Entrepreneurial Business and Economics Review

2025, Vol. 13, No. 3

10.15678/EBER.2025.130305

Long-run effects of fiscal policies on environmental pollution

Derya Tabiloğlu, Temel Gürdal

ABSTRACT

Objective: This study aims to investigate the long-run effects of fiscal policy instruments, including environmental taxes, environmental protection expenditures and renewable energy incentives on environmental pollution, measured as ecological footprint, in a sample of European Union countries and Turkey using annual data for the period 1996-2018.

Research Design & Methods: The conventional literature generally suggests that fiscal policy instruments can affect environmental pollution in the long run. To examine whether fiscal policy instruments will be effective on pollution in the long run, we employed both fully modified ordinary least squares (FMOLS) and dynamic ordinary least squares (DOLS) methods.

Findings: The estimation results showed that renewable energy incentives are the most effective policy instrument to mitigate pollution. We also found that environmental taxes have negative and statistically significant effects on pollution. However, the relationship between environmental protection expenditures and pollution is not robust and changes with respect to the estimation method.

Implications & Recommendations: The findings of this study indicate that fiscal policy instruments can reduce environmental pollution. In this vein, renewable energy incentives and environmental tax tools appear to be the most effective fiscal policy instruments. Therefore, policymakers can use fiscal policy instruments to deal with environmental pollution problems.

Contribution & Value Added: Given the limited research on the combined effects of fiscal policy instruments, we aimed to contribute to the literature by employing FMOLS and DOLS estimation procedures. These methods allowed us to examine the long-run relationship between fiscal policy instruments and the ecological footprint. To examine the long-run relationship between fiscal policy instruments and ecological footprint, we prefer to employ FMOLS and DOLS methods which consider potential autocorrelation and some degree of heterogeneity. Therefore, we aimed to contribute to the literature by investigating the effectiveness of fiscal policy instruments on environmental pollution in our sample of countries.

Article type:	research article
Keywords:	environmental pollution; fiscal policies; environmental protection expenditures; environmental taxes; renewable energy resources
JEL codes:	E62, H23, Q28

Received: 6 October 2024 Revised: 18 February 2025 Accepted: 31 March 2025

Suggested citation:

Tabiloğlu, D., & Gürdal, T. (2025). Long-run effects of fiscal policies on environmental pollution. *Entrepreneurial Business and Economics Review,* 13(3), 97-113. https://doi.org/10.15678/EBER.2025.130305

INTRODUCTION

Structural change, industrialization, urbanization and rapid population growth have led to a series of environmental problems such as global warming, climate change, and deterioration of air, soil and water quality. All these have contributed to the rapid rise in environmental pollution. Environmental problems are expected to be addressed through the joint participation of countries and the shared responsibility to deal with pollution. In this line, many countries contribute to the formation of environmental laws and try to implement environment-friendly policies.

United Nations member countries adopted Sustainable Development Goals in 2015 to reduce the environmental damage of economic activities. By 2030, it is planned to achieve the goals by adopting objectives such as ensuring universal access to cheap, reliable, and modern energy services, increasing the share of renewable energy sources, encouraging investments in clean energy areas and incorporating climate change-related actions into national policies. In this vein, this article aims to examine whether fiscal policy instruments can serve to mitigate pollution to achieve the Sustainable Development Goals.

Conventional wisdom maintains that fiscal policy aims to adjust public expenditures and revenues to achieve macroeconomic and social objectives. In addition to these classical duties, the state also aims to produce solutions when the market is insufficient in justice, health, education, and environmental protection. In this context, fiscal policy in a broad framework may also involve the use of fiscal policy tools to achieve sustainability in resource allocation. In this context, environmentally compatible fiscal policies are considered to be an effective policy instrument in reducing environmental pollution. For instance, government incentives for renewable energy investments can support clean energy production capacity and play a crucial role in achieving sustainable development goals. Moreover, economic activities with negative externalities can be internalized by selective taxation policy. This can reduce environmental pollution by transforming producer and consumer behaviour patterns in favour of the environment. In this context, we may define fiscal policy for environmental protection as a set of instruments implemented by the state to prevent environmental damage and contribute to environmental sustainability.

Fiscal policy instruments, such as renewable energy incentives, environmental taxes, and environmental protection expenditures, play a significant role in reducing the ecological footprint. Renewable energy consumption is reduced primarily through the substitution effect. This substitution reduces carbon emissions, air pollution, and resource depletion, significantly mitigating environmental damage. Moreover, renewable energy consumption decreases reliance on non-renewable resources, further conserving resources and minimizing degradation caused by fossil fuel extraction. Environmental taxes reduce pollution by internalizing the social costs of polluting activities, incentivizing both producers and consumers to adopt more sustainable behaviours. By increasing the cost of polluting activities, these taxes promote energy efficiency and promote the use of renewable energy, reducing carbon emissions and environmental harm. Environmental protection expenditures involve direct government investments in projects that conserve natural resources, improve air and water quality, protect biodiversity, and manage waste. When effectively managed, these investments can significantly reduce pollution, although their success may depend on the efficient allocation of funds and the feasibility of environmental protection projects.

These fiscal policy instruments align with the broader objective of fiscal policy to promote sustainability in resource allocation. As noted, fiscal policy is not only concerned with achieving macroeconomic goals but also with addressing market failures in areas such as health, education, and environmental protection. In this regard, environmentally compatible fiscal policies – such as renewable energy incentives, selective taxation, and government-funded environmental protection projects – serve as effective tools for reducing environmental pollution. By incentivizing clean energy production, internalizing negative externalities, and investing in sustainable environmental initiatives, fiscal policies contribute to achieving sustainable development goals and promoting environmental sustainability.

In line with all these explanations, the main objective of this study was to examine whether environmental protection expenditures, environmental taxes and renewable energy incentives, which are among the fiscal policy instruments, have a reducing effect on environmental pollution. In analyzing the impact of these fiscal policy instruments on pollution, we also considered real income per capita, which is the main determinant of environmental pollution as stated by Grossman and Krueger (1995). We applied fully modified ordinary least squares (FMOLS) and dynamic ordinary least squares (DOLS) estimation methods for the sample of 21 European Union (EU) countries and Turkey during the 1996-2018 period. We preferred these estimation methods because they consider potential autocorrelation and some degree of heterogeneity by incorporating leads and lags of first differenced regressors and provide the long-run impacts of fiscal policy instruments on ecological footprint.

The empirical results show that the most effective fiscal policy instrument to reduce pollution is renewable energy incentives. Moreover, environmental taxes also have negative and significant effects on pollution. However, the relationship between environmental protection expenditures and pol-lution is statistically positive and significant according to the DOLS estimation method while it is negative and statistically insignificant according to the FMOLS estimation method. In this context, it is possible to say that environmental protection expenditures are the least effective fiscal policy instrument to reduce environmental pollution.

The remainder of the article is organized as follows: The next section will present a brief overview of the recent studies in environmental economics. Then, we will report the methodology, data set, and definition of variables. We will present the empirical results derived from the DOLS and FMOLS methods in the findings section. Finally, this study concludes with a discussion of the results and policy recommendations for encouraging the adoption of environmentally friendly fiscal policies.

LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

Grossman and Krueger (1995) explored the relationship between environmental pollution and economic growth and made a pioneering contribution to the environmental economics literature. Their empirical findings show that there is an inverted-U relationship between pollution and per capita income. Accordingly, pollution first increases with income, then reaches a maximum level and then decreases. In the literature, this relationship is represented by the Environmental Kuznets Curve (EKC). 'Scale effect, structural (composition) effect, and technological effect' arguments serve to explain the inverted-U relationship. The scale effect refers to the increase in production leading to negative effects on the environment (Grossman & Krueger, 1991). The structural (composition) effect refers to the pollution-reducing effect of the structural change with the shift from manufacturing to the services sector. The technical effect refers to the reduction in pollution by the use of environmentally friendly technologies in the production process. Therefore, the scale effect argument serves to explain the positively sloped EKC, while the structural and technical effect arguments explain the negatively sloped part of EKC.

Following the study by Grossman and Krueger (1995), the literature often examines the validity of EKC for different countries and periods. However, there is no consensus on the validity of EKC in the literature. For example, some studies argue that an inverted-U relationship is valid (Dinda, 2004; Hilton & Levinson, 1998; Stern *et al*., 1996), while some studies show that there is an N-shaped (Torras & Boyce, 1998; Moomaw & Unruh, 1997), while the others find that a reverse-J-shaped (Selden & Song, 1994) relationships. According to some studies, environmental pollution is positively related to economic growth (Barra & Zotti, 2018; Şentürk *et al*., 2020; Taşdemir, 2022a). Furthermore, the results by Stern (2004) suggest that there is no statistically significant association between pollution and income.

In addition to the argument that real income per capita is the main driver of pollution, environmental economics literature also indicates that literacy rate, civil liberties, political rights (Torras & Boyce, 1998), labour/capital ratio (He & Wang, 2012), population density, returns to scale, the share of industry (as a per cent of income), and governance (Apergis & Öztürk, 2015) are important variables to explain pollution. Moreover, scholars also consider the following factors important: energy consumption, foreign direct investment and urbanization (Shahbaz *et al*., 2019), renewable energy consumption (Zhang & Cheng, 2009; Bloch *et al*., 2012; Soytas *et al*., 2007; Shahbaz *et al*., 2011), sectors' share in income (Taşdemir, 2022b), foreign direct investment (Cole, 2004), renewable energy consumption (Apergis *et al*., 2010; Bento & Moutinho, 2016; Chen *et al*., 2019; Tiwari, 2011), environmental tax (Jeffrey & Perkins, 2015; Morley, 2012) and environmental protection expenditures (Bostan *et al*., 2016; Huang, 2018). Since the environment is a global public good, it is emphasized that public policies are necessary to solve the environmental externalities caused by pollution. In this context, the literature states fiscal policy can play an effective role in reducing environmental pollution.

Studies examining the relationship between environmental pollution and environmental policies more specifically indicate that fiscal policy instruments such as taxes, incentives, and public expenditures will have an impact on pollution. Theoretical model results by Gupta and Barman (2009) indicate that fiscal policies play a significant role in reducing environmental pollution. Morley (2012) concludes that environmental taxes negatively affect greenhouse gas emissions by using the generalised method of moments (GMM) method for EU countries and Norway during the 1995-2016 period. López and Palacios (2014) found that public expenditure composition and energy taxes significantly improve air quality in 12

European countries. The study by Jeffrey and Perkins (2015) reveals that there is a negatively significant relationship between energy taxes and total carbon emissions by using the panel data for 27 EU countries during the 1996-2009 period. Kartal (2024) analyzes the effects of disaggregated and aggregated environmental taxes on the ecological footprint in EU5 countries from 1995-Q1 to 2021-Q4 using a nonlinear quartile estimation method. The study found that energy taxes are effective only in Germany and Italy, while there is no significant impact of transportation taxes on pollution. The results by Rafique *et al*. (2022) suggest that environmental taxes reduce the ecological footprint in the long run. Telatar and Birinci (2022) employed nonlinear regression analysis for Turkey during the 1994-2019 period and found that there was no significant impact of environmental taxes on ecological footprint. The empirical results by Postula and Radecka-Moroz (2020) suggest that environmental taxes lead to a faster and more effective decline in pollution in the long run.

Among the studies investigating the relationship between environmental pollution and environmental protection expenditures, Bostan *et al*. (2016) using data for Switzerland, Turkey, and 18 EU countries for the period 1995-2013, conclude that environmental protection expenditures lead to a reduction in air pollution. Similarly, using panel data for China during the 2008-2013 period, Huang (2018) found that environmental protection expenditures reduce environmental pollution. Akdağ *et al*. (2024) found that environmental protection expenditures are nearly twice as effective as environmental taxes in reducing greenhouse gas emissions in 26 EU countries during the 1995-2019 period by using system GMM method. However, the studies by Moshiri and Daneshmand (2020) and Ma *et al*. (2023) suggest that environmental protection expenditures are not significantly effective in reducing environmental pollution.

Studies on renewable energy consumption (REC) examine the effect on carbon dioxide emissions. For example, Tiwari (2011) reports that REC decreases carbon dioxide emissions. In a similar vein, Bento and Moutinho (2016) found that REC reduces carbon dioxide emissions in Italy. The results by Chen *et al*. (2019) suggest that REC reduces carbon emissions in the long run. On the other hand, Apergis *et al*. (2010) found that REC does not have a mitigating effect on carbon dioxide emissions. Usman *et al*. (2021) report that REC tends to reduce ecological footprint. Similarly, Wang *et al*. (2024) analyzed the impact of renewable energy on the ecological footprint in 14 developing EU economies between 1995 and 2020 by using augmented mean group and common correlated effect mean group methods, finding that renewable energy mitigates environmental degradation and enhances sustainability. According to the results by Bozatlı and Akça (2023) and Ali and Kirikkaleli (2024), environmental taxes and REC reduce the ecological footprint. However, Appiah *et al*. (2023) found that REC increases the ecological footprint, suggesting that in some countries, renewable energy policies may be insufficient or implemented alongside fossil fuel consumption, limiting the expected environmental benefits.

The literature often investigates the individual effects of fiscal policy instruments on environmental pollution excluding the studies by Postula and Radecka-Moroz (2020), Zahra *et al*. (2022) and Villanthenkodath *et al*. (2024). Postula and Radecka-Moroz (2020) remark that the most effective solution for environmental pollution is the employment of mixed fiscal policy instruments. Zahra *et al*. (2022) found that tax revenues and social expenditures mitigate pollution while Villanthenkodath *et al*. (2024) report that fiscal policy instruments are ineffective on pollution. The research gap identified in the cited literature suggests a limited number of studies examining the joint effect of fiscal policy instruments on environmental pollution. We consider environmental protection expenditures, environmental taxes and renewable energy incentives as fiscal policy instruments. Our measure of environmental pollution is ecological footprint, a comprehensive indicator that quantifies the total environmental impact of human activities, including carbon emissions, land use, water consumption, and resource depletion. Thus, given there are limited studies in the literature on the joint effects of fiscal policy instruments, we aimed to contribute by examining their effectiveness in reducing ecological footprint. Considering the policy changes will be effective in the long run, this article investigates the effects of fiscal policy instruments on ecological footprint by employing FMOLS and DOLS estimation procedures which allowed us to investigate the long-run relationship between our variables of interest. These estimation methods also consider potential autocorrelation and some degree of heterogeneity by including leads and lags of first-differenced regressors as briefly explained by Kao and Chiang (2000), Saikkonen (1991), and Stock and Watson (1993).

In this study, we considered the following research hypotheses:

H1: There is a negative relationship between renewable energy incentives and environmental pollution.

Renewable energy sources are expected to significantly lower environmental pollution as compared to fossil fuels. These energy types include biomass, hydroelectric, solar, wind, and geothermal energy sources. The literature often finds that renewable energy lowers environmental pollution by decreasing carbon emissions. Renewable energy incentives promote the use of renewable energy sources, enabling them to replace fossil fuels, thereby reducing the pressure on the environment. This hypothesis is based on the assumption that investments and incentives in renewable energy are expected to be effective in reducing environmental pollution. These will accelerate the adoption of clean energy technologies in the energy sector, thus helping to reduce the ecological footprint.

H2: There is a negative relationship between environmental taxes and environmental pollution.

Environmental taxes are fiscal instruments used to reduce pollution. These taxes aim to encourage producers and consumers to adopt more environmentally friendly behaviours by increasing the cost of polluting activities. Based on Pigou's theory of externalities, environmental taxes serve to internalize the social costs of pollution. Increasing tax rates raises the cost of polluting activities, thus encouraging avoidance of such behaviours. The literature often maintains that environmental taxes are effective in reducing carbon emissions and other environmental damages. These taxes will serve as an effective tool to increase energy efficiency, promote the use of renewable energy, and foster a more environmentally conscious model of production and consumption.

H3: There is a negative relationship between environmental protection expenditures and environmental pollution.

Environmental protection expenditures include direct investments by governments to protect the environment and reach sustainable development goals. These expenditures can be directed towards areas such as the preservation of natural resources, improvement of air and water quality, biodiversity protection, and waste management. Although the effectiveness of environmental protection expenditures in reducing environmental pollution is debated in the literature, there is evidence that these expenditures play a significant role in reducing pollution when managed effectively. However, the effectiveness of these expenditures may vary depending on how governments utilize these funds and the feasibility of implementing environmental protection projects.

RESEARCH METHODOLOGY

Data and Variables

The main goal of this study was to empirically examine whether fiscal policy instruments are effective in reducing environmental pollution in a sample of 21 EU[1](Germany, Austria, Croatia, Belgium, Greece, Denmark, Luxembourg, Estonia, Czechia, France, Netherlands, Italy, Latvia, Lithuania, Poland, Romania, Portugal, Slovakia, Slovenia, Spain, Sweden) countries and Turkey using annual data for the 1996-2018 period. For this purpose, we constructed the following regression model:[2]

$$\log(\mathrm{EF})_{\mathrm{it}} = \alpha_0 + \alpha_1 \log(\mathrm{GDPpc})_{\mathrm{it}} + \alpha_2 \mathrm{EPE}_{\mathrm{it}} + \alpha_3 \mathrm{ET}_{\mathrm{it}} + \alpha_4 \mathrm{REC}_{\mathrm{it}} + \mathrm{u}_{\mathrm{it}} \quad (1)$$

In equation (1), sub-indices i and t represent countries and years, respectively. The log(EF) is the logarithm of the ecological footprint (in global hectares), log(GDPpc) is the logarithm of real GDP per capita, EPE is the share of environmental protection expenditures in income, ET is the share of total

[1] We were unable to include Bulgaria, Cyprus, Finland, Hungary, Ireland and Malta because of the data unavailability.

[2] We also consider the square term of log(GDPpc) to investigate the validity of EKC. We appreciate the anonymous referees for highlighting this important point. Our preliminary results suggest that the square term of log(GDPpc) is statistically insignificant. We did not report the results to save the space but available on request.

environmental taxes in income, and REC is the share of renewable energy consumption in total energy consumption. We maintained that REC can serve as a proxy for public incentives,[3] as the indirect promotion of renewable energy through government fiscal policies may reduce pollution. In this vein, we suggest that the pollution-reducing effect of REC may prompt fiscal authorities to consider public incentives to increase renewable energy use. Table 1 gives the main data sources for the variables.

Table 1. Definition of variables and data sources

Abbreviation	Variable	Data source
Log(EF)	Global ecological footprint in hectare (in log.)	Global Footprint Network
Log(GDPpc)	Real income per capita (in log.)	World Bank, World Development Indicators
EPE	Environmental protection expenditures (as a per cent of income)	International Monetary Fund (IMF)
ET	The share of environmental taxes as a per cent of income	Eurostat
REC	The share of renewable energy consumption as a percent of total energy consumption	World Bank, World Development Indicators

Source: own study.

Table 2. Basic descriptive statistics

Statistics	log(EF)	log(GDPpc)	EPE	ET	REC
Mean	5.678	10.086	16.214	2.653	7.20
Median	5.330	10.072	13.484	2.510	6.80
Maximum	17.778	11.626	52.892	5.300	18.83
Minimum	2.346	8.471	1.148	0.860	0.30
St. Deviation	2.364	0.716	11.159	0.703	3.40

Note. Abbreviations for variables: log(EF): natural logarithm of ecological footprint, log(GDPpc): natural log. of real income per capita, EPE: environmental protection expenditure, ET: environmental taxes, REC: renewable energy consumption.
Source: own study.

Table 2 presents descriptive statistics for our variables. The mean value of the ecological footprint was 5.68. The average real income per capita was 10.09. The share of REC in total energy consumption was 7.2. The average environmental tax (share of income) was 2.65. The minimum and maximum values of environmental tax may imply that some countries impose relatively high tax rates. The mean value of environmental protection expenditure was 16.21. The standard deviation of environmental protection expenditure was much higher than the rest of the variables. This may be related to an argument that environmental taxes as compared to environmental protection expenditure are a more common policy instrument to mitigate pollution.[4]

RESULTS AND DISCUSSION

To investigate the long-run effect of fiscal policy instruments on ecological footprint, we first investigated the stationary degrees of the variables. In this vein, we employed Levin, Lin, and Chu (LLC, 2002) and Im, Pesaran, and Shin (IPS, 2003) panel unit root tests. To employ panel unit root tests, we considered the following equation:

$$\Delta Y_{it}=\alpha_0+\alpha_1 Y_{i,t-1}+\sum_{i=1}^{m}\alpha_i \Delta Y_{i,t-1}+u_{it} \quad (2)$$

[3] It is conventionally assumed that government interventions – such as subsidies, tax credits, and public investments – play a significant role in shaping renewable energy markets. These fiscal measures reduce the cost of renewable energy production and consumption, thereby incentivizing its adoption. Consequently, renewable energy consumption (REC) may, to some extent, reflect the impact of fiscal policies aimed at promoting cleaner energy sources. Moreover, we may consider REC an indirect outcome of energy policies or incentives. Unfortunately, data on renewable energy incentives are not available for most of the countries in our sample, which has led us to use REC as a proxy. We appreciate the anonymous referee for highlighting this important point.

[4] For detailed information on environmental taxes applied in EU countries, see: European Commission, 2017, 2021.

We also included the lagged dependent variable in equation (2) to tackle the potential autocorrelation. The LLC and IPS tests maintain these hypotheses:

H_0 : α_1=0, Y variable is non-stationary.

H_A : α_1<0, Y variable is stationary.

Table 3 reports the unit root test results. According to the results, our variables appeared to be stationary in the first difference.

Table 3. Unit root test

Variables	Levin, Lin, and Chu test results		Im, Pesaran, and Shin test results	
	Level	1st Difference	Level	1st Difference
log(GDPpc)	-0.699 [0.242]	-6.357 [0.00]	2.078 [0.981]	-15.734 [0.00]
REC	3.204 [0.990]	-11.635 [0.00]	4.646 [0.778]	-17.939 [0.00]
ET	-0.173 [0.431]	-16.783 [0.00]	0.601 [0.726]	-15.660 [0.00]
log(EF)	-1.013 [0.156]	-5.491 [0.00]	-1.074 [0.142]	-11.787 [0.00]
EPE	1.011 [0.844]	-12.119 [0.00]	-1.708 [0.143]	-20.080 [0.00]

Note. Abbreviations for variables: log(GDPpc): natural log. of real income per capita, EPE: environmental protection expenditure, ET: environmental taxes, log(EF): natural log. of ecological footprint, REC: renewable energy consumption; Unit root test equations include a constant term and [.] denotes the p-value corresponding to the relevant test; The Akaike Information Criterion (AIC) is used to select the lagged value.
Source: own study.

To investigate the validity of the long-run relationship between our variables of interest, we utilized the panel cointegration test by Pedroni (1999). We used Pedroni cointegration test because it allows for testing whether cointegration is valid in a multiple regression model. Pedroni cointegration test includes seven different tests (Panel V, Panel rho, Panel PP, Panel ADF, Group rho, Group PP, Group ADF).

Table 4. Panel cointegration test

Pedroni panel cointegration results	
(Within-dimension= In-group approach)	
	t-statistic
Panel v-Statistics	0.956
Panel rho-Statistics	-1.219*
Panel PP-Statistic	-5.660***
Panel ADF-Statistic	-5.673***
(Between-dimension=Inter-group approach)	
Group rho-Statistics	0.819
Group PP-Statistic	-7.807***
Group ADF-Statistic	-6.774***

Notes. ***, **, * indicate significance at the 1%, 5% and 10% levels, respectively.
Source: own study.

Table 4 shows the Pedroni cointegration test results. According to the cointegration test results, the Panel v-statistic in the within-group approach and the Group rho statistic in the between-group approach indicated that the null hypothesis stating that cointegration is not valid should not be rejected. The remaining cointegration test results (Panel rho, Panel PP, Panel PP, Panel ADF, Group PP, Group ADF) indicate that the null hypothesis should be rejected. Except for Panel v and Group rho statistics, the remaining five test statistics indicate that there was a cointegration. This implies that there was a long-run rela-tionship between the variables included in the regression. Since our variables were stationary in first-order differences and cointegration is valid, we could employ FMOLS and DOLS estimation methods.

DOLS Estimation Results

The DOLS method allows parameter estimation by considering potential autocorrelation and some degree of heterogeneity by including leads and lags of first-differenced regressors (Kao & Chiang, 2000; Saikkonen, 1991; Stock & Watson, 1993). Kao and Chiang (2000) argue that the DOLS estimation method is superior to the other panel cointegration methods. Pedroni (1999) states that the DOLS estimation method allows for consistent parameter estimates even if the sample size is small.

Table 5. DOLS estimation results

Variables	Equation (1)
$\log(GDPpc_{it})$	0.526*** (0.023)
EPE_{it}	-0.034* (0.021)
ET_{it}	-0.017* (0.009)
REC_{it}	-0.017*** (0.001)
R^2	0.976
LRV	0.003
N	21
NT	445

Note. Abbreviations for variables: log(GDPpc): natural log. of real income per capita, EPE: environmental protection expenditure, ET: environmental taxes, REC: renewable energy consumption; LRV denotes long-run variance, N and NT represent, respectively, the number of countries and observations. (.) values denote the standard error. ***, ** and * denote 1%, 5% and 10% significance level, respectively.
Source: own study.

Table 5 shows the DOLS estimation results of equation (1). Accordingly, there was a positive and significant relationship between real income per capita (GDPpc) and pollution. The income elasticity of pollution was estimated at 0.5. This coefficient implies that an increase in real income per capita leads to an increase in pollution. This empirical result aligns with the scale effect argument proposed by Grossman and Krueger (1995). There was a negative and statistically significant relationship between environmental protection expenditure (EPE) and ecological footprint. This result is consistent with the empirical findings by Huang (2018) and Akdağ *et al*. (2024). Environmental taxes also tend to mitigate pollution. We also found that there was a negative and statistically significant relationship between renewable energy consumption (REC) and ecological footprint. This was in line with the results by Bento and Moutinho (2016), Chen *et al*. (2019), Usman *et al*. (2021), Wang *et al*. (2023) and Tiwari (2011). According to Table 5, real income per capita, environmental protection expenditure, environmental tax and REC are among the important determinants of pollution. Consistent with the findings by Gupta and Barman (2009), López and Palacios (2014) and Postula and Radecka-Moroz (2020), our empirical results suggest that fiscal policy instruments are effective in reducing ecological footprint.

Table 6 shows the country-specific DOLS estimation results of Equation (1). The income elasticity of pollution was estimated at 0.526 in the whole sample. It was much higher in Austria, Italy, Netherlands, Slovakia, and Spain as compared to the other countries. However, the income elasticity of pollution was relatively lower in Denmark, Germany and Turkey. The results in Table 6 reveal that the income elasticity of pollution differed with respect to the countries in our sample. This may related to the argument that the adoption of environmentally sensitive production processes takes time.

Table 6. DOLS results of equation (1) by country

Countries	log(GDPpc)	ET	REC	EPE
Austria	1.078*** (0.098)	-0.079** (0.035)	-0.012*** (0.002)	0.101 (0.105)
Belgium	0.184*** (0.013)	-0.012 (0.062)	-0.035*** (0.007)	0.156 (0.099)
Croatia	0.491*** (0.105)	-0.028 (0.039)	-0.015*** (0.002)	-1.026*** (0.216)
Czechia	0.503** (0.218)	0.033 (0.078)	-0.034*** (0.010)	0.068 (0.047)
Denmark	0.169*** (0.013)	0.058 (0.036)	-0.006*** (0.001)	0.112 (0.173)
Estonia	0.192*** (0.036)	0.125 (0.129)	-0.021 (0.016)	0.290 (0.278)
France	0.226*** (0.022)	-0.121 (0.086)	-0.019** (0.009)	-0.336* (0.166)
Germany	0.161*** (0.028)	-0.008 (0.074)	-0.011* (0.006)	0.111 (0.186)
Greece	0.272* (0.154)	-0.149*** (0.045)	0.006 (0.010)	-0.098 (0.071)
Italy	1.733*** (0.426)	0.030 (0.050)	-0.009** (0.003)	-0.523** (0.157)
Latvia	0.447*** (0.127)	0.002 (0.063)	0.006 (0.011)	0.178 (0.154)
Lithuania	0.491*** (0.103)	-0.036 (0.034)	-0.002 (0.005)	-0.052 (0.054)
Luxembourg	0.195*** (0.020)	0.172 (0.098)	0.002 (0.011)	0.030 (0.189)
Netherlands	0.998*** (0.298)	-0.008 (0.158)	-0.068*** (0.017)	0.229 (0.180)
Poland	0.177*** (0.011)	-0.024 (0.034)	-0.020*** (0.006)	0.123 (0.087)
Portugal	0.231*** (0.020)	-0.058* (0.031)	-0.025*** (0.003)	-0.181 (0.179)
Romania	0.310* (0.170)	-0.078* (0.046)	-0.008 (0.010)	-0.209** (0.080)
Slovakia	1.026*** (0.230)	-0.116 (0.086)	-0.050*** (0.015)	0.195 (0.114)
Slovenia	0.514*** (0.074)	-0.048*** (0.016)	-0.018*** (0.003)	0.064 (0.051)
Spain	0.630*** (0.095)	-0.357** (0.099)	-0.050*** (0.002)	-0.912** (0.316)
Sweden	0.237*** (0.054)	-0.157 (0.147)	-0.014** (0.006)	0.606 (0.453)
Turkey [5]	0.076** (0.005)	0.100 (0.021)	-0.032* (0.006)	1.507** (0.092)
Panel overview:	**0.526*** (0.023)**	**-0.017* (0.009)**	**-0.017*** (0.001)**	**-0.034* (0.021)**

Note. Abbreviations for variables: log(GDPpc): natural log. of real income per capita, EPE: environmental protection expenditure, ET: environmental taxes, REC: renewable energy consumption; ***, ** and * denote 1%, 5% and 10% significance level, respectively.
Source: own study.

[5] There are only 9 observations for Turkey.

We observed the pollution-reducing effect of environmental taxes in Austria, Greece, Portugal, Romania, Slovenia, and Spain. As indicated by the European Commission (2017), taxes in Austria (landfill tax, Vienna tree protection law), Portugal (charging for water resources, ecological fiscal transfers), Spain (landfill tax), Slovenia (private forest management), Romania (packaging fees and taxes) may have a reducing effect on the ecological footprint. The relationship between environmental taxes and pollution varies across countries because environmental taxes are often implemented for fiscal purposes rather than for pollution prevention. Moreover, the share of environmental taxes in both GDP and total tax revenues[6] may imply that there is no consensus among EU countries on the harmonization of environmental taxes at a sufficient level. Therefore, environmental taxes may have a significant effect on pollution in some countries, while it is insignificant in some other countries.

The pollution-reducing effect of renewable energy consumption seems to be held in most countries excluding Estonia, Greece, Latvia, Lithuania, Luxembourg and Romania. The ecological footprint-reducing effect of environmental protection expenditure is valid for Croatia, France, Italy, Spain and Romania. From Turkey's perspective, it is local governments that mostly conduct environmental protection services. Conventionally, environmental protection expenditures are often considered a cost item and have a very low share of income. Therefore, local governments may not have sufficient and necessary financial resources to fulfil environmental protection activities. Because of these reasons, environmental protection expenditures may lead to an increase in pollution in Turkey.[7]

FMOLS Estimation Results

To investigate the long-run effect of fiscal policy instruments on pollution, we also employ a fully modified ordinary least squares (FMOLS) estimation method developed by Pedroni (2001) and Phillips and Hansen (1990). In a similar vein to DOLS, the FMOLS method considers autocorrelation and some degree of heterogeneity among our variables. Pedroni (2001) suggests that the FMOLS method provides super-consistent parameter estimation.

Table 7. FMOLS estimation results

Variables	Equation (1)
$\log(GDPpc_{it})$	0.468*** (0.016)
EPE_{it}	-0.008 (0.013)
ET_{it}	-0.027*** (0.007)
REC_{it}	-0.017*** (0.001)
R^2	0.949
LRV	0.003
N	22
NT	471

Note. Abbreviations for variables: log(GDPpc): natural log. of real income per capita, EPE: environmental protection expenditure, ET: environmental taxes, REC: renewable energy consumption; LRV denotes long-run variance, N and NT represent, respectively, the number of countries and observations. (.) values denote the standard error. ***, ** and * denote 1%, 5% and 10% significance level, respectively.
Source: own study.

Table 7 presents FMOLS estimation results of Equation (1). According to Table 7, there is a positive and statistically significant relationship between real income per capita and ecological footprint. This empirical result aligns with the scale effect argument proposed by Grossman and Krueger (1995).

[6] In the EU, the share of environmental tax revenues in total tax revenues varies from country to country (4%-10%) but averages around 6.15% (Eurostat, 2022).
[7] The result obtained for Turkey should be evaluated by considering the fact that we conducted the analysis with only nine observations.

There is no statistically significant relationship between environmental protection expenditure and ecological footprint. Increasing environmental taxes results in a reduction in the ecological footprint.

Table 8. FMOLS results of equation (1) by country

Countries	$\log(\mathrm{GDPpc})$	ET	REC	EPE
Austria	1.179*** (0.132)	-0.285* (0.153)	-0.138 (0.204)	0.375 (0.230)
Belgium	0.208*** (0.009)	-0.074** (0.035)	-0.026*** (0.003)	0.052 (0.033)
Croatia	0.737*** (0.068)	-0.017 (0.018)	-0.021*** (0.002)	-0.016 (0.209)
Czechia	0.540*** (0.089)	0.084 (0.095)	-0.029*** (0.006)	0.075 (0.045)
Denmark	0.533*** (0.161)	-0.058* (0.029)	-0.016*** (0.002)	0.057 (0.128)
Estonia	0.210*** (0.027)	0.053 (0.090)	-0.017 (0.014)	0.221 (0.148)
France	0.237*** (0.019)	-0.154** (0.073)	-0.015* (0.008)	-0.449*** (0.144)
Germany	0.152*** (0.028)	0.015 (0.068)	-0.012** (0.005)	0.172 (0.209)
Greece	0.233* (0.127)	-0.107** (0.040)	-0.015* (0.009)	0.007 (0.056)
Italy	0.818*** (0.203)	-0.086*** (0.029)	-0.014*** (0.002)	-0.080 (0.120)
Latvia	0.419** (0.160)	-0.017 (0.184)	0.281 (0.284)	0.274 (0.211)
Lithuania	0.459*** (0.098)	-0.065* (0.034)	-0.004 (0.004)	-0.058 (0.049)
Luxembourg	0.398* (0.223)	0.098 (0.058)	-0.005 (0.004)	-0.038 (0.155)
Netherlands	1.377*** (0.177)	0.304 (0.270)	-0.403* (0.212)	0.258 (0.151)
Poland	1.860*** (0.093)	-1.449*** (0.149)	-1.784*** (0.154)	0.075 (0.267)
Portugal	0.178*** (0.022)	0.030 (0.031)	-0.020*** (0.003)	0.114 (0.199)
Romania	0.369** (0.155)	-0.089** (0.041)	-0.008 (0.010)	-0.278*** (0.074)
Slovakia	0.908*** (0.195)	-0.125 (0.080)	-0.049*** (0.013)	0.070 (0.093)
Slovenia	0.942*** (0.149)	-0.418* (0.213)	0.005 (0.110)	-0.583** (0.226)
Spain	0.544*** (0.072)	0.041 (0.041)	-0.043*** (0.001)	0.074 (0.089)
Sweden	0.225*** (0.055)	-0.139 (0.147)	-0.012* (0.006)	0.577 (0.443)
Turkey	0.081*** (0.009)	0.040 (0.024)	-0.011* (0.005)	1.173*** (0.141)
Panel Overview:	**0.468*** (0.016)**	**-0.027*** (0.007)**	**-0.017*** (0.001)**	**-0.008 (0.013)**

Note. Abbreviations for variables: log(GDPpc): natural log. of real income per capita, EPE: environmental protection expenditure, ET: environmental taxes, REC: renewable energy consumption; ***, ** and * denote 1%, 5% and 10% significance level, respectively.
Source: own study.

Consistent with the results by Bento and Moutinho (2016), Chen *et al*. (2019), Tiwari (2011), and Rafique *et al*. (2022), our results suggest that a rise in REC reduces ecological footprint.

Table 8 shows the FMOLS estimation results of Equation (1) with respect to the countries in our sample. According to the empirical results, the positive relationship between real income per capita and ecological footprint was much higher for Austria, the Netherlands, and Poland. Austria, Belgium, Denmark, France, Greece, Italy, Lithuania, Poland, Romania and Slovenia were the countries where environmental taxes led to a decrease in pollution. We found REC to be effective in reducing ecological footprint in Belgium, Denmark, Croatia, France, Czechia, Greece, Germany, Netherlands, Italy, Portugal, Poland, Slovakia, Sweden, Spain, and Turkey. The negative effect of environmental protection expenditures on ecological footprint was statistically significant in France, Romania and Slovenia, while this parameter was estimated as statistically insignificant across the panel. In Turkey[8], an increase in environmental protection expenditure led to an increase in ecological footprint.

CONCLUSIONS

This article investigated whether fiscal policy instruments can solve environmental problems. These instruments may include environmental taxes, environmental protection expenditures, and renewable energy incentives. The conventionally used fiscal policy instrument in practice is environmental taxes. Environmental taxes serve to restrict, prevent, or reduce pollution-intensive economic activities. Renewable energy incentives may support clean energy production and enable producers to compete with firms using fossil fuels. Environmental protection expenditures may also serve to reduce environmental pollution. In this context, this article examines the long-run effects of fiscal policy instruments on the ecological footprint in our sample including 21 EU countries and Turkey during the annual sample of the 1996-2018 period.

To study the long-run effects of fiscal policy instruments on ecological footprint, we prefer to use DOLS and FMOLS estimation methods. The empirical results show that the most effective fiscal policy instrument to mitigate the ecological footprint is renewable energy incentives. Both DOLS and FMOLS estimation results suggest that renewable energy consumption tends to reduce ecology-ical footprint. Renewable energy incentives appear as a pollution-reducing factor in almost all countries included in the analysis. To compete with cheap and polluting fossil fuels, renewable energy consumption needs to be supported by the government. A renewable energy incentive policy that prioritizes the employment of renewable energy is expected to contribute to the countries achieving their sustainable development goals.

In addition to renewable energy incentives, we found that environmental taxes reduce pollution in most of the countries in our sample. However, environmental taxes may also serve other purposes than environmental protection. We suggest that revenues from environmental taxes could be directly used to address environmental problems.

Environmental protection expenditures appear to be the least effective fiscal policy instrument. Although environmental protection expenditures have a small share in income, they are very important in dealing with environmental problems, protecting natural life and achieving sustainable development goals. Therefore, allocating more resources to environmental protection services will contribute to making it an effective policy instrument.

Policy implications derived from these findings emphasize the necessity of a well-coordinated approach that integrates environmental taxation, renewable energy incentives, and strategic environmental expenditures to achieve sustainability goals effectively. Environmental taxes should be structured not only as revenue-generating instruments but also as mechanisms to incentivize cleaner production and innovation in green technologies, ensuring that tax revenues are reinvested into environmental projects. Similarly, increasing renewable energy incentives can accelerate the transition towards low-carbon energy systems, enhancing energy security while fostering technological advancements. Furthermore, environmental protection expenditures should be strategically allocated to

[8] This result require cautious evaluation because there were only nine observations for Turkey.

targeted, results-oriented pro-jects, such as green infrastructure, waste management, and R&D in clean technologies, to maximize their effectiveness in reducing pollution. Policymakers should also prioritize cultivating environmentally responsible behaviours to reinforce the long-term sustainability of policy interventions.

A holistic and well-designed policy framework that aligns taxation, incentives, and expenditures can ensure that environmental policies mitigate ecological damage. By adopting such an approach, governments can balance the financial burden of environmental taxes with renewable energy incentives and direct the revenue generated from these taxes towards environmental protection expenditures. This strategic alignment and coordination will create a more effective policy framework not only for reducing environmental pollution but also for achieving sustainable development goals. Therefore, policymakers must plan and implement various fiscal policy tools in an integrated and strategic manner to enhance environmental policies' effectiveness.

Future studies should focus on using more recent data, exploring different pollution indicators, and examining the combined effects of fiscal policies through advanced econometric models to assess the effectiveness of environmental policies comprehensively. It would also be interesting for future studies which investigate the short- and long-run effects of fiscal policy instruments on environmental pollution by employing the autoregressive distributed lag (ARDL) model. Moreover, future studies may benefit from a comparative analysis across countries with varying levels of economic development and environmental regulations to better understand the heterogeneous impacts of fiscal policies on pollution.

REFERENCES

Akdag, S., Yildirim, H., & Alola, A.A. (2024). Comparative benefits of environmental protection expenditures and environmental taxes in driving environmental quality of the European countries. *Natural Resources Forum*, 1-16. https://doi.org/10.1111/1477-8947.12464

Ali, M., & Kirikkaleli, D. (2024). Environmental tax, renewable energy and environmental sustainability in Germany: evidence from wavelet and Fourier-based approaches. *Management of Environmental Quality*, *35*(6), 1213-1232. https://doi.org/10.1108/MEQ-09-2023-0310

Apergis, N., & Öztürk, İ. (2015). Testing Environmental Kuznets Curve Hypothesis in Asian Countries. *Ecological Indicators*, *52*, 16-22. https://doi.org/10.1016/j.ecolind.2014.11.026

Apergis, N., Payne, J.E., Menyah, K., & Wolde-Rufael, Y. (2010). On The Causal Dynamics Between Emissions, Nuclear Energy, Renewable Energy, And Economic Growth. *Ecological Economics*, *69*(11), 2255-2260. https://doi.org/10.1016/j.ecolecon.2010.06.014

Appiah, M., Li, M., Naeem, M.A., & Karim, S. (2023). Greening the globe: Uncovering the impact of environmental policy, renewable energy, and innovation on ecological footprint. *Technological Forecasting and Social Change*, *192*, 122561. https://doi.org/10.1016/j.techfore.2023.122561

Barra, C., & Zotti, R. (2018). Investigating The Non-Linearity Between National İncome And Environmental Pollution: International Evidence of Kuznets Curve. *Environmental Economics and Policy Studies*, *20*(1), 179-210. https://doi.org/10.1007/s10018-017-0189-2

Bento, J.P.C., & Moutinho, V. (2016). CO2 Emissions, Non-Renewable And Renewable Electricity Production, Economic Growth, And İnternational Trade in Italy. *Renewable and Sustainable Energy Reviews*, *55*, 142-155. https://doi.org/10.1016/j.rser.2015.10.151

Bloch, H., Rafiq, S., & Salim, R. (2012). Coal Consumption, CO2 Emission and Economic Growth in China: Empirical Evidence And Policy Responses. *Energy Economics*, *34*(2), 518-528. https://doi.org/10.1016/j.eneco.2011.07.014

Bostan, I., Onofrei, M., Doina Dascalu, E., Firtescu, B., & Toderaşcu, C. (2016). Impact of Sustainable Environmental Expenditures Policy on Air Pollution Reduction, During European Integration Framework. *Amfiteatru Economic Journal*, *18*(42), 286-302. Retrieved from https://www.proquest.com/docview/1794832250/fulltextPDF/75B5DCE2BA324451PQ/1?accountid=25096&sourcetype=Scholarly%20Journals on October 20, 2023.

Bozatli, O., & Akca, H. (2023). The effects of environmental taxes, renewable energy consumption and environmental technology on the ecological footprint: Evidence from advanced panel data analysis. *Journal of Environmental Management*, *345*, 118857. https://doi.org/10.1016/j.jenvman.2023.118857

Chen, Y., Wang, Z., & Zhong, Z. (2019). CO2 Emissions, Economic Growth, Renewable And Non-Renewable Energy Production And Foreign Trade in China. *Renewable Energy*, *131*, 208-216. https://doi.org/10.1016/j.renene.2018.07.047

Cole, M.A. (2004). Trade, the Pollution Haven Hypothesis And The Environmental Kuznets Curve: Examining the Linkages. *Ecological Economics*, *48*(1), 71-81. https://doi.org/10.1016/j.ecolecon.2003.09.007

Dinda, S. (2004). Environmental Kuznets Curve Hypothesis: A survey. *Ecological Economics*, *49*(4), 431-455. https://doi.org/10.1016/j.ecolecon.2004.02.011

European Commission. (2017). Capacity Building, Programmatic Development and Communication in the Field of Environmental Taxation and Budgetary Reform. Retrieved from https://ieep.eu/uploads/articles/attachments/de8980ef-e9cc-49f2-b66e-ac7a71be9e15/ETR and Civil Society Final Report 191217 FINAL.pdf?v=63680917736 on April 13, 2023.

European Commission. (2021). Green Taxation and Other Economic İnstruments: Internalising Environmental Costs to Make the Polluter Pay. Retrieved from https://ieep.eu/uploads/articles/attachments/134d9257-53c5-4a20-885b-9f6615452486/Green taxation and other economic instruments – Internalising environmental costs to make the polluter pay_Study_10.11.2021.pdf?v=63807385248 on May 15, 2023.

Eurostat. (2022). European Community Statistical Office. Retrieved from https://ec.europa.eu/eurostat/ on May 15, 2023.

Grossman, G., & Krueger, A. (1991). Environmental Impacts of a North American Free Trade Agreement. In *National Bureau of Economic Research* Working Paper No: 3914. https://doi.org/10.3386/w3914

Grossman, G.M., & Krueger, A.B. (1995). Economic Growth And The Environment. *Quarterly Journal of Economics*, 353-377. https://doi.org/10.2307/2977834

Gupta, M.R., & Barman, T.R. (2009). Fiscal policies, Environmental Pollution and Economic Growth. *Economic Modelling*, *26*(5), 1018-1028. https://doi.org/10.1016/j.econmod.2009.03.010

He, J., & Wang, H. (2012). Economic Structure, Development Policy and Environmental Quality: An Empirical Analysis Of Environmental Kuznets Curves with Chinese Municipal Data. *Ecological Economics*, *76*, 49-59. https://doi.org/10.1016/j.ecolecon.2012.01.014

Hiton, H., & Levinson, A. (1998). Factoring the Environmental Kuznets Curve: Evidence from Automotive Lead Emissions. *Journal of Environmental Economics and Mangement, 35*, 126-141. https://doi.org/10.4324/9781351161084-3

Huang, J.T. (2018). Sulfur Dioxide (SO2) Emissions and Government Spending on Environmental Protection in China – Evidence from Spatial Econometric Analysis. *Journal of Cleaner Production*, *175*, 431-441. https://doi.org/10.1016/j.jclepro.2017.12.001

Im, K.S., Pesaran, M.H., & Shin, Y. (2003). Testing for Unit Roots in Heterogeneous Panels. *Journal of Econometrics*, *115*(1), 53-74. https://doi.org/10.1016/S0304-4076(03)00092-7

Jeffrey, C., & Perkins, J.D. (2015). The Association Between Energy Taxation, Participation İn An Emissions Trading System, And The İntensity Of Carbon Dioxide Emissions İn The European Union. *International Journal of Accounting*, *50*(4), 397-417. https://doi.org/10.1016/j.intacc.2015.10.004

Kao, C., & Chiang, M.H. (2000). On The Estimation And Inference Of A Cointegrated Regression In Panel Data. *Advances in Econometrics*, *15*, 179-222. https://doi.org/10.1016/S0731-9053(00)15007-8

Kartal, M.T. (2024). Quantile-Based Effect of Energy, Transport, and Total Environmental Tax on Ecological Footprint in EU5 countries. *Environmental Science and Pollution Research*, *31*(13), 20033-20047. https://doi.org/10.1007/s11356-024-32214-3

Levin, A., Lin, C.F., & Chu, C.S.J. (2002). Unit root tests in panel data: Asymptotic and finite-sample properties. *Journal of Econometrics*, *108*(1), 1-24. https://doi.org/10.1016/S0304-4076(01)00098-7

López, R., & Palacios, A. (2014). Why has Europe Become Environmentally Cleaner? Decomposing the Roles of Fiscal, Trade and Environmental Policies. *Environ Resource Econ*, *58*, 91-108. https://doi.org/10.1007/s10640-013-9692-5

Ma, B., Sharif, A., Bashir, M., & Bashir, M.F. (2023). The dynamic influence of energy consumption, fiscal policy and green innovation on environmental degradation in BRICST economies. *Energy Policy*, *183*, 113823.

https://doi.org/10.1016/j.enpol.2023.113823

Moomaw, W.R., & Unruh, G.C. (1997). Are Environmental Kuznets Curves Misleading Us? The Case of CO2 Emissions. *Environment and Development Economics*, *2*(4), 451-463. https://doi.org/10.1017/S1355770X97000247

Morley, B. (2012). Empirical Evidence on The Effectiveness of Environmental Taxes. *Applied Economics Letters*, *19*(18), 1817-1820. https://doi.org/10.1080/13504851.2011.650324

Moshiri, S., & Daneshmand, A. (2020). How effective is government spending on environmental protection in a developing country ? An empirical evidence from Iran. *Journal of Economic Studies*, *47*(4), 789-803. https://doi.org/10.1108/JES-12-2018-0458

Pedroni, P. (1999). Critical values for cointegration tests in heterogeneous panels with multiple regressors. *Oxford Bulletin of Economics and Statistics*, *61*, 653-670. https://doi.org/10.1111/1468-0084.61.s1.14

Pedroni, P. (2001). Fully modified OLS for heterogeneous cointegrated panels. In Baltagi, B.H., Fomby, T.B. and Carter Hill, R. (Eds.) *Nonstationary Panels, Panel Cointegration, and Dynamic Panels* (Advances in Econometrics, Vol. 15, pp. 93-130), Emerald Group Publishing Limited, Leeds, https://doi.org/10.1016/S0731-9053(00)15004-2

Phillips, P.C.B., & Hansen, B.E. (1990). Statistical İnference İn İnstrumental Variables Regression With I(1) Processes. *Review of Economic Studies*, *57*(1), 99-125. https://doi.org/10.2307/2297545

Postula, M., & Radecka-Moroz, K. (2020). Fiscal policy instruments in environmental protection. *Environmental Impact Assessment Review*, *84*, 106435. https://doi.org/10.1016/j.eiar.2020.106435

Rafique, M.Z., Fareed, Z., Ferraz, D., Ikram, M., & Huang, S. (2022). Exploring the heterogenous impacts of environmental taxes on environmental footprints: An empirical assessment from developed economies. *Energy*, *238*. https://doi.org/10.1016/j.energy.2021.121753

Saikkonen, P. (1991). Asymptotically Efficient Estimation Of Cointegration Regressions. *Econometric Theory*, *7*(1), 1-21. https://doi.org/10.1017/S0266466600004217

Selden, T.M., & Song, D. (1994). Environmental Quality and Development: Is There a Kuznets Curve For Air Pollution Emissions?. *Journal of Environmental Economics and Management*, *27*(2), 147-162. https://doi.org/10.1006/jeem.1994.1031

Şentürk, H., Omay, T., Yildirim, J., & Köse, N. (2020). Environmental Kuznets Curve: Non-Linear Panel Regression Analysis. *Environmental Modeling and Assessment*, *25*(5), 633-651. https://doi.org/10.1007/s10666-020-09702-0

Shahbaz, M., Haouas, I., & Hoang, T.H. Van. (2019). Economic Growth And Environmental Degradation in Vietnam: Is The Environmental Kuznets Curve a Complete Picture?. *Emerging Markets Review*, *38*, 197-218. https://doi.org/10.1016/j.ememar.2018.12.006

Shahbaz, M., Lean, H.H., & Shabbir, M. (2011). Environmental Kuznets Curve and The Role Of Energy Consumption In Pakistan. *MPRA Paper No. 34929*, 1-32. Retrieved from https://mpra.ub.uni-muenchen.de/34929/ on June 20, 2023.

Soytas, U., Sari, R., & Ewing, B.T. (2007). Energy Consumption, İncome, And Carbon Emissions in the United States. *Ecological Economics*, *62*(3-4), 482-489. https://doi.org/10.1016/j.ecolecon.2006.07.009

Stern, D. (2004). The Rise and Fall of the Environmental Kuznets Curve. *World Development*, *32*(8), 1419-1439. https://doi.org/10.1016/j.worlddev.2004.03.004

Stern, D., Common, M., & Barbier, E. (1996). Economic Growth and Environmental Degradation: The Environmental Kuznets Curve and Sustainable Development. *World Development*, *24*(7), 1151-1160. https://doi.org/10.1016/0305-750X(96)00032-0

Stock, J., & Watson, M. (1993). A Simple Estimator of Cointegrating Vectors in Higher Order Integrated Systems. *Econometrica*, *61*(4), 783. https://doi.org/10.2307/2951763

Tabiloğlu, D. (2022). Effectiveness of financial policies to protect the environment in the struggle against environmental problems (Ph.D. Thesis). Sakarya University. Retrieved from https://acikerisim.sakarya.edu.tr/bitstream/handle/20.500.12619/100676/T10241.pdf?sequence=1 on August 18, 2025.

Taşdemir, F. (2022a). Development, Trade Openness and Pollution: Is There any Threshold? In H. Dinçer & S. Yüksel (Eds.), *Sustainability in Energy* (p. 8356). Springer. https://doi.org/10.1007/978-3-030-94051-5_10

Taşdemir, F. (2022b). Industrialization, Servicification, and Environmental Kuznets Curve: Non-Linear Panel Regression Analysis. *Environmental Science and Pollution Research*, *29*(5), 6389-6398. https://doi.org/10.1007/s11356-021-16012-9

Telatar, O.M., & Birinci, N. (2022). The effects of environmental tax on Ecological Footprint and Carbon dioxide emissions: a nonlinear cointegration analysis on Turkey. *Environmental Science and Pollution Research*, *29*(29), 44335-44347. https://doi.org/10.1007/s11356-022-18740-y

Tiwari, A.K. (2011). A Structural VAR Analysis of Renewable Energy Consumption, Real GDP And Co2 Emission:Evidence from İndia. *Economics Bulletin*, *31*(2), 1793-1806. Retrieved from https://www.accessecon.com/Pubs/EB/2011/Volume31/EB-11-V31-I2-P164.pdf on April 15, 2023.

Torras, M., & Boyce, J.K. (1998). Income, Inequality, And Pollution: A Reassessment Of The Environmental Kuznets Curve. *Ecological Economics*, *25*(2), 147-160. https://doi.org/10.1016/S0921-8009(97)00177-8

Usman, O., Iorember, P.T., Jelilov, G., Isik, A., Ike, G.N., & Sarkodie, S.A. (2021). Towards Mitigating Ecological Degradation in G-7 Countries: Accounting for Economic Effect Dynamics, Renewable Energy Consumption, and İnnovation. *Heliyon*, *7*, e08592. https://doi.org/10.1016/j.heliyon.2021.e08592

Villanthenkodath, M.A., Pal, S., & Ansari, M.A. (2024). Unlocking sustainable development: Evaluating the impact of monetary and fiscal policies on ecological footprint in India. *World Development Sustainability*, *5*, 100186. https://doi.org/10.1016/j.wds.2024.100186

Wang, Q., Fan, X., & Zhang, B. (2024). Who will Spend more Pollution Abatement Costs: does Size Matter?. *Environmental Management*, *73*(5), 985-1004. https://doi.org/10.1007/s00267-024-01937-x

Zahra, S., Khan, D., & Nouman, M. (2022). Fiscal policy and environment: a long-run multivariate empirical analysis of ecological footprint in Pakistan. *Environmental Science and Pollution Research*, *29*(2), 2523-2538. https://doi.org/10.1007/s11356-021-15665-w

Zhang, X.P., & Cheng, X.M. (2009). Energy Consumption, Carbon Emissions, and Economic Growth in China. *Ecological Economics*, *68*(10), 2706-2712. https://doi.org/10.1016/j.ecolecon.2009.05.011

Authors

The contribution share of authors is equal and amounted to 50% for each of them.
DT – conceptualisation, literature writing, TG – methodology, calculations, discussion.

Derya Tabiloğlu (corresponding author)

PhD in Finance (2022, Sakarya University, Turkey), Assistant Professor at the Sinop University (Turkey). Her research interests include finance and fiscal law.

Correspondence to: Dr. Derya Tabiloğlu, Boyabat Faculty of Economics and Administrative Sciences, Department of International Business and Trade, Esentepe Mah. Fakülte Cad. No:4 57000, Boyabat/SİNOP, Turkey. e-mail: dtabiloglu@sinop.edu.tr

ORCID https://orcid.org/0000-0001-5672-4970

Temel Gürdal

PhD in Finance (2001, Dokuz Eylül University, Turkey), Professor at the Sakarya University (Turkey), Her research interests include finance and fiscal law. In 2014, Gürdal was a visiting researcher at Durham University in England. He has published numerous books and articles in the areas of the Turkish tax system, tax law, public finance, and fiscal policy.

Correspondence to: Professor Temel Gürdal, Faculty of Political Sciences, Department of Public Finance, Siyasal Bilgiler Fakültesi, Esentepe Kampüsü, 54187 Serdivan/SAKARYA. e-mail: tgurdal@sakarya.edu.tr

ORCID https://orcid.org/0000-0001-6304-9766

Acknowledgements and Financial Disclosure

This paper is mainly based on Chapter 4 of my Ph.D. thesis (Tabiloğlu, 2022). The authors would like to thank the anonymous referees for their useful comments, which allowed to increase the value of this article.

Use of Artificial Intelligence

The manuscript is free of AI/GAI usage.

Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Copyright and License

Published by Krakow University of Economics – Krakow, Poland