



The Relationship Between Environmental Taxes as a Regulatory Public Policy Instrument and Carbon Emissions: Empirical Evidence from Türkiye

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Düzenleyici Bir Kamu Politika Aracı Olarak Çevre Vergileri ile Karbon Emisyonları Arasındaki İlişki: Türkiye’den Ampirik Kanıtlar

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Abstract

This study aims to examine the relationship between environmental taxes as a public regulatory instrument and carbon emissions in Türkiye, controlling for industrial production and the clean energy share. The analysis uses annual data for 1994-2023. Carbon emissions are the dependent variable, while environmental taxes, the industrial production index, and the share of clean energy production in total energy production are the independent variables. The ARDL bounds testing approach is employed, with DOLS as a complementary long-run estimator. Granger causality analysis examines short-run predictive relationships. The long-run environmental tax coefficient is negative but statistically insignificant in ARDL and significant at the 10% level in DOLS. In the short run, the coefficient on the one-period lagged change in environmental taxes is positive and significant at the 1% level. Industrial production is positively and significantly associated with emissions, whereas the clean energy share is negatively and significantly associated with them. Standard Granger tests suggest bidirectional predictability between environmental taxes and emissions, although the variables' integration properties require cautious interpretation. Overall, evidence that environmental taxes alone reduce emissions is limited, suggesting coordination of fiscal policy with industrial policy and energy transformation. The negative association between the clean energy share and emissions is more consistent across estimators.

Keywords: Environmental taxes, carbon emissions, clean energy, Türkiye, fiscal policy, ARDL bounds test.

Öz

Bu çalışma, kamusal düzenleme aracı olarak çevre vergilerinin Türkiye’de karbon emisyonlarıyla ilişkisini, sanayi üretimi ve temiz enerji payını kontrol ederek sınamayı amaçlamaktadır. Analizde 1994-2023 dönemine ait yıllık veriler kullanılmıştır. Modelde bağımlı değişken karbon emisyonları, bağımsız değişkenler ise çevre vergileri, sanayi üretim endeksi ve temiz enerji üretiminin toplam enerji üretimi içindeki payıdır. ARDL sınır testi yaklaşımı kullanılmış, DOLS tamamlayıcı uzun dönem tahmincisi olarak uygulanmıştır. Granger nedensellik analiziyle kısa dönem öngörü ilişkileri incelenmiştir. Bulgular, çevre vergileri katsayısının uzun dönemde negatif, ARDL tahmininde istatistiksel olarak anlamsız, DOLS tahmininde ise %10 düzeyinde anlamlı olduğunu göstermektedir. Kısa dönemde ise çevre vergilerindeki değişimin bir dönem gecikmeli katsayısı pozitif ve %1 düzeyinde anlamlıdır. Sanayi üretimi karbon emisyonlarıyla pozitif, temiz enerji payı ise negatif ve anlamlı ilişkilidir. Standart Granger testleri çift yönlü öngörü ilişkisine işaret etmekle birlikte, serilerin bütünleşme özellikleri nedeniyle bu bulgu ihtiyatla yorumlanmalıdır. Genel olarak bulgular, Türkiye’de çevre vergilerinin tek başına karbon emisyonlarını azalttığına ilişkin sınırlı kanıt sunmakta ve maliye politikalarının sanayi politikası ve enerji dönüşümüyle eşgüdüm içinde tasarlanmasına işaret etmektedir. Temiz enerji payının emisyonlarla negatif ilişkisi ise tahminciler arasında daha tutarlı bulgularla desteklenmektedir.

Anahtar Kelimeler: Çevre vergileri, karbon emisyonları, temiz enerji, Türkiye, maliye politikası, ARDL sınır testi.

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1. Introduction

Climate change presents a public policy challenge that links environmental sustainability to public finance, industrial production and energy use. Carbon emissions (CE) generate social costs that are not fully reflected in market prices, providing a rationale for public intervention. Environmental taxes (ET) seek to internalise these costs and influence production and consumption decisions, serving both revenue-generating and regulatory functions. Their environmental effectiveness therefore depends on whether they contribute to reducing emissions. For Türkiye, the relationship between environmental taxation and emissions is particularly relevant given the pressures associated with industrial production, rising energy demand and dependence on imported energy. The Organisation for Economic Co-operation and Development (OECD) identifies energy use and transport as important drivers of increasing greenhouse gas emissions (OECD, 2025a), while World Bank data provide further context on Türkiye's per capita carbon dioxide emissions (World Bank, 2026). These conditions highlight the need to evaluate environmental taxation within Türkiye's production and energy context.

Türkiye-focused studies examine different dimensions of the relationship between taxation and environmental outcomes. Karşıyakalı et al. (2024) investigate causality between CO₂ emissions and total environmental, energy and transport taxes, without incorporating industrial production or the clean energy share. Akçay et al. (2023) examine total tax revenue as a share of public revenue and CO₂ emissions, controlling for population rather than industrial production or energy composition. Bişgin (2025) analyses the relationship between environmental taxes and the ecological footprint, excluding these production and energy variables. Sumerli Sarıgül and Altay Topcu (2021) examine the environmental tax-CO₂ relationship over 1994-2015 using FMOLS, DOLS and CCR, controlling for GDP growth and the share of renewable energy in total final energy consumption. Their model does not include the industrial production index or the clean energy production share. Emirkadı (2026) examines environmental tax components over 1997-2022 using ARDL, threshold regression and causality analyses, controlling for GDP and energy consumption without including industrial production or the clean energy share. Building on Sumerli Sarıgül and Altay Topcu (2021), who control for the share of renewable energy in total final energy consumption, the present study extends the environmental tax-CO₂ framework by incorporating the industrial production index and measuring the clean energy share as the share of clean energy production in total energy production for Türkiye over 1994-2023.

The study addresses three research questions: Are ET negatively associated with CE in Türkiye? Is this relationship statistically significant when industrial production and the share of clean energy production in total energy production are controlled for? Is there Granger causality between ET and CE, and in which direction does it operate? The main hypothesis is that ET are negatively associated with CE in the long run, conditional on industrial production and the clean energy share. Including these variables allows the tax-emissions relationship to be assessed while accounting for production activity and energy composition.

The study's contribution to the Türkiye-specific literature lies in incorporating the industrial production index and using a production-based measure of the clean energy share within an environmental tax-CO₂ framework using annual data for 1994-2023. The ARDL bounds testing approach, complemented by DOLS estimation and Granger causality analysis, provides evidence on the long-run relationship, its sensitivity to the estimator and the direction of predictive relationships between taxation and emissions. The remainder of the article is organised as follows. Section 2 presents the conceptual framework, and Section 3 reviews the empirical literature. Section 4 describes the data and methodology and presents the empirical findings. Section 5 concludes with a discussion of the results, policy implications and limitations.

2. Conceptual Framework

A fundamental issue in the economic analysis of environmental problems is that the market mechanism alone may fail to achieve a socially optimal level of pollution. The main reason for this is that environmental pollution, and particularly CE, create social costs that are not fully borne by producer or consumer decision-makers. This situation is defined in public economics as a negative externality. Under conditions of negative externalities, private marginal cost diverges from social marginal cost, with the result that market actors engage in more polluting activities than is socially desirable. Therefore, environmental pollution is considered a classic example of market failure (Pigou, 1932; International Monetary Fund (IMF), 2019).

One of the most effective theoretical solutions for eliminating/reducing negative externalities is the Pigouvian tax approach developed within the welfare economics tradition. According to Pigou, a corrective tax imposed on activities that pollute the environment ensures that external costs are incorporated into the price mechanism. This limits tendencies towards overproduction or overconsumption. The theoretical aim of Pigouvian taxation is not so much for the state to generate revenue, but rather to redirect the behaviour of economic units in a way that increases social welfare. In this respect, Pigouvian taxes are fundamental instruments that reveal not only the financing function of fiscal policy, which generates revenue for the budget, but also its regulatory and allocative functions (Pigou, 1932; OECD, 2025b).

Theoretical and empirical studies in the literature largely evaluate ET within the logic of Pigouvian taxes. The fundamental characteristic of ET is that they increase the cost of activities harmful to the environment, thereby generating revenue for the budget and shifting the decisions of economic actors in favour of the environment. Therefore, ET should be considered not only as a budget revenue item from a public finance perspective, but also as corrective and regulatory tax instruments that support the achievement of environmental objectives (OECD, 2025b).

The importance of ET is becoming even more apparent in the context of CE. Carbon-intensive activities are exacerbating environmental damage. However, the environmental damage caused by these activities is often not fully reflected in market prices. Therefore, carbon taxes or carbon-based ET are considered among the most fundamental financial instruments for pricing the social cost of greenhouse gas emissions. According to the IMF, ET play a "central" role in reducing greenhouse gases (IMF, 2021). This is because ET, being reflected in market prices, discourage the use of fossil fuels and encourage the transition to lower-carbon fuels and renewable energy. Similarly, Parry (2019) explains that carbon taxation seeks to incorporate the social costs of carbon emissions into the prices of carbon-intensive fuels.

Consequently, the Pigouvian taxation approach provides a strong theoretical basis for ET, which are among the most important regulatory instruments of public finance in terms of internalising negative externalities. ET have the potential to transform environmental behaviour by increasing the cost of polluting activities, as they will be reflected in market prices. However, in countries such as Türkiye, which have high energy demand and emissions, the results of this potential need to be empirically tested. Therefore, studies examining the impact of ET on CE in Türkiye are critical for measuring the environmental effectiveness of fiscal policies and assessing the capacity of public intervention in the green transition process (Ertekin & Dam, 2020; Bişgin, 2025; Oğuz & Yıldız, 2024; Organ & Çiftçi, 2013).

3. Empirical Literature Review

Table 1 summarises empirical studies examining the relationship between ET and CE, including their country coverage, methods, variables and main findings. Following the table, these studies are discussed in three groups according to their findings on the effectiveness of environmental taxation.

Table 1. Empirical Studies Investigating the Relationship Between Environmental Taxes and Carbon Emissions

Authors	Period	Country	Method	Variables	Findings
Emirkadı (2026)	1997-2022	Türkiye	ARDL bounds testing, threshold regression, rolling-window and frequency-domain causality	CO ₂ emissions, pollution, energy and transport taxes, GDP and energy consumption	Only energy taxes exhibit a significant emission-reducing effect in the ARDL estimates. Tax effectiveness varies with tax intensity and over time.
Bişgin (2025)	1994-2022	Türkiye	Fourier Cointegration Test	ET, Ecological Footprint (environmental degradation data)	There is no cointegration relationship between the ecological footprint and the ET in Türkiye
Ugrinov (2025)	1996-2022	EU member states, Norway, Iceland	System GMM	Total ET; energy, transport, pollution/resource taxes; CE and other pollutants	Total ET generally reduce pollution; the strongest reduction effect occurs in energy taxes.
Liu (2025)	1970-2022	China	NARDL	CE, ET, green finance, fintech, natural resource rent, urbanisation, growth	The effect of ET on CE is asymmetric.
Arogundade & Hassan (2024)	1990-2021	OECD members	Panel data	Green growth (production-based and demand-based CO ₂ productivity), environmental taxes, renewable energy transition, real GDP per capita, globalisation, FDI and urbanisation.	Environmental taxes exhibit a U-shaped relationship with green growth measured by production-based and demand-based CO ₂ productivity. The effect is initially negative but becomes positive and significant beyond tax-to-GDP thresholds of 3.53% and 2.46%, respectively. Renewable energy transition promotes green growth.
Du et al. (2024)	2015-2020	China	Microeconomic analysis	CE, policy shift from environmental protection expenditure to taxation	The tax reform implemented in China in 2018 has been seen to significantly reduce CE at the company level.
Karşıyakalı et al. (2024)	1995-2021	Türkiye	Hatemi-J causality analysis	Total ET, energy taxes, transport taxes, CE	There is a causal link between CE and total ET and energy/transport taxes.
Rabhi et al. (2024)	1994-2018	36 developing countries	CS-ARDL panel approach	ET, renewable energy consumption, CE	Renewable energy consumption reduces CE; conversely, the emission-reducing effect of ET is not statistically significant.
Zhu et al. (2023)	2005-2020	51 countries	Spatial panel econometrics	ET, renewable energy, CE	Environmental taxes and renewable energy consumption can reduce domestic CE, while spatial spillovers may transfer emissions to neighbouring countries.
Wolde-Rufael & Mulat-Weldemeskel (2023)	1995-2012	20 European countries	Panel cointegration + quantile regression	Total ET, energy tax, transport tax, environmental policy stringency, CE	Both ET and environmental stringency indicators significantly reduce CE.
Akçay et al. (2023)	1923-2021	Türkiye	Quantile cointegration	Taxation, CE	There is a long-run cointegration between taxation and CE; it has been concluded that taxation increases environmental pollution.
Doğan et al. (2022)	1994-2014	G7 countries	Panel data analysis, EKC test	CE, ET, renewable and non-renewable energy, economic growth, natural resource rent, economic complexity	Environmental taxes reduce CE in G7 countries and moderate the relationships between emissions, energy consumption and natural resource rents.
Atay Polat & Ergün (2021)	1995-2017	21 European countries	AMG estimator and causality analysis	ET; greenhouse gases, CE, SO _x , NO _x	ET in EU countries reduce emissions; a two-way causality has been found between ET and CE, and a one-way causality from ET to greenhouse gases.

Table 1 (Cont.). Empirical Studies Investigating the Relationship Between Environmental Taxes and Carbon Emissions

Sumerli Sarıgül & Altay Topcu (2021)	1994-2015	Türkiye	Johansen cointegration, FMOLS, DOLS and CCR	CO ₂ emissions, environmental taxes, GDP growth and the share of renewable energy in total final energy consumption.	Environmental taxes and renewable energy consumption are negatively and significantly associated with CO ₂ emissions in the long run.
Wolde-Rufael & Mulat-Weldemeskel (2021)	1994-2015	7 emerging economies	Augmented Mean Group (AMG), FMOLS for robustness checks	CE, total ET, energy taxes, environmental policy stringency	Total environmental taxes and energy taxes are negatively and significantly associated with CO ₂ emissions. Environmental policy stringency exhibits an inverted U-shaped relationship with CO ₂ emissions.
Silajdzic & Mehic (2018)	1995-2015	10 European countries	Pedroni panel cointegration test and Fully Modified Ordinary Least Squares (FM-OLS)	CE, ET, per capita income	It has been determined that energy and transport taxes are ineffective in reducing environmental pollution.
Aydın & Esen (2018)	1995-2013	EU members	Dynamic panel threshold regression	CE, environment-related taxes (total, energy, transport, pollution/resource)	The reduction effect of taxes depends on the threshold level; energy and pollution taxes in particular significantly reduce CE beyond a certain level.

As shown in Table 1, the empirical literature on ET and CE does not provide a uniform conclusion. The divergence in findings can be attributed to differences in country groups, institutional structures, tax composition, energy dependence, production structure, and methodological choices. In this respect, the effect of ET should not be evaluated independently from the broader economic and policy environment. ET may generate stronger emission-reducing effects in countries where tax instruments are supported by renewable energy transition, environmental policy stringency, and structural transformation in production. Conversely, in economies where industrial expansion and fossil fuel dependence remain strong, the environmental effectiveness of such taxes may be limited. This consideration is particularly relevant for Türkiye, where industrial production and energy composition are central determinants of CE.

Türkiye-focused studies also differ in their environmental indicators and methodological approaches, limiting direct comparisons of their findings on environmental taxation (Karşıyakalı et al., 2024; Akçay et al., 2023; Bişgin, 2025). In the literature, empirical studies investigating the relationship between ET and CE can be grouped into three categories. The first group consists of studies demonstrating that ET produce statistically significant results in reducing CE and pollution. In other words, these are studies that provide empirical support for the effectiveness of Pigouvian taxation, which outlines the framework for internalising externalities. It is reported that this effect is particularly pronounced in country economies with high institutional development. In this context, it is possible to say that ET serve as both a fiscal tool and a regulatory mechanism (Ugrinov, 2025; Wolde-Rufael & Mulat-Weldemeskel, 2023; Atay Polat & Ergün, 2021; Wolde-Rufael & Mulat-Weldemeskel, 2021; Du et al., 2024).

The second group consists of studies demonstrating that the impact of ET on CE depends on policy elements. Accordingly, ET do not automatically reduce emissions on their own; they are effective when combined with complementary elements such as energy transition, environmental policy stringency, and energy composition. Therefore, the impact of ET is shaped by the overall policy framework (Arogundade & Hassan, 2024; Zhu et al., 2023; Aydın & Esen, 2018; Doğan et al., 2022; Liu, 2025).

The third group consists of studies reporting limited or statistically insignificant emission-reducing effects of ET. These findings suggest that environmental taxation does not consistently deliver the expected environmental benefits in the economies examined (Rabhi et al., 2024; Silajdzic & Mehic, 2018). Against this background, the present study extends the Türkiye-specific literature by jointly considering ET, industrial production and the clean energy share in explaining CE.

4. Data, Methodology and Empirical Findings

Before presenting the empirical findings, the data structure and methodological framework of the study are briefly introduced. The analysis uses annual data for Türkiye covering the 1994-2023 period and employs ADF and PP unit root tests, the ARDL bounds testing approach, DOLS estimation and Granger causality analysis. In line with the theoretical framework, the main hypothesis of the study is that environmental taxes are negatively associated with carbon emissions when industrial production and the clean energy share are taken into account.

4.1. Data and Descriptive Overview

In this study, the dependent variable is carbon emissions, represented by the CO₂ variable. The independent variables included in the model are industrial production (SAN), environmental tax revenue as a percentage of GDP (ETAX), and the share of clean energy production in total energy production (TEM). The logarithms of all variables were taken.

Table 2. Variables and Data Sources

Variable	Abbreviation	Data source
Carbon dioxide emissions	CO ₂	OECD
Industrial production index	SAN	Turkish Statistical Institute (TurkStat)
Environmental tax revenue as a percentage of GDP	ETAX	OECD
Clean energy share	TEM	International Energy Agency (IEA)

In the empirical assessment of the relationship between ET and CE in Türkiye, it is important to examine the trend of key variables over time graphically. Graphical analysis serves an explanatory function in that it reveals the long-run trends of the series, possible breakpoints, and the relationship structure between variables. Within this framework, Türkiye's data for the period 1994-2023 was used to separately evaluate CE, the environmental tax revenue as a percentage of GDP, the industrial production index, and the share of clean energy production in total energy production. The findings indicate that the potential impact of ET on CE must be considered alongside changes in industrial production and energy composition. Therefore, the assessments presented below provide a descriptive set of preliminary findings prior to the transition to the econometric analysis section of the study.

As can be seen in Figure 1, the CO₂ emissions series shows a clear upward trend over the period 1994-2023. This pattern indicates that increased production and expanded energy consumption are intensifying environmental pressures. Although there are short-term fluctuations in the series, the long-run upward trend indicates that CE constitute a structural environmental problem in the Turkish economy (Dinçel Kıratoğlu, 2025, p. 113).

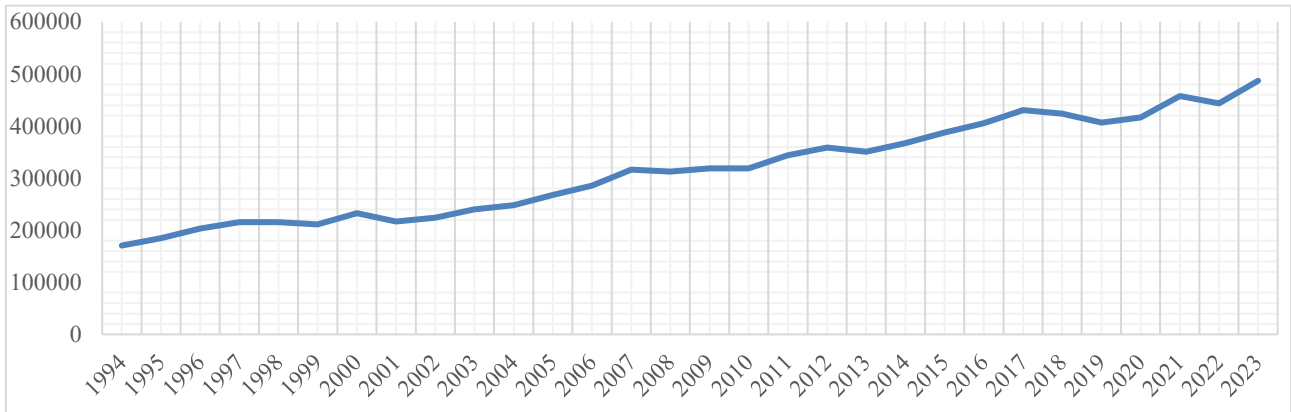


Figure 1. CO₂ Emissions in Türkiye, tCO₂e (1994-2023)

Source: OECD (2025c).

As can be seen in Figure 2, environmental tax revenue as a percentage of GDP has fluctuated over the period 1994-2023. The increase observed between 1994 and 2005 gave way to a fluctuating and unstable trend in subsequent years.

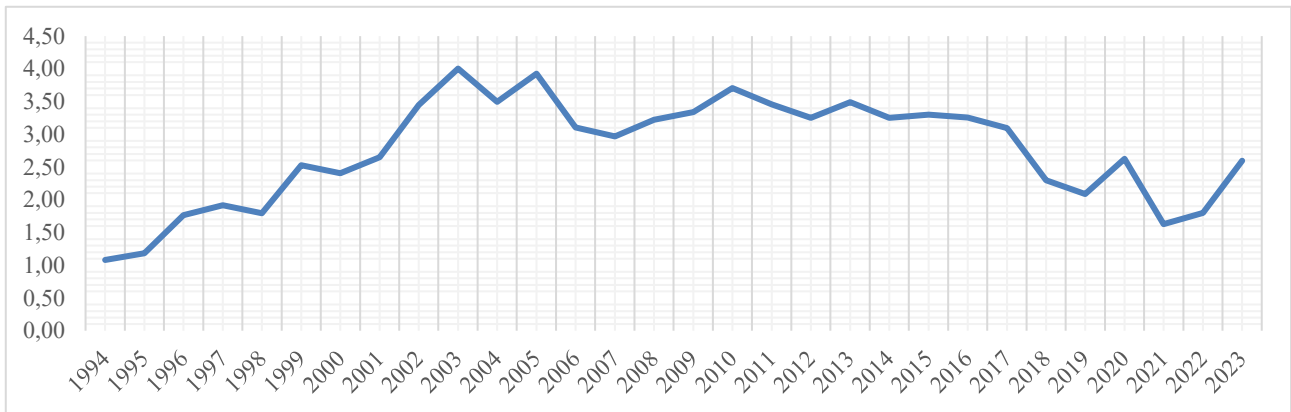


Figure 2. Environmental Tax Revenue as a Percentage of GDP in Türkiye (%) (1994-2023)

Source: OECD (2025d).

As can be seen in Figure 3, the industrial production index has shown a strong upward trend throughout the period from 1994 to 2023. This pattern indicates that production capacity and industrial activity have expanded in Türkiye. The increase in industrial production is expected to support an increase in emissions through energy use and carbon-intensive production processes. Therefore, the industrial production index stands out as one of the key structural variables explaining CE.

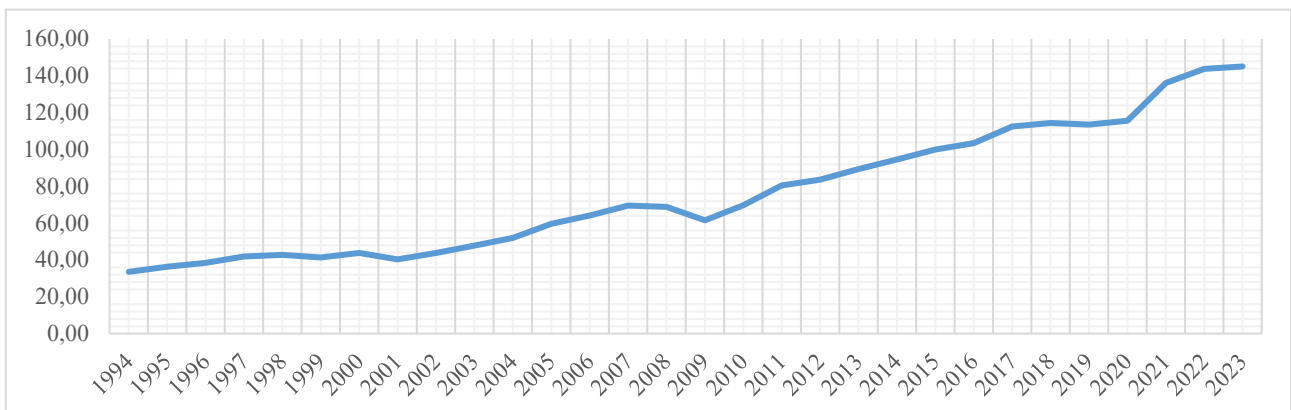


Figure 3. Industrial Production Index in Türkiye (1994-2023)

Source: TurkStat (2025).

As can be seen in Figure 4, the share of clean energy production in total energy production declined between 1994 and 2008, but recovered and increased in the subsequent period. This pattern indicates a trend towards a shift in favour of clean energy in the energy mix in recent years. However, the fact that CE remained high during the same period reveals that the increase in the share of clean energy alone was not sufficient to reduce CE.

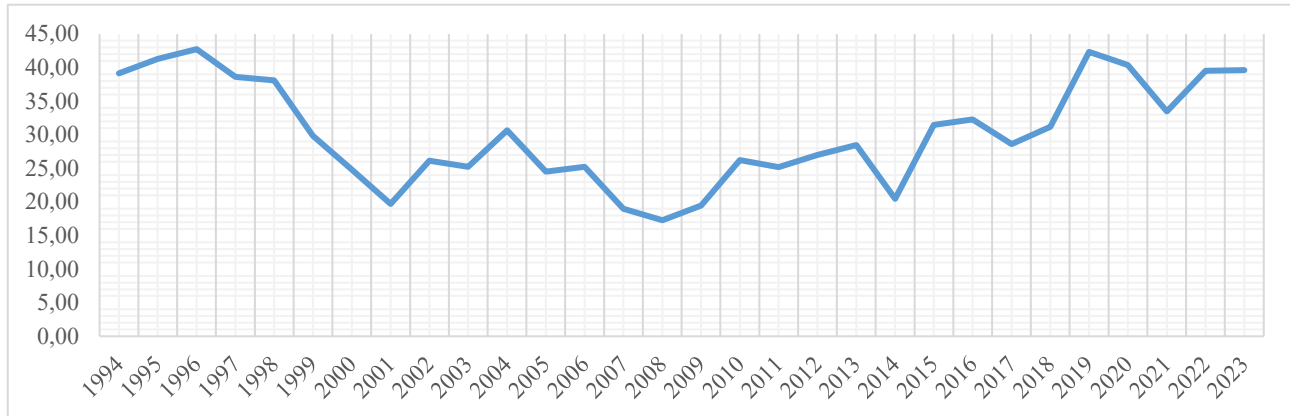


Figure 4. Clean Energy Production / Total Energy Production (%) in Türkiye (1994-2023)
Source: IEA (2025).

Preliminary findings obtained by visualising the series separately indicate that the relationship between ET and CE in Türkiye is not unidimensional. The upward trend in CE is shaped not only by the level of ET but also by the expansion of industrial production and the transformation in the energy mix. While the pressure from industrial production to increase CE is clearly evident, it is understood that the increase in the share of clean energy plays a limiting but not yet dominant role in this pressure. The fact that ET did not present a stable regulatory tool throughout the period necessitates further empirical testing of this variable's effect on CE. Accordingly, this study aims to analyse the relationship between these variables using econometric methods.

This study investigates the effects of ET, industrial production, and the share of clean energy production in total energy production in Türkiye between 1994 and 2023 on CE, one of the main indicators of pollution, as shown in Equation 1.

$$\ln CO2_t = \alpha_0 + \alpha_1 \ln SAN_t + \alpha_2 \ln ETAX_t + \alpha_3 \ln TEM_t + u_t \quad (1)$$

Table 3. Descriptive Statistics

Variables	Mean	Median	Max	Min	Std. Dev.
lnCO2	12.617	12.668	13.095	12.047	0.305
lnSAN	4.234	4.236	4.777	3.512	0.457
lnETAX	0.963	1.108	1.387	0.077	0.342
lnTEM	2.598	2.590	2.942	2.250	0.216

According to Table 3, the average value of the lnCO2 variable for the period 1994-2023 is 12.617, and its standard deviation of 0.305 indicates that the series fluctuates within limited bounds. The average and standard deviation values of the lnSAN, lnETAX, and lnTEM variables also reveal that there is no excessive volatility in the variables throughout the period. The main reason for using logarithmic transformation in the model is to ensure that the coefficients can be interpreted as elasticity (percentage effect). Furthermore, logarithmic transformation balances variance, reduces scale differences, and contributes to a more linear analysis of the relationship between variables.

In the initial phase of the empirical analysis, the stationarity characteristics of the variables were examined by employing the Augmented Dickey-Fuller (ADF) unit root test and the Phillips-Perron (PP) test. The corresponding test statistics and results are reported in Table 4.

Table 4. Unit Root Test Results

Variables	ADF						PP					
	None		Intercept		Trend & Intercept		None		Intercept		Trend & Intercept	
	Level	First Difference	Level	First Difference	Level	First Difference	Level	First Difference	Level	First Difference	Level	First Difference
lnCO2	4.039	-3.984***	-1.098	-5.967***	-3.120	-5.873***	5.165	-4.021***	-1.204	-6.445***	-	-6.686***
lnSAN	4.298	-3.406***	-0.253	-4.313***	-	-4.250**	9.362	-3.350***	0.036	-5.906***	3.146	-6.107***
					3.380*						2.613	
lnETAX	-	-5.297***	-	-5.315***	-2.528	-5.676***	-	-5.299***	-	-5.318***	-	-6.056***
	0.070		2.930*				0.049		2.952*		2.556	
lnTEM	-1.081	-4.829***	-1.081	-4.829***	-0.735	-6.096***	-	-4.940***	-1.340	-4.851***	-	-6.591***
							0.062				0.735	

Note: The reported critical values are -2.64 (1%), -1.95 (5%) and -1.61 (10%) for the specification without an intercept or trend; -3.67 (1%), -2.96 (5%) and -2.62 (10%) for the intercept-only specification; and -4.30 (1%), -3.57 (5%) and -3.22 (10%) for the specification with an intercept and trend. ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively. The null hypothesis of the ADF and PP tests is that the series contains a unit root. "Level" and "First Difference" identify the transformations used in testing. I(0) and I(1) denote orders of integration: an I(0) series is stationary at level, whereas an I(1) series becomes stationary after first differencing.

According to the ADF and PP unit root test results presented in Table 4, the variables display a mixed order of integration. When the calculated test statistics are compared with the critical values reported in the note to Table 4, lnCO2 and lnTEM are generally non-stationary at their level values but become stationary after first differencing, mostly at the 1% significance level. Similarly, lnSAN is not stationary in the no-intercept and intercept specifications at level; although weak stationarity is observed under the trend-and-intercept specification at the 10% level, the variable becomes clearly stationary after first differencing, especially in the ADF and PP results with intercept and trend. In contrast, lnETAX is stationary at level under the intercept specification in both the ADF and PP tests only at the 10% significance level, while its first differences are stationary under the remaining specifications. These findings indicate that the empirical model contains variables integrated at I(0) and I(1), but no variable is integrated at I(2). Therefore, the use of the ARDL bounds testing approach is methodologically appropriate, since this approach allows the joint analysis of variables with mixed integration orders as long as none of the series is I(2).

The ARDL approach was preferred because the variables exhibit a mixed order of integration, I(0) and I(1), while none is integrated of order two. In addition, considering the relatively small sample size, the finite-sample critical values proposed by Narayan (2005) were also used in evaluating the bounds test. Although bootstrap-based procedures may provide additional finite-sample robustness, the present analysis follows the conventional ARDL bounds-testing framework using Narayan's (2005) finite-sample critical values. DOLS estimation is additionally employed as a complementary long-run estimator, and the findings are interpreted cautiously in light of the limited sample size.

Table 5. ARDL Bounds Test Results

Model (1,2,2,0)	F_{test}			
$LnCo2=f(lnSAN\ lnETAX\ lnTEM)$	8.455***			
	Pesaran et al. (2001)		Narayan (2005)	
	F_{test}		F_{test}	
Critical Values	I (0)	I (1)	I (0)	I (1)
%1	4.428	5.816	4.614	5.966
%5	3.164	4.194	3.272	4.306
%10	2.618	3.532	2.676	3.586

Note: *** indicates a significance level of 1%. Optimal lag lengths in the ARDL model were selected using the AIC (Akaike Information Criterion).

The ARDL bounds test findings presented in Table 5 indicate that the calculated F-statistic is 8.455 and statistically significant at the 1% level. Since this value exceeds the upper bound critical values (I(1)) reported by Pesaran et al. (2001) and Narayan (2005), the existence of a cointegration relationship among the variables is confirmed. Accordingly, the null hypothesis (H_0), which assumes no long-run association among the variables, is rejected. Hence, a stable long-run equilibrium relationship among $\ln\text{CO}_2$, $\ln\text{SAN}$, $\ln\text{ETAX}$, and $\ln\text{TEM}$ is identified. The estimated long-run coefficients together with the diagnostic test results are reported in Table 6.

Table 6. ARDL Long-Run Coefficients

Variables	Coefficients	Standard Errors	t-statistics	Diagnostic tests
$\ln\text{SAN}$	0.675***	0.014	47.762	LM= 0.133(0.960)
$\ln\text{ETAX}$	-0.020	0.023	-0.890	BPG= 1.893 (0.120)
$\ln\text{TEM}$	-0.165***	0.043	-3.772	Ramsey=0.004(0.951)
C	9.183***	1.592	5.767	CUSUM/CUSUMSQ = Stable
				JB=3.770 (0.151)

Note: The sample period covers 1994-2023, and the number of included observations is 28 after adjustments. ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively. Values in parentheses for diagnostic tests indicate probability values. LM, BPG, Ramsey RESET and JB refer to serial correlation, heteroskedasticity, functional form and normality tests, respectively. CUSUM and CUSUMSQ indicate parameter stability.

The diagnostic test results indicate that the estimated ARDL model satisfies the key econometric assumptions. The Breusch-Godfrey LM test for serial correlation yields a statistic of 0.133 with a p-value of 0.960; therefore, the null hypothesis of no serial correlation cannot be rejected. The Breusch-Pagan-Godfrey (BPG) test for heteroskedasticity shows a value of 1.893 (p-value = 0.120), so the null hypothesis of homoskedasticity cannot be rejected. The Ramsey RESET test statistic of 0.004 (p-value = 0.951) indicates that the null hypothesis of correct functional form cannot be rejected. Additionally, the Jarque-Bera normality test produces a statistic of 3.770 (p-value = 0.151); thus, the null hypothesis that the residuals are normally distributed cannot be rejected. Finally, both CUSUM and CUSUM of squares tests remain stable within the critical bounds, indicating parameter stability over the sample period. Overall, the diagnostic tests provide no evidence of serial correlation, heteroskedasticity, functional form misspecification, or non-normality problems, and indicate that the model parameters are stable over the sample period.

Figure 5 presents the CUSUM and CUSUMSQ graphs.

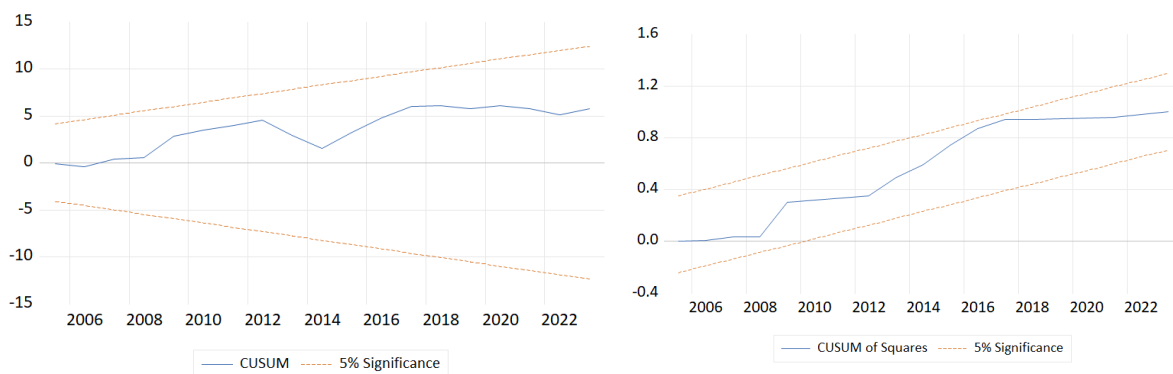


Figure 5. CUSUM and CUSUMSQ graphs

Table 7 presents the ARDL short-run coefficients, while Table 8 presents the DOLS estimation results.

Table 7. ARDL Short-Run Coefficients

Variables	Coefficients	Standard error	t-statistics
$\Delta \ln \text{SAN}$	0.397***	0.057	6.957
$\Delta \ln \text{SAN}(-1)$	-0.135*	0.069	-1.950
$\Delta \ln \text{ETAX}$	0.005	0.021	0.255
$\Delta \ln \text{ETAX}(-1)$	0.091***	0.022	4.005
ECT(-1)	-0.897***	0.125	-7.154

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

The ARDL short-run estimates indicate that the contemporaneous change in industrial production is positively associated with CO₂ emissions and statistically significant at the 1% level. Its one-period lagged change has a negative coefficient and is significant at the 10% level, indicating that the direction of the association differs across lags. The contemporaneous environmental tax coefficient is statistically insignificant, whereas its one-period lagged coefficient is positive and significant at the 1% level. Thus, the short-run estimates do not support an emission-reducing effect of environmental taxes. The negative and statistically significant error correction coefficient indicates adjustment towards the long-run equilibrium. The DOLS estimation results in Table 8 show the long-run coefficients.

Table 8. DOLS Estimation Results

Variables	Coefficients	Standard error	t-statistics
$\ln \text{SAN}$	0.623***	0.022	27.665
$\ln \text{ETAX}$	-0.054*	0.029	-1.839
$\ln \text{TEM}$	-0.192***	0.038	-5.055
C	10.546	0.174	60.300

Note: The adjusted sample covers 1996-2022 (27 observations). Leads and lags are fixed at 1. ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

The findings indicate that the coefficient of the industrial production variable ($\ln \text{SAN}$) is estimated at 0.623 and remains statistically significant at the 1% level. This result implies that a 1% rise in industrial production is associated with an approximately 0.62% increase in CE.

The estimated coefficient of the ET variable ($\ln \text{ETAX}$) is -0.054 and statistically significant at the 10% level in the DOLS estimation. This result suggests that, according to the DOLS estimator, a 1% increase in ET is associated with an approximately 0.05% decrease in CO₂ emissions. However, this finding should be interpreted with caution, since the ARDL long-run coefficient of $\ln \text{ETAX}$ reported in Table 6 is negative but statistically insignificant. In this study, the ARDL model is treated as the baseline estimator because the unit root test results indicate a mixed order of integration, namely $I(0)$ and $I(1)$, and the ARDL bounds testing approach is suitable under this condition. DOLS is employed as a supplementary estimator to compare the long-run coefficient estimates with those obtained from the baseline ARDL model. However, the evidence of level stationarity for $\ln \text{ETAX}$ under the intercept specification raises a methodological concern regarding the conventional $I(1)$ cointegration framework underlying DOLS estimation. Therefore, the DOLS results are interpreted cautiously as supplementary evidence, and the main conclusions are based on the ARDL estimates. The DOLS model is estimated with a fixed specification of one lead and one lag, and the long-run variance is estimated using the Bartlett kernel with a Newey-West fixed bandwidth of 3.

Therefore, the negative sign of $\ln \text{ETAX}$ in both estimations is consistent with theoretical expectations, but the statistical significance of this effect is estimator-sensitive. Although the statistical significance differs between the two estimators, the negative sign of the environmental tax coefficient is consistent across both ARDL and DOLS. The difference in significance may be related to the distinct estimation structures of the two methods: ARDL jointly captures short-run dynamics and long-run adjustment through its lag structure, whereas DOLS estimates the long-run relationship

while controlling for possible endogeneity and serial correlation through leads and lags of differenced regressors. Therefore, the findings are better interpreted as evidence of estimator sensitivity rather than as contradictory results. Accordingly, the findings do not provide strong evidence that ET have a decisive emission-reducing effect; rather, they indicate a weak, limited and estimator-sensitive regulatory effect. The negative coefficient is partly consistent with the emission-reducing findings reported by Kaplan Dönmez (2026), Yang et al. (2024), and Savranlar et al. (2024), although the evidence in the present study is weaker and sensitive to the estimator employed.

Likewise, the coefficient of the lnTEM variable, representing the share of clean energy production in total energy production, is calculated as -0.192 and is statistically significant at the 1% significance level. Accordingly, a 1% increase in the clean energy share is associated with an approximate 0.19% decrease in CE. This outcome is consistent with the findings of Sakilu & Chen (2025), which indicate that both clean energy use and environmental taxation contribute to lowering CE. Overall, the empirical findings suggest that industrial production increases environmental degradation, whereas the clean energy share contributes to improving environmental quality. The emission-reducing effect of ET, however, should be interpreted with caution, as it is statistically significant only at the 10% level in the DOLS estimation and insignificant in the ARDL model.

Table 9. Granger Causality Test Results

Null hypothesis	Observation	F-Statistics	Probability	Result
LNETAX does not Granger Cause LNCO2	28	3.04369	0.0672	Significant at the 10% level lnETAX → lnCO ₂
LNCO2 does not Granger Cause LNETAX	28	3.99527	0.0324	Significant at the 5% level lnCO ₂ → lnETAX
LNSAN does not Granger Cause LNCO2	28	2.58660	0.0970	Significant at the 10% level lnSAN → lnCO ₂
LNCO2 does not Granger Cause LNSAN	28	0.12283	0.8850	
LNTEM does not Granger Cause LNCO2	28	0.20692	0.8146	
LNCO2 does not Granger Cause LNTEM	28	3.70743	0.0402	Significant at the 5% level lnCO ₂ → lnTEM
LNSAN does not Granger Cause LNETAX	28	2.52689	0.1019	
LNETAX does not Granger Cause LNSAN	28	1.58939	0.2257	
LNTEM does not Granger Cause LNETAX	28	2.24605	0.1285	
LNETAX does not Granger Cause LNTEM	28	3.16548	0.0610	Significant at the 10% level lnETAX → lnTEM
LNTEM does not Granger Cause LNSAN	28	0.69812	0.5078	
LNSAN does not Granger Cause LNTEM	28	4.42716	0.0236	Significant at the 5% level lnSAN → lnTEM

Note: Pairwise Granger causality tests are conducted at levels with 2 lags. The sample period is 1994-2023 (28 observations).

Table 9 reports standard pairwise Granger causality tests conducted in levels with two lags to explore predictive relationships among the variables. However, the presence of I(1) variables means that the conventional F-statistics may not follow their standard distribution, limiting the reliability of the reported significance levels. Cointegration established by the ARDL bounds test does not, by itself, ensure the validity of these pairwise tests. Accordingly, the results are treated as exploratory indications of predictive relationships rather than conclusive evidence of causality. Their robustness requires further assessment using an integration-robust procedure such as the Toda-Yamamoto test. The conventional pairwise tests suggest a predictive relationship from industrial production to CO₂ emissions at the nominal 10% significance level. They also suggest predictive relationships from environmental taxes to CO₂ emissions at the nominal 10% level and in the reverse direction at the nominal 5% level. However, given the distributional limitations associated with testing I(1) variables in levels, these results should be regarded as exploratory indications of bidirectional predictability

rather than statistically conclusive evidence of Granger causality. They do not establish that environmental taxes cause changes in emissions or that emission pressures induce fiscal policy responses. The conventional pairwise tests suggest predictive relationships from CO₂ emissions and industrial production to the clean energy share, both at the nominal 5% significance level. In addition, a predictive relationship from environmental taxes to the clean energy share is suggested at the nominal 10% level. These findings provide exploratory indications that past values of emissions, industrial production and environmental taxes may help predict the clean energy share. However, because some variables are I(1) and the tests are conducted in levels, the conventional F-statistics may not follow their standard distribution. The reported significance levels therefore require caution, and these findings should not be treated as conclusive evidence of Granger causality or as establishing causal effects on the energy mix.

5. Conclusion

This study aims to empirically examine whether ET reduce CE in Türkiye when industrial production and the share of clean energy production in total energy production are controlled for, within the framework of environmental taxes as public regulation instruments. The study utilises data from Türkiye for the period 1994-2023; CE are the dependent variable, while ET, the industrial production index, and the share of clean energy production in total energy production are included in the model as independent variables.

Regarding environmental taxes, the findings should be interpreted with caution. In response to the first research question, the coefficient of ET is negative in both long-run estimations. Regarding the second question, when industrial production and the clean energy share are controlled for, the ARDL long-run coefficient is negative but statistically insignificant, whereas the DOLS estimation produces a negative coefficient that is statistically significant only at the 10% level. According to the DOLS estimate, a 1% increase in ET is associated with an approximately 0.05% decrease in CE. Although the negative sign in both estimations is consistent with theoretical expectations, the difference in statistical significance indicates that the evidence for an emission-reducing effect is sensitive to the estimator employed. Accordingly, the long-run hypothesis receives only limited and estimator-sensitive support, as the negative ET coefficient is statistically significant only at the 10% level in DOLS and insignificant in ARDL. This assessment refers exclusively to the long-run estimates. In the short run, the coefficient on the one-period lagged change in environmental taxes is positive and statistically significant at the 1% level (0.091). Thus, the short-run results do not support an emission-reducing effect and preclude extending the limited long-run support to both time horizons. One possible explanation is that environmental tax revenues rise alongside economic activity and fossil fuel use, generating a positive association with emissions. Reverse feedback from emissions to taxation is another possibility, but the exploratory pairwise Granger results do not establish this mechanism. These explanations remain tentative and are not directly tested by the model. Therefore, the results do not provide strong evidence that environmental taxes alone decisively reduce carbon emissions in Türkiye. These findings do not refute the theoretical validity of the Pigouvian taxation approach, but suggest that environmental taxation should be evaluated together with complementary structural factors such as clean energy transformation and production dynamics.

Industrial production is positively and significantly associated with CE, with estimated long-run elasticities of approximately 0.62-0.68. The findings regarding the share of clean energy production in total energy production are more consistent across estimators. Both the ARDL and DOLS results indicate that an increase in the clean energy share is negatively associated with carbon emissions. The estimated coefficients suggest that a 1% increase in the clean energy share is associated with an approximately 0.17% to 0.19% decrease in carbon emissions. This finding provides more consistent evidence of a negative association with CE for the clean energy share than for environmental taxation.

In response to the third research question, the conventional pairwise Granger tests suggest bidirectional predictability between ET and CE. They also suggest predictive relationships from industrial production to CE and from CE, industrial production and ET to the clean energy share. However, because the tests are conducted in levels with $I(1)$ variables, the conventional F-statistics may not follow their standard distribution. The reported significance levels therefore require caution, and the findings should be treated as exploratory indications of predictive relationships rather than conclusive evidence of Granger causality. The statistically insignificant ARDL coefficient of ET is consistent with Rabhi et al. (2024), who report no significant emission-reducing effect of environmental taxes. The findings also relate to Zhu et al. (2023), who emphasise that the tax-emissions relationship depends on the level of renewable energy consumption. The exploratory indications of bidirectional predictability between ET and CE broadly parallel the directions reported by Atay Polat and Ergün (2021) and Karşıyakalı et al. (2024), although the distributional limitations of the present tests prevent a firm comparison of statistical evidence. For Türkiye, the insignificant ARDL tax coefficient also parallels the limited evidence reported by Bişgin (2025), although that study examines the ecological footprint rather than CE. Overall, the findings are broadly consistent with the second group of studies identified in the literature review, which emphasises complementary policy and energy factors. However, the present model does not directly test whether these factors moderate the relationship between ET and CE.

The contribution of this study lies in extending the environmental tax- CO_2 framework for Türkiye by incorporating the industrial production index and using a production-based measure of the clean energy share over 1994-2023. While Sumerli Sarıgül and Altay Topcu (2021) already control for the renewable energy share in total final energy consumption, the present specification accounts for industrial production dynamics and the composition of total energy production. The policy implications of the findings should be derived cautiously from the empirical results. Since industrial production has a positive and statistically significant association with carbon emissions, with estimated elasticities of approximately 0.62-0.68, priority should be given to emission-reduction measures in carbon-intensive industrial activities and energy-intensive production processes. In this respect, the findings support prioritising reductions in the carbon intensity of industrial production. Moreover, the consistently negative coefficients of the clean energy share, approximately -0.17 to -0.19, support increasing the role of clean energy in total energy production. However, the estimated model does not allow the calculation of a precise threshold level for the clean energy share. Therefore, rather than suggesting a fixed target ratio, the findings support a gradual and sustained increase in the clean energy share. For environmental taxes, the insignificant ARDL long-run coefficient, the weak DOLS significance and the positive lagged short-run coefficient suggest a need to reassess the emission-reduction effectiveness of the existing tax structure, although the aggregate indicator does not identify which tax components require reform. These elasticities represent conditional relationships rather than precise forecasts of policy impacts.

This study has some limitations that should be acknowledged. First, the use of annual data for the 1994-2023 period limits the ability to capture within-year fluctuations and short-term adjustments. Second, the relatively small number of observations requires cautious interpretation of the empirical findings. Future studies may employ bootstrap ARDL procedures to assess the robustness of the findings in a small sample. Third, the 1994-2023 period includes major economic and institutional developments, such as economic crises, the COVID-19 pandemic, and changes in the international environmental policy framework, including the Paris Agreement. These developments may have generated structural changes in the relationships examined; however, given the limited number of annual observations and the focus of the study on the overall long-run relationship, such potential breaks were not modelled separately. Therefore, the estimated coefficients should be interpreted as average relationships over the sample period. Future studies may employ tests and models allowing for structural breaks or Fourier-based approaches to examine potential changes in these relationships. Fourth, environmental taxes are represented by an aggregate indicator, although their subcomponents

may have different effects on carbon emissions. Fifth, the I(0) classification of lnETAX requires caution when interpreting DOLS estimates within the conventional I(1) cointegration framework. Accordingly, DOLS findings should be treated as supplementary evidence, and future studies should assess robustness using estimators appropriate to the variables' mixed integration orders. Sixth, standard pairwise Granger tests were conducted in levels despite the presence of I(1) variables, which may invalidate inference based on the conventional F-distribution. Future research should reassess these predictive relationships using the Toda-Yamamoto procedure with an appropriately specified lag-augmented VAR. Seventh, no comparison model excluding industrial production and the clean energy share was estimated. Therefore, the analysis cannot establish how including these controls changes the estimated environmental tax coefficient or its statistical significance. Future studies should compare models with and without these controls over the same sample period. Finally, the single-country scope limits the generalisability of the findings. Cross-country analyses could assess their applicability beyond Türkiye.

Overall, these findings suggest that carbon emission dynamics in Türkiye should be evaluated jointly with fiscal policy instruments, industrial production and energy transformation. The estimator-sensitive evidence for ET and the more consistent findings for the clean energy share support coordinating fiscal policies with industrial policy and clean energy transformation.

References

- Akçay, F., Yavuz, E., & Kılıç, E. (2023). Karbon emisyonu ile vergileme arasındaki ilişkinin cumhuriyetten günümüze analizi: Kantil eşbütünleşme yaklaşımından kanıtlar. *Anadolu Üniversitesi Sosyal Bilimler Dergisi*, 23(Special Issue), 59-78. <https://doi.org/10.18037/ausbd.1310434>
- Arogundade, S., & Hassan, A. S. (2024). The path to green economy: Do environmental taxes and renewable energy transition matter in OECD countries? *World Development Sustainability*, 5, Article 100189. <https://doi.org/10.1016/j.wds.2024.100189>
- Atay Polat, M., & Ergün, S. (2021). Kirlilik emisyonlarının azaltılmasında çevre vergilerinin rolü: AB ülkeleri örneği. *İzmir İktisat Dergisi*, 36(2), 379-397. <https://doi.org/10.24988/ije.202136209>
- Aydın, C., & Esen, Ö. (2018). Reducing CO2 emissions in the EU member states: Do environmental taxes work?. *Journal of Environmental Planning and Management*, 61(13), 2396-2420. <https://doi.org/10.1080/09640568.2017.1395731>
- Bişgin, A. (2025). Türkiye’de çevre vergileri ekolojik ayak izini azaltmada etkin mi? Fourier yaklaşımı. *MANAS Sosyal Araştırmalar Dergisi*, 14(4), 1557-1569. <https://doi.org/10.33206/mjss.1504481>
- Dinçel Kıratoğlu, İ. Y. (2025). Türkiye’nin 2030 CO2 emisyon hedefinin Holt-Winters üstel düzeltme modeli ile tahmini. *Maliye ve Finans Yazıları, Özel Sayı 3*, 109-127. <https://doi.org/10.33203/mfy.1834216>
- Doğan, B., Chu, L. K., Ghosh, S., Truong, H. H. D., & Balsalobre-Lorente, D. (2022). How environmental taxes and carbon emissions are related in the G7 economies? *Renewable Energy*, 187, 645-656. <https://doi.org/10.1016/j.renene.2022.01.077>
- Du, J., Li, Z., Shi, G., & Wang, B. (2024). Can “environmental protection fee to tax” reduce carbon emissions? Evidence from China. *Finance Research Letters*, 62, Article 105184. <https://doi.org/10.1016/j.frl.2024.105184>
- Emirkadı, Ö. (2026). Çevre vergilerinin karbon emisyonları üzerindeki etkisi: Türkiye için eşik ve zamanla değişen bir analiz. *Sayıştay Dergisi*, 37(141), 411-444. <https://doi.org/10.52836/sayistay.1902263>

- Ertekin, Ş., & Dam, M. (2020). Türkiye’de çevre vergilerinin çevresel etkileri üzerine bir değerlendirme. *Yaşar Üniversitesi E-Dergisi*, 15, 66-87. <https://doi.org/10.19168/jyasar.655644>
- International Energy Agency Database. (2025). *Energy statistics data browser*. Retrieved December 20, 2025, from <https://tinyurl.com/3m4t278j>
- International Monetary Fund. (2019). *Fiscal monitor: How to mitigate climate change*. <https://www.imf.org/en/publications/fm/issues/2019/09/12/fiscal-monitor-october-2019>
- International Monetary Fund. (2021). *Tax policy and climate change: IMF report for the G20 finance ministers and central bank governors*. <https://www.imf.org/external/np/g20/pdf/2021/040721.pdf>
- Kaplan Dönmez, N. F. (2026). Policy instruments against climate change: A panel data analysis of carbon taxation and emissions trading in OECD countries. *Economies*, 14(1), Article 12. <https://doi.org/10.3390/economies14010012>
- Karşıyakalı, B., Aydın, Ü., & Şanlısoy, S. (2024). The causal relationship between environmental taxes for sustainable development and greenhouse gas emissions (CO₂): A case study of Türkiye. *Trakya Üniversitesi İİBF e-Dergi*, 13(1), 82-100. <https://doi.org/10.47934/tife.13.01.06>
- Liu, Y. (2025). Whether fintech, natural resources, green finance and environmental tax affect CO₂ emissions in China? A step towards green initiatives. *Energy*, 320, Article 135181. <https://doi.org/10.1016/j.energy.2025.135181>
- Narayan, P. K. (2005). The saving and investment nexus for China: Evidence from cointegration tests. *Applied Economics*, 37(17), 1979-1990. <https://doi.org/10.1080/00036840500278103>
- Oğuz, N. S., & Yıldız, S. (2024). Bir çevre vergisi olarak karbon vergisi. *Anadolu University Journal of Faculty of Economics*, 6(1), 19-35. <https://doi.org/10.54737/aujfe.1475971>
- Organ, İ., & Çiftçi, T. E. (2013). Karbon vergisi. *Niğde Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi*, 6(1), 81-95. <https://izlik.org/JA99RG55CR>
- Organisation for Economic Co-operation and Development. (2025a). *Environment at a glance: Türkiye*. <https://tinyurl.com/2rmeywmv>
- Organisation for Economic Co-operation and Development. (2025b). *Methodological guidelines for environmentally related tax revenue accounts*. <https://doi.org/10.1787/d752d120-en>
- Organisation for Economic Co-operation and Development. (2025c). *Air and GHG emissions*. Retrieved December 15, 2025, from <https://www.oecd.org/en/data/indicators/air-and-ghg-emissions.html>
- Organisation for Economic Co-operation and Development. (2025d). *Environmentally related tax revenue*. Retrieved December 20, 2025, from <https://www.oecd.org/>
- Parry, I. (2019). What is carbon taxation? *Finance & Development*, 56(2), 54-55. <https://www.imf.org/en/publications/fandd/issues/2019/06/what-is-carbon-taxation-basics>
- Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics*, 16(3), 289-326. <https://doi.org/10.1002/jae.616>
- Pigou, A. C. (1932). *The economics of welfare* (4th ed.). Macmillan.
- Rabhi, A., Soujaa, I., & Parsons, B. (2024). Do environmental taxes and renewable energy consumption play a role in climate change mitigation? International evidence from developing economies. *Research in Globalization*, 9, Article 100266. <https://doi.org/10.1016/j.resglo.2024.100266>
- Sakilu, O. B., & Chen, H. (2025). Realizing carbon neutrality in top-emitter countries: Do green technology innovation, renewable energy, financial development, and environmental tax matters? *Sustainability*, 17(1), 37. <https://doi.org/10.3390/su17010037>
- Savranlar, B., Ertaş, S. A., & Aslan, A. (2024). The role of environmental tax on the environmental quality in EU counties: Evidence from panel vector autoregression approach. *Environmental Science and Pollution Research*, 31(24), 35769-35778. <https://doi.org/10.1007/s11356-024-33632-z>

- Silajdzic, S., & Mehic, E. (2018). Do environmental taxes pay off? The impact of energy and transport taxes on CO2 emissions in transition economies. *South East European Journal of Economics and Business*, 13(2), 126-143. <https://doi.org/10.2478/jeb-2018-0016>
- Sumerli Sarıgül, S., & Altay Topcu, B. (2021). The impact of environmental taxes on carbon dioxide emissions in Turkey. *International Journal of Business and Economic Studies*, 3(1), 43-54. <https://izlik.org/JA68HP64GE>
- Turkish Statistical Institute (TurkStat). (2025). *İstatistiksel temalar: Sanayi*. Retrieved December 20, 2025, from <https://veriportali.tuik.gov.tr/tr/statistical-themes?q=sanayi>
- Ugrinov, S. (2025). The effects of environmental taxes on environmental pollution in the member states of the European Union. *Economic Systems*, 49(3), Article 101308. <https://doi.org/10.1016/j.ecosys.2025.101308>
- Wolde-Rufael, Y., & Mulat-Weldemeskel, E. (2021). Do environmental taxes and environmental stringency policies reduce CO2 emissions? Evidence from 7 emerging economies. *Environmental Science and Pollution Research*, 28, 22392-22408. <https://doi.org/10.1007/s11356-020-11475-8>
- Wolde-Rufael, Y., & Mulat-Weldemeskel, E. (2023). Effectiveness of environmental taxes and environmental stringent policies on CO2 emissions: The European experience. *Environment, Development and Sustainability*, 25(6), 5211-5239. <https://doi.org/10.1007/s10668-022-02262-1>
- World Bank. (2026). *Carbon dioxide (CO2) emissions excluding LULUCF per capita (t CO2e/capita)*. Retrieved February 28, 2026, from <https://data.worldbank.org/indicator/EN.GHG.CO2.PC.CE.AR5?locations=TR>
- Yang, Y., Zhang, Y., Zhang, Y., Liu, T., & Xu, H. (2024). Environmental taxes promote the synergy between pollution and carbon reduction: Provincial evidence from China. *Journal of Environmental Management*, 372, Article 123378. <https://doi.org/10.1016/j.jenvman.2024.123378>
- Zhu, Y., Taylor, D., & Wang, Z. (2023). The role of environmental taxes on carbon emissions in countries aiming for net-zero carbon emissions: Does renewable energy consumption matter? *Renewable Energy*, 218, Article 119239. <https://doi.org/10.1016/j.renene.2023.119239>