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INVESTIGATING THE ENVIRONMENTAL KUZNETS CURVE HYPOTHESIS WITH ENERGY CONSUMPTION FOR TÜRKIYE: EVIDENCE FROM FOURIER ADF AND ARDL APPROACH[1]

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Abstract. In this study, the validity of the Environmental Kuznets Curve for the Turkish economy is investigated using the variables of per capita GDP, CO2 emissions, and energy consumption for the period between 1971 and 2019. The stationarity of the variables used in the study is examined with Augmented Dickey-Fuller (ADF) and Fourier ADF tests that consider structural breaks. The long-term relationship between GDP, CO2 emissions, and energy consumption is analyzed using the Autoregressive Distributed Lag (ARDL) bounds testing approach. Empirical analyses reveal that the first difference of GDP and CO2 emissions is stationary, while energy consumption is stationary at the level, indicating cointegration among the variables. The coefficients of the long-term model obtained through ARDL approach demonstrate an inverted U-shaped relationship between GDP and CO2 emissions, supporting the Environmental Kuznets Curve hypothesis in Turkey. Additionally, in the long run, energy consumption positively impacts CO2 emissions.

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1 Introduction

The increase in the emission of harmful gases in the atmosphere constitutes one of the fundamental causes of environmental issues such as global warming and climate change, putting pressure on ecological balance. Therefore, identifying the factors associated with harmful gas emissions and analyzing their effects is crucial. Economic growth, production activities, and the rise in energy demand lead to an increase in environmental pollution. Particularly, the nature of production activities is known for its polluting effects. Changes in economic development and production activities, coupled with the growing energy demand, result in an increase in carbon emissions (CO2), contributing to the deterioration of environmental quality. Simon Kuznets (1955) examined the relationship between income distribution and economic growth in his study, stating that economic growth increases income inequality in the initial stages, but beyond a certain turning point, inequality decreases alongside the growth. This relationship, known as the Kuznets Curve hypothesis, suggests an inverted U-shaped relationship between

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income distribution and economic growth. With the emergence of issues like global warming, the environmental impact of increasing production and the use of natural resources as the main inputs in production has gained significance. The relationship between income and the environment has been extensively explored through various studies. Grossman and Kruger (1991) further developed Simon Kuznets' pioneering work by examining the relationship between per capita income and environmental pollution. This relationship between per capita income and environmental pollution was first expressed as the Environmental Kuznets Curve (EKC) hypothesis in Panayotou (1993). Kaika and Zervas (2013) represent the Environmental Kuznets Curve with the graph in Figure 1.

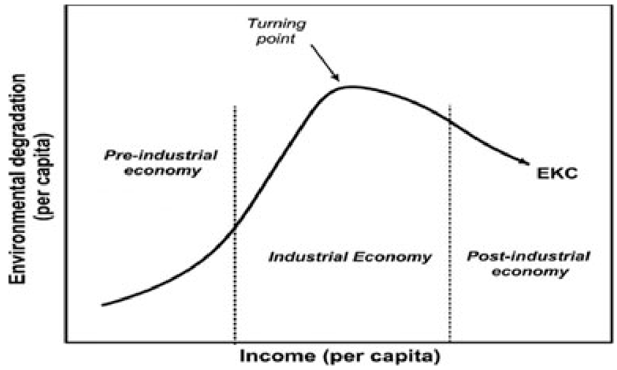

Figure 1: An Environmental Kuznets Curve (EKC). **Ref:** Kaika and Zervas (2013)

The underlying idea of the Environmental Kuznets Curve hypothesis suggests that there are specific dynamics between economic activities and the environment. When representing this relationship visually, it is referred to as an inverted U-shaped curve, indicating that pollution levels increase with income in an economy, but after reaching a turning point, environmental pollution starts to decrease. However, observing the expected pattern in the short term is not possible. This is because the Environmental Kuznets Curve hypothesis is a long-term phenomenon consisting of various stages (Dinda, 2004). The model structure in Equation 1 is employed to explain the hypothesis of the Environmental Kuznets Curve.

$$Y_t = \alpha + \beta_1 X_t + \beta_2 X_t^2 + \beta_3 X_t^3 + \varepsilon_t \quad (1)$$

Equation 1 represents time t. Y denotes the explained (dependent) variable CO2, while X represents GDP, X^2 represents the square of GDP, and X^3 represents the cube of GDP. The model established in Equation 1 helps determine the relationships between CO2 and GDP based on the signs of the β coefficients (Dinda, 2004; Bozoklu et al., 2020). Therefore, the expected relationship based on coefficient signs in econometric analyses is as follows:

1. $\beta_1 = \beta_2 = \beta_3 = 0$, There is no relationship between the variables.
2. $\beta_1 > 0$ and $\beta_2 = \beta_3 = 0$, There is a monotonically increasing relationship between the variables.
3. $\beta_1 < 0$ and $\beta_2 = \beta_3 = 0$, There is a monotonically decreasing relationship between the variables.
4. $\beta_1 > 0$, $\beta_2 < 0$ and $\beta_3 = 0$, There is an inverted U-shaped relationship between the variables (Environmental Kuznets Curve hypothesis holds).
5. $\beta_1 < 0$, $\beta_2 > 0$ and $\beta_3 = 0$, There is a U-shaped relationship between the variables.
6. $\beta_1 > 0$, $\beta_2 < 0$ and $\beta_3 > 0$, There is an N-shaped relationship.

7. $\beta_1 < 0$, $\beta_2 > 0$ and $\beta_3 < 0$, There is an inverted N-shaped relationship.

The inverted U-shaped relationship between the variables is determined using a quadratic model, while the N-shaped relationship is determined using a cubic model.

In this study, the Environmental Kuznets Curve hypothesis of Turkey will be tested in conjunction with energy consumption. Unit root tests that take into account structural breaks and the ARDL bounds test are employed in the study. The second section following this part examines studies investigating the validity of the EKC hypothesis both in Turkey and other countries. The third section provides a brief overview of the model constructed and the data used. In the fourth section, the econometric methodology used in the study is presented, while the findings obtained from these methods are interpreted in the fifth section. Lastly, the sixth section includes the conclusions and policy recommendations.

2 Literature Review

There are numerous studies in the literature that test the Environmental Kuznets Curve hypothesis. These studies generally employ quadratic and cubic models. By using quadratic models, the relationship between CO2 emissions and GDP is examined to determine whether it follows a U-shaped or an inverted U-shaped curve. Cubic models, on the other hand, investigate whether the relationship between variables forms an N-shaped or an inverted N-shaped curve. Furthermore, besides the quadratic or cubic models, the literature indicates the inclusion of additional variables in the analysis. These variables often include non-renewable energy consumption, renewable energy consumption, total population, urban population, trade openness, or foreign direct investments. In this study, total energy consumption was added to the quadratic model to test the Environmental Kuznets Curve hypothesis for Turkey.

Previous research examining Turkey's Environmental Kuznets Curve hypothesis mostly found that the EKC hypothesis holds true for Turkey. In his study, Bulut (2021) tested both the Environmental Kuznets Curve (EKC) hypothesis and the Pollution Haven Hypothesis (PHH) in Turkey for the period 1970-2016 by adding foreign direct investments, renewable energy consumption, and industrialization variables to the quadratic model using the ARDL approach. According to the long-term estimation results obtained by DOLS, it was found that the EKC hypothesis is valid for Turkey, while the PHH hypothesis is not valid.

Bese and Kalayci (2019) tested the validity of the Environmental Kuznets Curve (EKC) hypothesis for Turkey, Egypt, and Kenya during the period of 1971-2014. They incorporated energy consumption as an additional variable in the quadratic model. Through the use of Johansen and VAR analysis, the study found no significant causality among the variables for all three countries, indicating that the EKC hypothesis is not valid. In the studies conducted by Pata (2019), Akca (2021), and Destek (2018), the Environmental Kuznets Curve (EKC) hypothesis was tested for Turkey using different time intervals. In these studies, the Bootstrap Autoregressive Distributed Lag (ARDL), Augmented ARDL, and ARDL methods were employed, and all three studies provided support for the EKC hypothesis in Turkey.

In the literature, there are studies in which the EKC hypothesis is not supported for Turkey and the cubic model is used. Güzel (2021) and Ceylan and Karaağaç (2020) employed the ARDL and Gregory-Hansen methods, considering structural breaks. As a result, a non-linear relationship (N-shaped) was found among the variables. A brief summary of studies examining the validity of the EKC hypothesis in Turkey is presented in Table 1 as follows:

There are studies in the literature that examine the validity of the Environmental Kuznets Curve (EKC) hypothesis in a grouped manner by countries. These studies are generally analyzed using panel data methods. Grossman and Krueger (1991) investigated the validity of the EKC hypothesis in 42 countries using the Panel Generalized Least Squares (GLS) method and found that the hypothesis holds true in these countries. Panayotou (1993) and Panayotou (1997) conducted studies on 55 and 30 countries, respectively, using the Panel GLS method and also found supporting evidence for the validity of the EKC hypothesis in these countries.

Table 1: Previous studies examining the EKC hypothesis for Turkey

Author(s)	*Country(ies)*	*Time period*	*Method*	*EKC Hypothesis*
Bulut (2021)	Turkey	1970-2016	ARDL	Valid
Bese and Kalayci (2019)	Egypt, Kenya and Turkey	1971-2014	Johansen	Not Valid
Pata (2019)	Turkey	1969-2017	Bootstrap ARDL	Valid
Akca (2021)	Turkey	1965-2018	Augmented ARDL	Valid
Bölük and Mert (2015)	Turkey	1961-2010	ARDL	Valid
Güzel (2021)	Turkey	1960-2015	ARDL	Not Valid, N Shape
Yurtkuran (2021)	Turkey	1995-2016	Fourier ADL	Valid
Pata (2018)	Turkey	1974-2014	Gregory-Hansen and Hatemi-J	Valid
Genc et al. (2022)	Turkey	1980-2015	ARDL	Valid
Özpolat and Özsay (2021)	Turkey	1990-2015	ARDL	Valid
Karasoy (2021)	Turkey	1980-2016	Augmented ARDL	Not Valid
Ceylan and Karaağgaç (2020)	Turkey	1960-2014	Gregory-Hansen	Not Valid, N Shape
Özaydın and Apaydın (2019)	Turkey	1961-2015	ARDL	Valid
Öztürk and Gülen (2019)	Turkey	1960-2014	ARDL	Valid
Destek (2018)	Turkey	1990-2014	ARDL	Valid
Çağlar and Mert (2017)	Turkey	1990-2013	Gregory-Hansen and Hatemi- J	Valid

Chen et al. (2019) used the Vector Error Correction Model (VECM) and Autoregressive Distributed Lag (ARDL) methods and found that the Environmental Kuznets Curve (EKC) hypothesis was not valid for China.

Sarkodie and Ozturk (2020) conducted a study on Kenya, investigating the EKC hypothesis using Vector Error Correction Model (VECM), ARDL, and U test methods. The results of their study showed that the EKC hypothesis holds true for Kenya. In the study conducted by Ma et al. (2021) to investigate the Environmental Kuznets Curve (EKC) hypothesis for France and Germany, they utilized the Panel Pedroni and Westerlund methods. The results of their analysis revealed that the EKC hypothesis holds true for both France and Germany. The validity of the EKC hypothesis for other countries is presented briefly in Table 2. The main difference between this study from other research is the investigation of the EKC hypothesis for Turkey using up-to-date data and examining the stationarity of variables under structural breaks. It is believed that the findings of this study will contribute to the literature.

3 Model and Data

In this study, using annual data covering the period from 1971 to 2019, the research investigates the Environmental Kuznets Curve hypothesis with energy consumption in Turkey. The EKC (Environmental Kuznets Curve) using the model from the study by Bese and Kalayci (2019) is as follows:

$$LCO2_t = \beta_1 + \beta_2 LGDP_t + \beta_3 LGDP_t^2 + \beta_4 LTFC_t + u_t, \tag{2}$$

Table 2: Previous studies examining the EKC hypothesis for other countries

Author(s)	*Time period*	*Country*	*Method*	*EKC Hypothesis*
Grossman and Krueger (1991)	1977-1988	42 countries	Panel GLS	Valid
Panayotou (1993)	1985-1987	55 countries	Panel Data	Valid
Panayotou (1997)	1982-1994	30 countries	Panel GLS	Valid
Pata and Caglar (2021)	1980–2016	China	Augmented ARDL	Not Valid. U shape
Sarkodie and Ozturk (2020)	1971-2013	Kenya	ARDL, SIMPLS, and U test	Valid
Chen et al. (2019)	1980-2014	China	VECM and ARDL	Not Valid
Ma et al. (2021)	1995-2015	France and Germany	Pedroni and Westernlund	Valid
Ergun and Rivas (2020)	1971-2014	Uruguay	ARDL	Valid
Saqib and Benhmad (2021)	1995-2015	European countries	Panel MG	Valid
Sultan (2021)	1978-2014	India	Johansen	Valid
Van Chien (2020)	1990-2014	Vietnam	ARDL	Valid
Mikayilov et al. (2018)	1992-2013	Azerbaijan	Johansen and Juselius	Not Valid
Hasanov et al. (2019)	1992-2013	Kazakhstan	Johansen and ARDLBT	Not Valid
Wang et al. (2023)	1990-2018	208 countries	Pedroni and Kao	Valid
Sarkodie and Adams (2018)	1971-2017	South Africa	ARDL	Valid
Velayutham (2023)	1971-2014	Sri Lanka	ARDL	Not Valid
Islam et al. (2023)	1976-2014	Bangladesh	ARDL	Not Valid
Pata et al. (2023)	1995-2018	ASEAN	Panel ARDL	Valid
Pata et al. (2023)	1974-2018	Germany	Fourier ADL	Valid

where $CO2_t$ represents carbon dioxide emissions (metric tons per capita), GDP_t is GDP per capita (constant 2010 US$), GDP_t^2 shows square of GDP per capita, TFC_t is total final consumption (Petajoule) and u_t is an error term. The variables were then transformed into natural logs. We obtained CO2 and GDP from the World Development Indicators (WDI) online database, TFC from BP statistical review. If the coefficient β_2 is positive and the coefficient β_3 is negative in the Eq 2, the EKC hypothesis will be applicable to Turkey.

Table 3: Descriptive statistics of the variables

	CO2	*GDP*	*TFC*
Mean	2.992975	6435.157	2192.490
Median	2.876906	5739.262	2014.000
Maximum	5.127197	11938.78	4398.000
Minimum	1.336297	3378.500	677.0000
Std. Dev.	1.071422	2496.577	1088.278
Skewness	0.288794	0.825032	0.508993
Kurtosis	1.937659	2.560349	2.111756
Jarque-Bera	2.985279	5.953506	3.726597
Probability	0.224779	0.050958	0.155160
Observations	49	49	49

The descriptive statistics of the variables are shown in Table 3. The GDP variable had the highest per capita income of $11,938 and the lowest per capita income of $3,378 between the years 1971-2019. We find that the series are normally distributed as revealed by Jarque–Bera statistics. The calculated p-values are greater than 5%, so the null hypothesis is not rejected.

Figure 2: Time series graphs of the variables.

Time series graphs of CO2 emissions, per capita GDP, and energy consumption variables are displayed in Figure 2. All variables exhibit a positive (increasing) trend. Upon examining the graphs, abrupt declines are observed in 2000 and 2008 due to crises. Considering these abrupt breaks, a unit root test that takes into account structural breaks is also applied to the variables.

4 Methodology

4.1 ADF and Fourier ADF unit root tests

In this study, the Augmented Dickey-Fuller (ADF) unit root test, developed by Dickey and Fuller (1981), was used to examine the stationarity of variables. The ADF unit root test is an extended version of the unit root test in the study by Dickey and Fuller (1979). In this test, the lags of the dependent variable are added to address the issue of autocorrelation. The ADF unit root test is examined for three different models: the model without a constant and trend, the model with a constant but no trend, and the model with both a constant and trend. In this study, for the example of energy consumption (TFC) used, the equation for the ADF unit root test in the model with a constant and trend is as follows:

$$\triangle TFC_t = \beta_0 + \beta t + \beta_1 TFC_{t-1} + \beta_2 \Delta TFC_{t-1} + u_t \tag{3}$$

In Eq 3, the $\triangle$ (difference) operation represents the β_0 constant term, t trend, β_1 coefficient of the lagged value of the energy consumption variable, and β_2 coefficient of the differenced lagged value of the energy consumption variable. Here, when the calculated τ statistic value for the coefficient β_1 is larger than the critical values in absolute terms, the null hypothesis of "presence of a unit root, non-stationarity" will be rejected. In other words, the TFC series will be stationary at the level. The examination of the time series graphs of the variables in Figure 2 reveals that sudden decreases was observed in the year 2008. In time series with structural breaks, the results of the ADF unit root test are not reliable. Therefore, in this study, the Fourier ADF unit root test, which takes into account structural breaks, was used. The Fourier ADF unit root test was introduced to the literature by Enders and Lee (2012). In their study, Enders and Lee developed a new unit root test that incorporates sine and cosine terms from the Fourier series into the ADF equation proposed by Dickey and Fuller (1981), yielding good results even in the presence of structural breaks. The equation in Eq 3 is written as the Fourier ADF equation in Eq 4.

$$\triangle TFC_t = \beta_0 + \beta t + \beta_1 TFC_{t-1} + \lambda_1 sin\left(\frac{2\pi kt}{T}\right) + \lambda_2 cos\left(\frac{2\pi kt}{T}\right) + \beta_2 \Delta TFC_{t-1} + u_t \tag{4}$$

In Equation 4, π represents 3.1415, k denotes the frequency value, T represents the number of observations, and t represents the trend. It is important to note that the sine (λ_1) and cosine (λ_2) terms should be statistically significant. If the sine and cosine terms are not statistically significant, the results of the normal ADF test will be valid (Aliyev et al., 2022). If the Fourier terms are statistically significant and the test statistic value of the TFC coefficient is greater than the critical values in the study by Enders and Lee (2012), the null hypothesis will be rejected, indicating stationarity at the level according to the Fourier ADF test for the series.

4.2 ARDL (Autoregressive Distributed Lag) Bound Test

The ARDL (Autoregressive Distributed Lag) cointegration test, introduced to the literature by Pesaran et al. (2001), is widely used by researchers. The main difference of this cointegration test from other cointegration tests is that it allows the variables to be integrated at both levels and first differences. However, none of the variables should be integrated of order two I(2), and the dependent variable should be integrated of order one I(1). The model in Equation 2 can be rewritten as the ARDL model, similar to Equation 5.

$$\triangle LCO2_t = \alpha + \sum_{i=1}^{m} \beta_{1i} \triangle LCO2_{t-i} + \sum_{i=0}^{m} \beta_{2i} \triangle LGDP_{t-i} + \sum_{i=0}^{m} \beta_{3i} \triangle LGDP^2{}_{t-i} +$$

$$+ \sum_{i=0}^{m} \beta_{4i} \triangle LTFC_{t-i} + \gamma_1 LCO2_{t-1} + \gamma_2 LGDP_{t-1} + \gamma_3 LGDP^2{}_{t-1} + \gamma_4 LTFC_{t-1} + v_t. \quad (5)$$

The presence of a long-run equilibrium relationship among the variables is examined using a bounds test. The null hypothesis indicating no cointegration is $H_0: \gamma_1 = \gamma_2 = \gamma_3 = \gamma_4 = 0$, and if $H_0: \gamma_1 = 0$ is rejected, it implies the existence of a long-run equilibrium between the explanatory and explained variables. In this case, the F test (F_A) is used for testing the lag length of both the dependent and independent variables, while the t test (t) is used specifically for testing the lag length of the dependent variable. If the computed F and t statistic values are greater than the upper critical value, the null hypothesis will be rejected. On the other hand, if the F and t test statistic values are smaller than the lower critical value, the null hypothesis cannot be rejected. The short-term estimation of the Autoregressive Distributed Lag (ARDL) model, also known as the Error Correction Model (ECM), is in the following equation.

$$LCO2_t = \delta_0 + \sum_{i=0}^{p} \delta_{1i} \triangle LCO2_{t-i} + \sum_{i=0}^{q} \delta_{2i} \triangle LGDP_{t-i} + \sum_{i=0}^{j} \delta_{3i} \triangle LGDP^2{}_{t-i} + \theta_i +$$

$$+ \sum_{i=0}^{k} \delta_{4i} \triangle LTFC_{t-i} + \gamma ECM_{t-1} + \theta_t. \quad (6)$$

The parameter γ in Eq 6 indicates how many periods it takes for short-term deviations to converge to the long-term equilibrium. It should be negative and statistically significant. Criteria such as AIC, SIC, and Hannan-Quinn information criteria are used to select the lag values p, j, k, and q in Eq 6. In order for the results of the ARDL bounds test to be reliable, certain diagnostic tests need to be valid.

5 Estimation results

Firstly, the stationarity of the variables has been examined in this section. The time series plots of the variables shown in Figure 2 exhibit structural breaks. These abrupt breaks, observed around the years 2000 and 2008, are due to financial crises. Investigating these breaks solely with the ADF unit root test would be inadequate since the ADF test loses its power at the time of structural breaks in the series. Therefore, in this study, the Fourier ADF unit root test was also used. The results of both unit root tests are shown in Table 4. According to the ADF unit root test results, all variables exhibit stationarity at the first difference in the constant model. In the constant and trend model, both GDP and CO2 variables demonstrate stationarity at the first difference, whereas the energy consumption variable (TFC) is stationary at the level. According to the Fourier Augmented Dickey-Fuller (ADF) unit root test results, all variables are stationary at the first difference in both the constant and constant and trend models. For the

Fourier ADF unit root test to be valid, the sine and cosine (Fourier) terms should be statistically significant. However, in Table 4, the calculated F-statistic values for sine and cosine terms are not statistically significant. Therefore, there is no evidence of any structural breaks in the time series variables used. If there were structural breaks in the series, further analysis would have considered co-integration tests that account for structural breaks, such as Hatemi-J (2008), Maki (2012), and Yilanci et al. (2020). In the study, the ARDL bound test by Pesaran et al. (2001) was used to examine the co-integration relationship. Finally, since the Fourier terms were not statistically significant, we will rely on the results of the ADF unit root test. In conclusion, the GDP and CO2 emission variables are stationary at the first difference, while the energy consumption (TFC) variable is stationary at the level.

Table 4: Unit root test results

Tests	*ADF*		*Fourier ADF*					
Models	*Constant*	*C&t*	*Constant*			*C&t*		
Variables	*t-statistics*	*t-statistics*	*t-statistics*	*F-stat*	*k*	*t- statistics*	*F-stat*	*k*
LCO2	-1.558 [0]	-3.040 [2]	-1.462 [0]	3.201	5	-3.136 [1]	4.399	5
△LCO2	-6.758*** [0]	-6.766*** [0]	-7.737*** [0]	4.654	5	-7.723*** [0]	4.527	5
LGDP	0.332 [0]	-1.987 [0]	0.714 [0]	4.812	5	-1.897 [0]	4.729	5
△LGDP	-6.683*** [0]	-6.718*** [0]	-7.828*** [0]	5.470	5	-8.080*** [0]	6.300	5
LTFC	-1.217 [1]	-4.755*** [0]	-1.478 [0]	1.912	5	-3.120 [0]	4.745	5
△LTFC	-8.331*** [0]	-8.359*** [0]	-9.359*** [0]	4.434	5	-9.368*** [0]	4.347	5

Notes: *** represents stationarity at the 1% level. Values in parentheses indicate lags automatically selected by the AIC information criterion. k represents the frequency value.

According to the ADF unit root test results, GDP and CO2 variables are stationary at the first difference, while the energy consumption variable is stationary at the level. In cointegration analyses, all variables are required to be stationary at the same level. However, the ARDL bound test proposed by Pesaran et al. (2001) allows independent variables to be stationary at different levels, provided that the dependent variable is integrated of order I(1). The results of the ARDL bound test are presented in Table 5. According to the ARDL cointegration test, both the F and t statistics are greater than the critical values, leading to the rejection of the null hypothesis. Therefore, there is a cointegration relationship among the GDP, CO2, and energy consumption (TFC) variables.

According to the ARDL bounds test, there exists a cointegration relationship among the variables. In order for this result to be valid, certain assumption tests need to be satisfied. Table 5 also provides the results of these assumption tests. The results indicate that there are no issues of heteroscedasticity, autocorrelation, or non-normality in the residuals of the model. Additionally, the CUSUM and CUSUMSQ plots shown in Figure 3 confirm the stability of the model's parameters.

Since the assumptions of the ARDL bound test are valid, there exists a definite long-run equilibrium relationship between variables. In Table 6, long and short-term estimation results are provided. GDP takes a positive value, while GDP squared takes a negative value in the long-term estimation. This indicates the presence of an inverted U-shaped relationship between GDP and CO2 emissions, suggesting the validity of the Environmental Kuznets Curve hypothesis in Turkey. In the long-run model of ARDL, the turning point for income has been calculated as approximately \$13,585.1, where $-\beta_1/2\beta_2 \cong 13585.1\$$. However, it is observed that these turning points are not within the relevant period of the dataset. The energy consumption variable positively affects carbon emissions. A 1% increase in energy consumption in Turkey will result in a 0.42% increase in carbon emissions. As expected, with the increase in energy consumption, environmental pollution also increases.

Table 5: ARDL Bound test results

Model		Critical Values					
ARDL (1,0,0,1)		%10		%5		%1	
Test Statistics		I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
F	4.03*	2.873	3.973	3.5	4.7	4.86	6.36
t	-3.990**	-2.57	-3.46	-2.86	-3.78	-3.43	-4.37
Diagnostic Test Results							
Tests		Test Statistics		Prob			
LM_{SC}		0.006		0.993			
χ^2_{HETR}		0.342		0.884			
JB		0.300		0.860			
Ramsey-RESET		0.035		0.851			
CUSUM		Stable					
CUSUMsq		Stable					

Note: * and ** indicate significance at 10% and 5%, respectively.

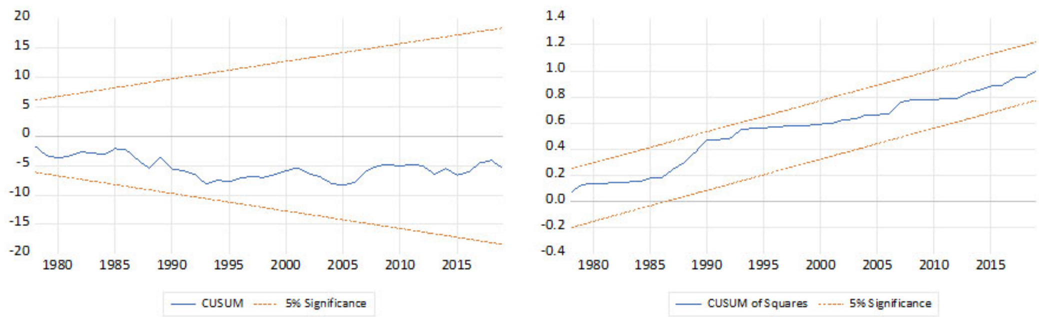

Figure 3: CUSUM and CUSUMSQ Graphs.

Table 6: Long-run and Short-run estimation results

***Panel A:** Long-term estimation*		
Variables	Coefficients	p-value
LGDP	5.120*	0.063
LGDP2	-0.269*	0.060
LTFC	0.429**	0.021
Constant	-14.634**	0.047
***Panel B:** Short-term estimation*		
Variables	Coefficients	p-value
△LTFC	0.640***	0.000
ECTr-1	-0.556***	0.000

Note: *, **, and *** indicate significance at 10%, 5%, and %1 respectively.

According to the short-term estimation results shown in Table 6, the error correction term is statistically significant and negative as expected. This indicates that disequilibrium in the short term will converge by 56% towards the long-term equilibrium. On the other hand, deviations from equilibrium in the short term will converge to the long-term equilibrium after 1.79 years. Furthermore, an increase in energy consumption in the short term also leads to a 0.64% increase in environmental pollution.

6 Conclusion and policy implications

The aim of this study is to investigate the validity of the Environmental Kuznets Curve (EKC) in Turkey between the years 1971 and 2019. In this study, a quadratic model was constructed, and in addition to the model, energy consumption variable was also included. The stationarity of the variables was examined using Augmented Dickey-Fuller (ADF) and Fourier ADF unit root tests. As the Fourier terms were not statistically significant, there were no structural breaks in the variables.

According to the ADF unit root test results, CO2 emissions and GDP were found to be first differenced stationary, while energy consumption was stationary at levels. Since the variables were stationary both in first differences and levels, the Autoregressive Distributed Lag (ARDL) bounds test was applied, and a long-run equilibrium relationship was found among the variables. According to the ARDL long-term forecast results, the GDP variable positively affects CO2 emissions, while the squared GDP variable has a negative effect. This implies that the EKC hypothesis holds true for Turkey. In the long-run model of ARDL, the turning point for income has been calculated as approximately $13,585. This turning point, however has been outside of the observed sample period.

The total energy consumption variable added to the quadratic model, on the other hand, positively affects carbon emissions in the long run. The main recommendation of our study is to strengthen incentives for renewable energy sources in order to reduce Turkey's dependency on fossil fuels and achieve sustainable growth while supporting economic development. In this regard, legal arrangements such as tax reductions, various subsidies, and credit facilities should be implemented. By promoting the adoption of renewable energy technologies, we can not only mitigate carbon emissions but also enhance energy security and reduce the environmental impact of economic growth. Transitioning towards cleaner and sustainable energy sources will contribute to a greener economy, create new job opportunities in the renewable energy sector, and foster innovation in clean technologies. Implementing these policy measures can lead Turkey towards a more environmentally friendly and sustainable development path, aligning with international efforts to combat climate change and promote a greener future for generations to come.

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