growth progresses (Onafowora & Owoye, 2014).

Although the existing evidence for Türkiye generally supports the EKC hypothesis (Şeyranlıoğlu, 2021; Ünal & Aktuğ, 2022; Polat & Ergün, 2023; Demir et al., 2024), the empirical findings remain inconclusive regarding whether Türkiye has reached the environmental turning point associated with sustainable growth. In line with the literature, our preliminary findings also indicate the expected EKC direction; however, the estimated turning point appears to lie outside the observed sample range. This suggests that the environmental costs of economic growth may persist in Türkiye despite structural transformation and increasing globalization.

The remainder of the study is organized as follows. The next section reviews the relevant literature on the EKC hypothesis. The following section presents the data set and econometric methodology employed in the analysis. Subsequently, the empirical findings are reported and discussed. Finally, the last section concludes.

2. LITERATURE

The existing literature on the Environmental Kuznets Curve (EKC) hypothesis has extensively examined the relationship between economic growth, globalization, energy consumption, financial development, and environmental degradation across different countries and regions. A large body of empirical research confirms the existence of an inverted U-shaped relationship between income growth and environmental pollution, although findings differ depending on country groups, methodologies, and explanatory variables.

Several country-specific studies employ time-series approaches, particularly ARDL and error correction models, to analyze the long-run and short-run dynamics between globalization, economic growth, and carbon emissions. For example, İmamoğlu and Onbaşıoğlu (2023) investigated Pakistan for the period 1975–2015 and found a long-run relationship between CO2 emissions, GDP, energy consumption, and globalization. Similarly, Khan and Ullah (2019) confirmed the EKC hypothesis in Pakistan using Johansen cointegration and ARDL approaches, while also emphasizing the contribution of economic, political, and social globalization to carbon emissions. In the case of India, Sinha and Shahbaz (2018) identified an inverted U-shaped EKC relationship and reported that renewable energy reduces carbon emissions, whereas Pal and Mitra (2017) found an N-shaped relationship between economic activity and CO2 emissions in India and China.

Several studies focusing on Türkiye also support the EKC hypothesis. Şeyranlıoğlu (2024) examined the effects of financial development on sectoral carbon emissions and concluded that financial development reduces emissions in the long run, whereas economic growth and energy consumption increase them. Polat and Ergün (2023) analyzed the effects of economic, social, and political globalization on environmental quality and found evidence of long-run relationships among globalization indicators, GDP, and CO2 emissions. Likewise, Demir et al. (2024) employed the augmented ARDL approach and confirmed the validity of the EKC hypothesis in Türkiye, emphasizing the positive effects of trade openness and energy consumption on carbon emissions. Ünal and Aktuğ (2022) also confirmed the EKC hypothesis for Türkiye by examining ecological footprint and biocapacity indicators.

Panel data studies covering broader country groups generally provide mixed but largely supportive evidence for the EKC hypothesis. Hacıimamoğlu (2022) analyzed BRICS-T countries and found an inverted U-shaped relationship between economic growth and environmental pollution. Aydoğdu and Özşahin (2023) confirmed the EKC hypothesis for emerging economies using panel data techniques. Similarly, Efeoğlu (2022) demonstrated that renewable energy and financial development reduce CO2 emissions in E7 countries, while industrialization and energy consumption increase emissions. Yılmaz and Çamkaya (2022), however, reported that the EKC hypothesis is not valid for N-11 countries based on AMG and CCEMG estimators.

Cross-country and regional analyses also reveal important insights regarding structural and income-related heterogeneity. Koçak (2024) verified the EKC hypothesis for 17 EU countries using second-generation panel techniques, showing that environmental degradation increases during early growth stages but decreases in later stages. Zhang et al. (2019) examined 121 countries and found that the EKC hypothesis was validated in 95 countries, with higher-income economies exhibiting a greater likelihood of reaching environmental turning points. Dogan and Inglesi-Lotz (2020) highlighted the role of economic structure in shaping the EKC relationship across European countries, while Dong et al. (2018) confirmed the validity of the EKC hypothesis in most Asia-Pacific countries regardless of income levels.

Another strand of literature focuses on globalization, tourism, and foreign direct investment as determinants of environmental degradation. Anser et al. (2020) found that tourism revenues and FDI inflows increase CO2 emissions in G7 countries, supporting the Pollution Haven Hypothesis, whereas government education expenditures help reduce environmental degradation. Overall, the literature suggests that the environmental impacts of globalization and economic growth are highly heterogeneous across countries and depend on structural characteristics such as energy composition, financial development, industrialization, and institutional capacity.

3. DATA, MODEL AND METHODOLOGY

This study uses annual data for the period 1970–2024 to investigate the validity of the Environmental Kuznets Curve in Türkiye. The dependent variable is total greenhouse gas emissions, while per capita income data are obtained from the World Bank (2026) database. Data on the share of renewable energy in energy consumption are taken from the Our World in Data (2026) database.

The empirical analysis begins by examining the unit root properties of the variables, for which the Phillips and Perron (1988) unit root test is employed. This test is based on the standard Dickey–Fuller equations and modifies the test statistic to ensure that the asymptotic distribution is not affected by serial correlation.

Subsequently, the Autoregressive Distributed Lag (ARDL) approach proposed by M. Hashem Pesaran et al. (2001) is employed to investigate the existence of a cointegration relationship among the series and to estimate the long-run and short-run coefficients. One of the main advantages of this method is that it can be applied to series integrated at mixed levels. For Türkiye, the Environmental Kuznets Curve model is constructed within an ARDL framework as follows:

$$LNGREEN_t = \alpha_0 + \alpha_1 t + \sum_{i=1}^{p} \psi_i \, LNGREEN_{t-i} + \sum_{j=0}^{q_1} \beta_{1j} LNGDPPER_{t-j} + \sum_{j=0}^{q_2} \beta_{2j} LNGDPPERSQ_{t-j} + \sum_{j=0}^{q_2} \beta_{3j} LNRENEW_{t-j} + \epsilon_t \quad (1)$$

Finally, to evaluate the robustness of the findings obtained from the Autoregressive Distributed Lag (ARDL) model, Dynamic Ordinary Least Squares (DOLS) methods proposed by Stock and Watson (1993) were employed. These methods correct the bias of Ordinary Least Squares (OLS) estimators and help mitigate potential endogeneity problems.

4. EMPIRICAL FINDINGS

Table 1 presents the descriptive statistics of variables. The descriptive statistics reveal moderate variation across the variables. LNGREEN and LNGDPPER display relatively symmetric distributions, as evidenced by skewness values close to zero and insignificant Jarque–Bera statistics. In contrast, LNRENEW is negatively skewed and departs from normality at the 5% significance level. Overall, the variables do not exhibit extreme dispersion or severe distributional concerns.

Table 1. Descriptive Statistics of Variables

	LNGREEN	LNRENEW	LNGDPPER	LNGDPPERSQ
Mean	5.573	2.381	8.756	76.880
Median	5.627	2.410	8.683	75.409
Maximum	6.366	2.984	9.641	92.964
Minimum	4.620	1.341	8.069	65.122
Std. Dev.	0.512	0.348	0.451	7.983
Skewness	-0.070	-0.844	0.381	0.443
Kurtosis	1.873	3.847	1.966	2.017
Jarque-Bera	2.952	8.180	3.778	4.016
Probability	0.228	0.016	0.151	0.134
Observations	55	55	55	55

Table 2 presents the correlation matrix of variables. Accordingly, there is a strong positive correlation between renewable energy share, per capita income and total greenhouse emissions.

Table 2. Correlation Matrix

	LNGREEN	LNRENEW	LNGDPPER	LNGDPPERSQ
LNGREEN	1.000			
LNRENEW	0.699	1.000		
LNGDPPER	0.984	0.672	1.000	
LNGDPPERSQ	0.980	0.668	1.000	1.000

Table 3 presents the unit root test results. According to the results, all variables except total greenhouse gas emissions exhibit a unit root at level. In contrast, all variables become stationary after first differencing.

Table 3. Phillips & Perron Unit Root Test Results

		At Level			
		LNGREEN	LNRENEW	LNGDPPER	LNGDPPERSQ
With Constant	t-Statistic	-1.652	-1.736	1.375	1.810
	Prob.	0.449	0.407	0.998	0.999
With Constant & Trend	t-Statistic	-3.726	-2.815	-1.53	-1.244
	Prob.	0.028	0.198	0.803	0.890
		At First Difference			
		d(LNGREEN)	d(LNRENEW)	d(LNGDPPER)	d(LNGDPPERSQ)
With Constant	t-Statistic	-7.861	-9.276	-7.003	-6.906
	Prob.	0.000	0.000	0.000	0.000
With Constant & Trend	t-Statistic	-8.027	-9.236	-7.374	-7.394
	Prob.	0.000	0.000	0.000	0.000

Table 4 presents the bounds test and error correction results for the model. The error correction term is negative and statistically significant, indicating the existence of a long-run equilibrium relationship. The coefficient of -0.716 suggests that approximately 72% of short-run deviations from the long-run equilibrium are corrected within one period, implying a relatively rapid speed of adjustment. On the other hand, the F-statistics exceeds the upper bound at the 1% significance level, confirming the existence of a long-term cointegration relationship among the variables. Furthermore, since the t-statistics also exceed the upper bound at the 1% significance level, the validity of this cointegration relationship is reinforced.

Table 4. Bounds Test and Error Correction

	F statistics		t-statistics	
Statistics Value	21.669		-9.770	
Bounds	I(0)	I(1)	I(0)	I(1)
10%	2.873	3.973	-2.57	-3.46
5%	3.5	4.7	-2.86	-3.78
1%	4.865	6.36	-3.43	-4.37
	Coefficient	Std. Error	t-Statistic	Prob.
CointEq(-1)	-0.716	0.126	-5.680	0.000

Table 5 presents the long-run coefficients. The results indicate that there is a non-linear association between per capita income and greenhouse gas emissions. This association exhibits an inverted U-shaped pattern. This suggests that total emissions rise during the early stages of development and begin to decline in the later stages. However, the calculated turning point corresponds to approximately USD 28,900, which lies outside the observed data range. Although the estimated coefficients imply a concave relationship consistent with the Environmental Kuznets Curve hypothesis, the findings do not confirm a fully realized inverted U-shaped pattern within the sample period. Instead, the results indicate that the positive relationship between income and emissions weakens as income levels increase.

Table 5. Long-Run Coefficient (ARDL, 1, 2, 1, 4)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNGDPPER	8.295	0.480	17.273	0.000
LNGDPPERSQ	-0.404	0.027	-14.883	0.000
LNRENEW	0.032	0.021	1.525	0.135
Turning Point	US$ 28.700			

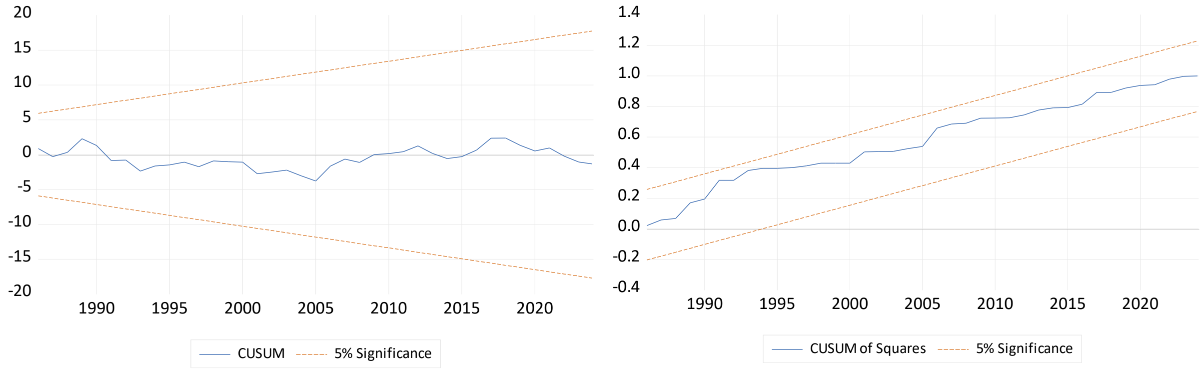
Table 6 reports diagnostic test results for the model. Results indicate that the model is well-specified. The residuals are normally distributed, with no evidence of serial correlation or heteroskedasticity. Furthermore, the Ramsey RESET test suggests that there is no functional form misspecification.

Table 6. Diagnostic Test Results

Test	Statistics	Probability
Jarque-Bera	1.449	0.485
Breusch-Godfrey	0.578	0.834
Breusch-Pagan-Godfrey	0.180	0.835
Ramsey Reset	0.271	0.788

Figure 1 shows the CUSUM and CUSUMQ test results. The results indicate that the estimated coefficients are stable over the sample period, as the plots remain within the critical bounds. This suggests the absence of structural instability in the model.

Figure 1. CUSUM and CUSUMQ Test Results



Robustness Check: DOLS estimates

To assess the robustness of the results, we employ the FMOLS and DOLS methods, which provide robust estimates against both autocorrelation and endogeneity problems. Tables 7 and 8 present the results obtained from these methods. The findings are consistent with the baseline results.

Table 7. DOLS results

Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
LNGDPPER	4.779	0.843	5.666	0.000
LNGDPPERSQ	-0.233	0.043	-5.432	0.000
LNRENEW	0.067	0.018	3.714	0.001
Turning Point		US$ 28.700		

5. CONCLUSION

This study investigates the validity of the EKC hypothesis in Türkiye over the period 1970–2024. The ARDL bounds testing approach is employed to examine the cointegration relationship among the variables and to estimate long-run coefficients. The main findings indicate that the inverted U-shaped pattern predicted by the EKC exists between economic development and greenhouse gas emissions in Türkiye; however, the turning point has not yet been reached.

The findings support the inverted U-shaped relationship between income growth and greenhouse gas emissions in Türkiye, but the fact that the turning point has not yet occurred indicates that economic growth is still increasing environmental pressures. This result suggests that environmental improvements are unlikely to emerge automatically through economic growth soon. Therefore, policymakers should accelerate investments in renewable energy sources, particularly solar and wind energy, improve energy efficiency in industry, transportation, and buildings, and support the adoption of cleaner production technologies. In addition, facilitating the transition toward low-carbon production systems through green innovation and sustainable infrastructure investments may help reduce environmental pressures while maintaining economic growth.

Finally, future studies could examine the dynamics of the EKC in more detail through sectoral emissions, energy consumption composition, structural breaks, and the role of environmental policy instruments.

Declaration of Research and Publication Ethics

This study was conducted in accordance with the principles of research and publication ethics. Since the study does not involve human or animal subjects, ethics committee approval and/or special legal permission were not required.

Author Contribution Statement

The authors contributed equally to all stages of the study.

Conflict of Interest Statement

The authors declare that there is no conflict of interest regarding the publication of this study.

Declaration of Artificial Intelligence Use

During the preparation of this manuscript, ChatGPT was used solely for language editing and proofreading purposes. All content was subsequently reviewed and revised by the authors, who assumed full responsibility for the final version of the manuscript.

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