Research Square

Preprints are preliminary reports that have not undergone peer review. They should not be considered conclusive, used to inform clinical practice, or referenced by the media as validated information.

The Effects of Environmental Tax On Ecological Footprint and Carbon Dioxide Emissions: a Nonlinear Cointegration Analysis On Turkey

Osman Murat Telatar (omtelatar@ktu.edu.tr)
Karadeniz Teknik Universitesi Iktisadi ve Idari Bilimler Fakultesi https://orcid.org/0000-0003-3016-0534
Nagihan Birinci
Karadeniz Technical University: Karadeniz Teknik Universitesi

Research Article

Keywords: Environmental degradation, environmental tax, ecological footprint, carbon dioxide emission, nonlinear unit root, nonlinear cointegration

Posted Date: December 21st, 2021

DOI: https://doi.org/10.21203/rs.3.rs-1142499/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License. Read Full License

Version of Record: A version of this preprint was published at Environmental Science and Pollution Research on February 7th, 2022. See the published version at https://doi.org/10.1007/s11356-022-18740-y.

Abstract

This article presents a nonlinear analysis in Turkey on the effect of an environmental tax (ET) on the ecological footprint (EF) and carbon dioxide (CO_2) emissions. In the literature, most of the studies examining the effects of Environmental Taxes (ETs) on Environmental Degradation (ED) have used linear methods. The number of studies examining this relationship with nonlinear methods is few. However, there is no study examining the long-run effects of ETs on the EF, which is one of the most important indicators of ED, using nonlinear analysis. This study contributes to the literature by investigating the long-run effects of ETs on EF and CO_2 emissions in Turkey by nonlinear analysis. Therefore, the model consisting of annual data for the period 1994–2019 was estimated by Dufrénot et al. (2006) nonlinear cointegration test. According to the estimation results obtained, ETs do not have any long-run effects on EF and CO_2 emissions. Accordingly, it can be concluded that ETs in Turkey do not affect preventing ED.

Introduction

Individuals and countries can't perform their economic activities without using energy to maintain economic growth and development (Vera and Sauma 2015). Especially in the 20th century, with the rapid growth of industrialization, intense population growth, and technological developments, the need for energy has increased significantly. This increasing need for energy has resulted in excessive use of natural resources and has increased the demand for fossil fuels such as oil, coal, and natural gas worldwide.

The primary causes of ED, climate change and global warming are greenhouse gas emissions from the use of non-renewable energy sources (Babatunde et al. 2017; Lin and Jia 2018). One of the most powerful greenhouse gas emissions is CO_2. However, at the global level, reducing carbon emissions, promoting a low-carbon economy, and implementing low-carbon economic activities are critical for achieving sustainable development. Therefore, ED, climate change and global warming; have become some of the most discussed topics among scientists, politicians, and business circles (Lin and Jia 2018).

In the “Global Weather 2019” report published by the American Institute of Health Effects, it was reported that air pollution ranked 5th among all health risk factors in the world. Furthermore, the intergovernmental panel on climate change advised that global warming be limited to 1.5°C, or the planet will experience catastrophic climate change by 2030. If unchecked, air pollution and climate change will increase the likelihood of severe widespread and irreversible risks to humans and ecosystems. Therefore, the need to reduce carbon emissions is urgent (Li and Peng 2020). In reality, if no meaningful emission reduction is achieved, the global atmosphere temperature may increase between 2.5°C and 7.8°C by the end of the century. More countries are joining in the cooperation agreement on climate change to reduce this great threat facing the world and accelerate the global transition to green and low-carbon sustainable development (Liu 2019).

ED has become one of the greatest threats facing humanity, affecting not just human health but also economic growth (World Bank 2016). According to the United Nations, “if immediate action is not taken, the devastating impact of climate change will be greater than the present COVID-19 pandemic.” In essence, the world is far from the target of limiting the global temperature increase to 1.5°C specified in the Paris Agreement (UN 2020). Because for energy consumption to boost economic growth; increases atmospheric CO_2 emissions, which cause climate change and global warming (Wolde-Rufael and Mulat-Weldemeske 2021).

Sustainable environmental quality is an essential part of successful sustainable economic development. Many studies have suggested that lower carbon emissions improve environmental quality. The expansion in economic activities contributes to environmental problems such as climate change and ED, as it contributes to a significant increase in greenhouse gas emissions, especially carbon emissions (Bashir et al. 2020). Carbon emission remains the main factor among greenhouse gases today, and the rise in emissions is due to the harmful use of non-renewable energies (Ghazouani et al. 2020). Because of intense industrial and economic activities, global energy consumption increased by 2.3% in 2018, resulting in a 1.7% increase in carbon emissions, from 32.5 to 33.1 gigatons. This increase poses a threat to environmental initiatives at the global level, and countries are committed to reducing their carbon emissions to preserve environmental quality (Bashir et al. 2020).

Although carbon emission was primarily used to test the Environmental Kuznets Curve hypothesis, it does not appear that the carbon emission alone can capture all environmental damage, as it is a pollutant indicator (Saleem et al. 2019). Therefore, while carbon emissions are generally acknowledged as the primary cause of environmental pollution, other indicators also affect environmental pollution. For example, the reduction of biodiversity, the destruction of forests and fertile agricultural lands, and the pollution of natural water resources. Thus, there is a need for a more comprehensive indicator than carbon emissions to represent environmental pollution (Aydın, 2020: 138). This indicator is known as EF.

Consequently, to measure the total human pressure on the natural environment, the concept of “environmental” or “ecological” footprint is used as a general term for different footprint concepts developed in the last two decades (Hoekstra and Weidmann 2014). The first study on this concept was conducted by Rees (1992). Wackernagel (1994), thus, implemented the concept and the calculation methods related to it. Wackernagel and Rees explained the relationship between EF and sustainable development in the book they published in 1996 and detailed their EF calculation methods (Wackernagel and Rees 1996). Recently, the ratio between the existing resources and the global consumption of these resources; is now expressed with the concept of EF. The EF reveals how many natural resources are consumed by an individual, city, region, state, or by people around the world to meet their needs and wants, which includes the following: food consumption, shelter, transportation, waste generated and allows to compare specific activities and their effects on the environment and natural resources (Belčáková et al. 2017).

However, compared to carbon emissions, EF; is a more comprehensive measure in terms of detecting ED because it covers the environment in all its dimensions, including multifaceted environmental indicators like settled lands, carbon emissions, cultivated lands, fishing areas, grazing lands, and forest products. Indeed, one of the most important sustainability indicators in today's world is the EF, together with the green economy (Zahra et al. 2020). The EF is an effective tool to measure the impact of human consumption on nature and the resources needed to meet human needs (Sun et al. 2020; Zahra et al. 2021). However, economic globalization has strengthened the ties between countries and has caused the EF of each country to change by exporting the pressure on the environment from the consumer country to the exporting country that supplies goods and services to this country (Sun et al. 2020).

Nevertheless, environmental problems increase the pressure on governments to reduce environmental damage without hindering economic growth (OECD 2011). Because studies on the environment show the net effect of global warming and the need for a global intervention to reduce greenhouse gases. Therefore, governments must implement strong environmental policies that limit the growing dependence on fossil fuels such as oil, natural gas, and coal; to reduce the increase in greenhouse gas emissions (Gemechu et al. 2012). Hence, governments have a range of tools such as regulations, information programs, environmental subsidies, and ETs. Among these tools, especially ETs have special significance (OECD 2011) and are included in tax legislation by many countries.

ETs are the most effective policy tool for reducing greenhouse gas emissions (Bashir et al. 2020). It aims to tax carbon emissions to increase energy efficiency, reduce environmental problems, and contribute to the protection of the environment; by internalizing negative externalities in the form of environmental pollution (Shahzad 2020; Kou et al. 2021; Bashir et al. 2021). In particular, it is potentially applied to goods that harm scarce natural resources (Rafique et al. 2021). ETs directly address market failure that causes markets to ignore environmental impacts. A well-designed ET raises the price of a good or activity to reflect the cost of environmental damage to others (OECD 2011). Accordingly, ETs refer to taxes applied to internalize environmental externalities. Because activities that cause greenhouse gas emissions, or more environmental pollution, are relatively not expensive. Individuals or firms do not consider the costs that emissions impose on others, especially future generations. A tax to be applied will force the units that cause the externality to consider all the consequences of this externality (Metcalf and Weisbach, 2013). Simultaneously, they are based on the Pigouvian tax, which is levied to burden the companies that emit external damage with the cost of the harm they cause to the society and are based on the polluter pays principle (Kou et al. 2021). According to the polluter pays principle, economic actors can strengthen pollution regulation or adopt cleaner production techniques. They can also reduce pollution emissions to internalize the external cost of pollution by analyzing cost-effectiveness (Lai et al. 2020). In addition, these taxes can contribute to the improvement of environmental quality by motivating the manufacturing sector to develop efficient technologies or producing environmentally friendly products (Jeager 2013; Elkins and Barker 2001; Rafique et al. 2021).

The European Union's (EU) official statistics evaluate ET revenues under four main groups, allowing for international comparisons. These are energy taxes, transport taxes, pollution taxes, and natural resource taxes (Eurostat 2013). From these taxes, energy taxes are collected on energy products such as coal, petroleum products, natural gas, and electricity used for both fixed and transportation purposes. Transport taxes mainly include taxes on the ownership and use of motor vehicles. Pollution and natural resource taxes, on the other hand, cover different tax types, whereas natural resource taxes are collected as the rental price of oil and mines (Eurostat 2021). Energy taxes are levied to reduce carbon emissions. The general purpose of transportation taxes is to contribute to the measures aimed at reducing carbon emissions and protecting the environment. Natural resource taxes, however, are levied to reduce environmental wastes originating from mines.

ETs in Turkey are not applied to solve environmental problems. In reality, the only tax put into practice to prevent environmental pollution and activities that will cause pollution is the Environmental Cleaning Tax. However, taxes such as Special Consumption Tax and Motor Vehicle Tax applied in Turkey have possible effects on the environment. Hence, they can be considered as an ET. Consequently, some existing taxes in Turkey that fall under the categories specified in the EU classification have an environmental character in terms of their effects. The share of ET revenues in total tax revenues is an indicator of the importance that countries attach to ETs. In terms of the share of ETs in total tax revenues, Turkey ranks high among OECD countries. However, the reason for this situation is not because of the importance Turkey gives to ETs. The primary reason is due to the structure of the Turkish tax system.

This study investigates the long-run effects of ETs on EF and CO_2 emissions in Turkey by performing non-linear time series analysis and thus, contributing to the literature. In the second part of the study, the literature section, which includes studies investigating the relationship between ETs and ED, is included. The data set, model and methodology are presented in the third section and the estimation results are evaluated in the fourth section. The final section contains the conclusions and policy recommendations.

Literature

Whether ETs are effective in preventing ED has become popular with the signing of the Kyoto protocol in the late 1990s and has begun to be studied. At the beginning of the pioneering studies on this subject in the literature, Tamura et al. (1996) is coming. According to the results of the input-output analysis carried out with the data of 1985, they determined that environmental taxes reduced CO_2 emissions in Japan. Similarly, Tamura et al. (1999) showed that carbon and energy taxes are effective in reducing CO_2 emissions, according to the results of the input-output analysis they performed with the 1990 data for Japan.

An important part of the studies investigating the effects of ET on ED consists of studies based on panel regression analysis. Lin and Li (2011) examined the effects of carbon taxes on CO_2 emissions in Denmark, Finland, the Netherlands, Norway and Sweden for the 1981-2008 period using panel regression estimation. According to the empirical findings from the study, carbon taxes do not have any effect on CO_2 in other countries except Finland. On the other hand, Morley (2012) finds that carbon taxes have reducing effects on greenhouse gas emissions by performing a panel regression estimation on 24 EU countries and Norway for the period 1995-2006. Likewise, Miller and Vela (2013) and Lai et al. (2020) observed that ETs are an effective policy tool in preventing EDs, according to their panel regression analysis results for fifty countries and China, respectively. There are also studies examining the long-run relationship between ET and ED with the panel cointegration method. For example, Sasmaz (2016), who examined the effects of ET on CO_2 emissions in EU-15 countries with the 1995-2012 data using panel cointegration test and fully modified ordinary least squares (FMOLS) estimation, found that the variables were cointegrated and ETs had a negative effect on CO_2. Bashir (2020) and Rafique et al. (2021) also examined it with the help of the panel cointegration test for 29 OECD countries. According to the results of both studies, it was determined that the variables were cointegrated and that ETs had a reducing effect on CO_2 emissions and EF. Topal (2017), on the other hand, examined the same relationship in 34 OECD countries for the period 1994-2013 and found that the negative relationship between ET and CO_2 emissions was valid only in 20 countries. On the other hand, Tekin and Sasmaz (2016) stated that ETs do not have any effect on CO_2 emissions in EU-25 over the period of 1995-2012.

Some other studies have examined the effects of ETs on ED with the help of general equilibrium model estimation. For example, Meng et al. (2013) determined that carbon taxes are effective in reducing CO_2 emissions, according to the results of the general equilibrium model they estimated for Australia with 2011 data. Lin and Jia (2011) and Niu et al. (2018) also examined the relationship between ET and CO_2 emissions for China with the help of general equilibrium model estimation. According to the empirical results obtained from both studies, ETs have a reducing effect on CO_2 emissions.

In the literature, the number of studies examining the relationship between ET and ED with the help of time series analysis is very few. Among these studies, Sarıgül and Topçu (2021) analyzed the relationship between ET and CO_2 emissions in Turkey with annual data for the period of 1994-2015. According to the FMOLS and dynamic ordinary least squares (DOLS) estimation results, ETs had a reducing effect on CO_2 emission was determined. Esen and Dundar (2021) were used the same methods for Turkey and found that energy taxes have a reducing effect on CO_2 emissions. Akkaya and Hepsag (2021), unlike Sarıgül and Topçu (2021) and Esen and Dündar (2021), examined the subject with nonlinear time series analysis. According to the empirical results obtained from the study, there is no relationship between fuel tax and CO_2 emissions in Turkey. Another study based on nonlinear analysis Ulucal et al. (2020) examined the effects of ETs on CO_2 emissions in Brazil, China, India, and South Africa by using nonlinear smooth transition regression estimation over the period of 1994-2015. They found that there is a positive relationship between ET and CO_2 emissions in the lower regime of globalization, and a negative relationship between the variables in the higher regime of globalization. Wolde-Rufael and Mulat-Weldemeskel (2021) examined the effects of environmental and energy taxes on CO_2 emissions in 9 countries with a panel augmented mean group estimation. According to the linear model estimation results obtained from the empirical analysis, environmental and energy taxes do not have any effect on CO_2. On the other hand, the nonlinear model estimation results reveal that both taxes are effective in reducing CO_2 emissions. The literature table containing the empirical studies on the subject is presented in Table 1.

Table 1 Empirical literature on environmental degradation and environmental tax

Author	Country	Sample	Method	Findings
Tamura et al. (1996)	Japan	1985	-input-output analysis	• carbon tax → CO_2 (-)
Tamura et al. (1999)	Japan	1990	-input-output analysis	• carbon tax → CO_2 (-) energy tax → CO_2 (-)
Lin and Li (2011)	Denmark, Finland, Netherlands, Norway, Sweden	1981-2008	-panel regression estimation	• carbon tax → CO_2 (-) /(only for Finland)
Morley (2012)	24 EU countries and Norway	1995-2006	-panel regression estimation	• carbon tax → greenhouse gas emission (-)
Meng et. al (2013)	Australia	2011	- computable general equilibrium (CGE) model estimation	• carbon tax → carbon emissions (-)
Miller and Vela (2013)	50 countries	1995-2008	-panel regression estimation	• ET → CO_2 (-)
Sasmaz (2016)	EU-15 countries	1995-2012	-panel cointegration test -panel FMOLS	• cointegrated • ET → CO_2 (-)
Tekin and Sasmaz (2016)	EU-25 countries	1995-2012	-panel cointegration test -panel FMOLS -panel causality test	• cointegrated • ET CO_2 (-) • ET CO_2 /causality
Topal (2017)	34 OECD countries	1994-2013	-panel cointegration test -panel FMOLS -panel causality test	• cointegrated • ET → CO_2 (-)/(for 20 countries) • ET → CO_2 /causality
Lin and Jia (2018)	China	2010	- CGE model estimation	• carbon tax → CO2 (-)
Niu et al. (2018)	China	-	-dynamic stochastic general equilibrium	• ET → CO_2

			(DSGE) model	variance decomposition impulse-response functions
Aydın (2020)	11 OECD countries	1995-2016	-fourier causality test	• ET → EF/Germany, Sweden, Denmark • EF → ET/France, Spain • ET EF/ Belgium, Netherlands, UK, Italy, Norway, Portugal
Bashir (2020)	29 OECD countries	1995-2015	-panel cointegration test -panel regression estimation -panel causality test	• cointegrated • ET → CO_2 (-) /regression • ET CO_2/causality
Sun et al. (2020)	China	2015	-dynamic CGE model estimation	• energy tax → EF(-)
Lai et al. (2020)	China	2005-2015	-panel regression estimation	• resource tax → pollution(-) • excise tax pollution
Ulucal et al. (2020)	Brazil, China, India, South Africa	1994-2015	-nonlinear panel regression estimation (smooth transition regression)	• ET → CO_2 (+) /lower regime of globalization • ET → CO_2 (-) /higher regime of globalization
Akkaya and Hepsag (2021)	Turkey	1985-2018	-nonlinear cointegration test -nonlinear causality test	• no cointegration • Fuel tax CO_2 /causality
Esen and Dündar (2021)	Turkey	1994-2017	-johansen cointegration test -FMOLS	• cointegrated • energy tax → carbon emission

			-DOLS	(-) /FMOLS, DOLS
Rafique et al. (2021)	29 OECD countries	1994-2016	-panel cointegration test -panel autoregressive distributed lag (ARDL) model estimation -panel causality test	• cointegrated • ET → EF (-)/long and short run • ET EF/causality
Sarıgül and Topçu (2021)	Turkey	1994-2015	-johansen cointegration test -FMOLS -DOLS	• cointegrated • ET → CO_2 (-) /FMOLS, DOLS
Wolde-Rufael and Mulat-Weldemeskel (2021)	9 countries (Czech Republic, Greece, Hungary, Korea, Poland, South Africa, and Turkey)	1994-2015	-panel augmented mean group (AMG) estimation -panel Granger causality test	• for linear model ET CO_2 energy tax → CO_2 (-) • for nonlinear model ET → CO_2 (-) energy tax → CO_2 (-) • ET CO_2 /causality energy tax CO_2 /causality

As can be seen in Table 1, CO_2 emissions have been used as an indicator of ED in a significant part of the studies in the literature. On the other hand, the number of studies using the EF, which is a more comprehensive indicator of ED, is very few. However, almost all of the studies on the subject are based on the estimation of linear models. The number of studies conducted with nonlinear estimation methods is rare. Moreover, there is no study examining the effects of ETs on EF using nonlinear methods. Therefore, in this study, it is aimed to contribute to the literature by investigating the effect of ETs on CO_2 emissions and EF with nonlinear time series analysis.

Data, Model And Methodology

Data description and model specification

The long-run effects of the ET variable on the EF and CO_2 emission were investigated using time series analysis in this study. For this purpose, ET was used as an independent variable, and EF and CO_2 variables were used as dependent variables. The sample range covers the period 1994–2017 for Model (1) and 1994–2019 for Model (2). The reason why the sample period started in 1994 is that the ET variable started in 1994 for Turkey, and why it ended in 2017 and 2019 because the carbon footprint and CO_2 emission variables have data until 2017 and 2019, respectively. The models estimated in the analysis are as follows.

$EF_t = \alpha_0 + \alpha_1 ET_t + u_{1t}$ (1)

$CO_{2t} = \beta_0 + \beta_1 ET_t + u_{2t}$ (2)

With the help of Model (1), the effect of ET on the EF, and with the help of Model (2), the effect of the ET on CO_2 emissions was investigated. The variables used in the above models and the databases from which they were provided are shown in detail in Table 2.

Table 2
Variables used in the analysis and databases

Variable	Definition	Database
ET	Environmental Tax (as a percentage of GDP)	OECD
EF	Ecological Footprint (gha per person)	Global Footprint Network
CO_2	carbon dioxide emission (in logarithmic form)	OECD

Estimation methods

The number of studies on this subject in the literature is high and most of the studies are based on linear model estimation. Similarly, linear model analysis was used for studies conducted in Turkey. Macroeconomic variables can follow nonlinear processes due to different reasons such as data generation processes, changing sub-items, or changing base years (Telatar 2016). Therefore, it contributed to the literature by examining the effects of ET on EF, and CO_2 emissions with nonlinear time series analysis in this study.

Nonlinear unit root analysis

In a significant number of studies in the literature, unit root tests are conducted based on the linear approach. Although linear unit root tests are widely used, the criticisms of these tests are increasing. For example, Phillips (1987) and Kwiatkowski et al. (1992) in small samples, Gweke and Porter-Hudak (1983) and Robinson (1994) in the case of fractional cointegration, Bierens (1997) and Kapetanios et al. (2003) in the presence of nonlinear structure argue that the Augmented Dickey-Fuller (ADF) unit root test does not yield effective results. In addition, since an incorrect specification in deterministic components may affect the validity of the relevant test, criticisms are increasing against the classical unit root hypotheses that do not consider the possibility of non-linearity in deterministic components (Liu and He 2010).

Alternative approaches is been developed to determine whether the variables contain a unit root or not, after the increase in criticism toward linear unit root tests. Studies in this direction in the literature are conducted in two different ways. The first is to use the panel data set to increase the power of standard unit root tests, while the other is the use of fractional cointegration or nonlinear forms of time series models. Studies such as Balke and Fomby (1997), Enders and Granger (1998), Berben and van Dijk (1999), Caner and Hansen (2001), Lo and Zivot (2001), and Kapetanios and Shin (2006), examined the relationship between cointegration and nonlinearity by examining the interactions, they discussed the unit root analysis within the framework of the nonlinear model. (Kapetanios et al. 2003).

Similarly, Kapetanios, et al. (2003) developed a new approach that considers the nonlinear structure in unit root testing, unlike classical unit root tests. According to this test, which is called the KSS test (Kapetanios, Shin and Shell) in the literature, the null hypothesis asserts that there is the unit root, while the alternative hypothesis expresses a nonlinear exponential smooth transition autoregressive model process, unlike ADF (Bahmani-Oskooee and Gelan 2006). The model to be estimated in the KSS test can be shown as follows (Kapetanios et al. 2003):

$$\Delta y_t = \delta y_{t-1}^3 + \sum_{k=1}^{n} \rho_k \Delta y_{t-1} + \varepsilon_t \quad (3)$$

In the above equation, y_t is the variable analyzed for the unit root and n is the optimal lag length that has no autocorrelation problem. The null and alternative hypotheses belonging to Equation (3) are as follows:

H_0: $\delta = 0$

H_1: $\delta > 0$

The t-statistic (t_{NL}), which will be obtained from the δ parameter because of the estimation of equation (3), allows testing the null and alternative hypotheses. The t_{NL} statistic is calculated according to the following equation:

$$t_{NL} = \hat{\delta} / s.e(\hat{\delta}) \quad (4)$$

In the above equation, $\hat{\delta}$ is the ordinary least squares (OLS) estimation result of δ, and s.e. represents the standard error. The t_{NL} statistic compares with the critical table values prepared by KSS (2003) since it does not have an asymptotic normal distribution. Accordingly, if the calculated t_{NL} statistic is less than the critical table value, the null hypothesis cannot be rejected. Here, it is decided that the relevant series contains a unit root and has a linear process. If the calculated t_{NL} statistic is greater than the critical table value, the null hypothesis is rejected. Thus, it is decided that the series is stationary but follows a nonlinear process.

Nonlinear cointegration test

Dufrénot et al. (2006) cointegration test refer to the nonlinear form of Engle and Granger's (1987) cointegration test. Engle and Granger's (1987) cointegration test consists of two stages. In the first stage, the model in which the long-run relationship is investigated is estimated by the OLS method. In the second stage, the residues obtained from the OLS estimation are subjected to unit root testing. Dufrénot et al. (2006) performed the nonlinear version of the Engle and Granger (1987) test by performing a nonlinear unit root test on the residues in this second stage.

The logistic STAR (LSTAR) cointegration model used in this study can be expressed as follows (Dufrénot et al. 2006):

$$\Delta z_t = \phi_0^1 z_{t-1} + \phi_1^1 z_{t-1} x_{t-d} + \phi_3^1 z_{t-1} x_{t-d}^3 + \omega_t^1 \quad (5)$$

In the above equation, z_t is residuals from the first stage of the cointegration test, x_t is the independent variable. $z_{t-1}x_{t-d}$ indicates the interaction term and the subscript d represents the optimum lag length with a minimum AIC value that does not contain autocorrelation problems. The null hypothesis to investigate the existence of cointegration is as follows:

$$H_0 : \phi_1^1 = \phi_3^1 = 0$$

Empirical Results

KSS unit root test was applied on the variables based on the possibility that the series used in this study can follow a nonlinear stationary process. The results of this non-linear unit root test are given in Table 3.

Table 3
The results of nonlinear unit root test

Variable	t_{NL}	Prob.		
		0.01	0.05	0.10
ET	-2.998(0)	-2.82	-2.22	-1.92
	-2.452(0)			
EF	-0.552(0)			
CO_2	-1.562(0)			

Notes: The values in parentheses indicate the optimum lag length determined according to AIC. Probability level values were obtained from Kapetanios et al., (2003) Table 1.

As shown in Table 3, the null hypothesis wasn't rejected because the test statistics of the EF and CO_2 series were smaller than the table critical values. However, the null hypothesis was rejected because the test statistic of the ET series was greater than the table critical values. Accordingly, while the EF and CO_2 series contain unit roots and follow a linear process [I(1)], the ET series are stationary and follow a nonlinear [I(0)] process. As a result, especially since the ET series has a non-linear process, analyzing the model in which ET takes place with linear methods may cause false estimation results. Thus, the existence of cointegration between the variables was investigated with the help of a nonlinear cointegration test.

Dufrénot et al. (2006) nonlinear cointegration test results are shown in Table 4.

Table 4
The results of Dufrénot et al. (2006) cointegration test

Model	d	ϕ_{0*}^{1}	Prob.	Decision
ET=f(EF)	1	-3.758	0.144	H_0 can not be rejected (not cointegrated)
ET=f(CO_2)	1	-0.890	0.251	H_0 can not be rejected (not cointegrated)

Note: * is the coefficient of error term lag in equation 5 and d indicates the optimum lag length in the interaction term.

As shown in Table 4, in cointegration models where ET is the dependent EF and CO_2 are the independent variables, the coefficients of the error term lag are statistically insignificant and the null hypothesis, which indicates that the variables are not cointegrated cannot be rejected. Therefore, the variables are not cointegrated. In other words, ETs do not move together with the variables of EF and CO_2 emission eventually. Accordingly, there is no long-run relationship from both the EF and the CO_2 emission variables to the ET variable.

Concluding Remarks

With the acceleration of industrialization, dense population growth, and technological developments, the need for energy, which is an indispensable element of human life, has also increased. Increasing energy demand has led to excessive use of natural resources and has increased the demand for fossil fuels such as oil, natural gas, and coal worldwide. Because of the increase in the use of fossil fuels, which are harmful to the environment, the number of greenhouse gases emitted to the atmosphere, especially CO_2, has increased. CO_2 emissions are accepted as the main cause of environmental pollution. However, other factors are affecting environmental pollution, such as the reduction of biological diversity, the destruction of forests and fertile agricultural areas, and the pollution of natural water resources. For this reason, a more comprehensive indicator than CO_2 emissions is needed to fully express and draw the framework of environmental pollution. This indicator is described as the EF and it is argued that the EF variable better represents environmental pollution compared to CO_2 emissions.

Therefore, environmental pollution is one of the negative externalities that prevents the efficient distribution of scarce resources and the realization of economic activities. One of the main objectives of the global world order is to be able to combat environmental pollution at a global level and to improve the quality of the environment, thus protecting the environment and reducing the factors that cause damage to the environment. ETs are at the forefront of the financial instruments that will serve this purpose. Consequently, ETs mainly aims to prevent or reduce environmental pollution. In Turkey, ETs do not find an application area for the solution of environmental problems. However, some existing taxes that fit into the aforementioned categories have an environmental character in terms of their impact.

This study investigates the long-run effects of ETs on the EF and CO_2 emissions from the 1994–2019 period in Turkey by using nonlinear time series analysis. Due to the unit root analysis, it was determined that the ET variable followed a nonlinear process. However, due to the cointegration test applied, it was determined that the variables were not cointegrated. In other words, ETs do not have any long-run effects on the EF and CO_2 emissions in Turkey. Therefore, the ET policy implemented in Turkey has no contribution to preventing or reducing ED. ETs in Turkey are not effective in preventing ED since they are allocated to increase public revenues rather than environmental purposes. This result also reveals that the ET policy that Turkey has followed is not effective. Thus, the “Law on Approval of the Paris Agreement” by the Turkish Grand National Assembly entered into force by being published in the Official Gazette on October 7, 2021, and numbered 31621. According to Turkey's national contribution statement, it is foreseen that greenhouse gas emissions will be reduced by 21% in 2030 compared to the reference scenario. Therefore, Turkey's re-evaluation of its ET policy, if made more effective; will contribute significantly to achieving its greenhouse gas emission reduction target.

Declarations

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Availability of data and materials

The datasets generated and/or analyzed during the current study are available in the [Organisation for Economic Co-operation and Development, Global Footprint Network] repository [https://data.oecd.org/https://www.footprintnetwork.org/]

Competing interest

The authors declare no competing interests

Funding

The authors declare that they have no funding

Authors' contribution

OMT: analyzed and interpreted the literature and performed the empirical models.

NB: determined the subject of study and interpreted introduction section.

All authors have contributed to the conclusion remarks section and read and approved the final manuscript.

Acknowledgements

Not applicable

References

1. Akkaya Ş, Hepsag, A (2021) Does fuel tax decrease carbon dioxide emissions in Turkey? evidence from an asymmetric nonlinear cointegration test and error correction model. Environmental Science and Pollution Research 28:35094–35101. https://doi.org/10.1007/s11356-021-12907-9
2. Aydın M (2020) Seçilmiş OECD ülkelerinde çevre vergilerinin çevre kirliliği üzerine etkileri: yapısal kırılmalı nedensellik testinden kanıtlar. Uluslararası İktisadi ve İdari İncelemeler Dergisi 28:137-154. https://doi.org/10.18092/ulikidince.704936

3. Babatunde KA, Begum RA, Said FF (2017) Application of computable general equilibrium (CGE) to climate change mitigation policy: a systematic review. Renewable and Sustainable Energy Reviews 78:61-71. https://doi.org/10.1016/j.rser.2017.04.064
4. Bahmani-Oskooee M, Gelan A (2006) Testing the PPP in the non-linear STAR framework: evidence from Africa. Economics Bulletin 6(17):1-15
5. Balke NS, Fomby TB (1997) Threshold cointegration. International Economic Review 38:627–645. https://doi.org/10.2307/2527284
6. Bashir MF, MA B, Shahbaz M, Jiao Z (2020) The nexus between environmental tax and carbon emissions with the roles of environmental technology and financial development. Plos One 15(11):1-20. https://doi.org/10.1371/journal.pone.0242412
7. Bashir MF, MA B, Komal B, Bashir MA (2021) Analysis of environmental taxes publications: a bibliometric and systematic literature review. Environmental Science and Pollution Research 28:20700-20716. https://doi.org/10.1007/s11356-020-12123-x
8. Belčáková I, Diviaková A, Belaňová E (2017) Ecological footprint in relation to climate change strategy in cities. IOP Conf. Series: Materials Science and Engineering 245. https://doi.org/10.1088/1757-899X/245/6/062021
9. Berben R, van Dijk D (1999) Unit root tests and asymmetric adjustment: a reassessment. Unpublished manuscript. Tinbergen Institute, Erasmus University of Rotterdam
10. Bierens H J (1997) Testing the unit root with drift hypothesis against nonlinear trend stationarity, with an application to the U.S. price level and interest rate. Journal of Econometrics 81:29-64. https://doi.org/10.1016/S0304-4076(97)00033-X
11. Caner M, Hansen BE (2001) Threshold autoregression with a near unit root. Econometrica, 69:1555–1596. https://www.jstor.org/stable/2692267. Accessed 10 July 2021
12. Dufrénot G, Mathieu L, Mignon V, Péguin-Feissolle A (2006) Persistent misalignments of the European exchange rates: some evidence from nonlinear cointegration. Applied Economics 38:203-229. https://doi.org/10.1080/00036840500390262
13. Elkins P, Barker T (2001) Carbon taxes and carbon emissions trading. Journal of Economic Surveys 15(3):325-376.
14. Enders W, Granger CWJ (1998) Unit root tests and asymmetric adjustment with an example using the term structure of interest rates. Journal of Business and Economics Statistics 16:304–311. https://doi.org/10.2307/1392506
15. Engle RF, Granger CWJ (1987) Co-integration and error correction: representation, estimation, and testing. Econometrica 55(2):251-276. https://doi.org/10.2307/1913236
16. Esen Ö, Dündar M (2021) Do energy taxes reduce the carbon footprint? evidence from Turkey. Journal of Emerging Economies and Policy 6(2):179-186
17. Eurostat (2013) Environmental taxes: A statistical guide. https://ec.europa.eu/eurostat/documents/3859598/5936129/KS-GQ-13-005-EN.PDF.pdf/706eda9f-93a8-44ab-900c-ba8c2557ddb0?t=1414782946000. Accessed 15 May 2021

18. Eurostat (2021) Environmental tax statistics-detailed analysis. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Environmental_tax_statistics_-_detailed_analysis. Accessed 23 July 2021
19. Gemechu ED, Butnar I, Llop M, Castells F (2012) Environmental tax on products and services based on their carbon footprint: a case study for the pulp and paper sector. Elsevier. Energy Policy 50:336-344. https://doi.org/10.1016/j.enpol.2012.07.028
20. Geweke J, Porter-Hudak S (1983) The estimation and application of long memory time series models. Journal of Time Series Analysis 4:221-238. https://doi.org/10.1111/j.1467-9892.1983.tb00371.x
21. Ghazouani A, Xia W, Jebli MB Shahzad U (2020) Exploring the role of carbon taxation policies on CO_2 emissions: contextual evidence from tax implementation and non-implementation European countries. Sustainability 12(20). https://doi.org/10.3390/su12208680
22. Global Footprint Network (2021) Ecological Footprint vs Biocapacity. https://data.footprintnetwork.org/?_ga=2.48164071.1548574759.16345755101323550536.1634575510#/countryTrends?cn=223&type=BCpc,EFCpc. Accessed 10 May 2021
23. Hoekstra AY, Wiedmann TO (2014) Humanity's Unsustainable Environmental Footprint. Science 344(6188):1114-1117. https://doi.org/10.1126/science.1248365
24. Jaeger WK (2013) Double dividend. Encyclopedia of Energy, Natural Resource, and Environmental Economics 1:37-40. https://doi.org/10.1016/B978-0-12-375067-9.00073-5
25. Kapetanios G, Shin Y (2006) Unit root tests in three-regime SETAR models. The Econometrics Journal 9(2):252-278. https://doi.org/10.1111/j.1368-423X.2006.00184.x
26. Kapetanios G, Shin Y, Snell A (2003) Testing for a unit root in the nonlinear STAR framework. Journal of Econometrics 112:359-379. https://doi.org/10.1016/S0304-4076(02)00202-6
27. Kou P, Han Y, Li Y (2021) An evolutionary analysis of corruption in the process of collecting environmental tax in China. Environmental Science and Pollution Research 28: 54852-54862. https://doi.org/10.1007/s11356-021-13104-4.
28. Kwiatkowski D, Phillips PCB, Schmidt P, Shin Y (1992) Testing the null hypothesis of stationarity against the alternative of a unit root. Journal of Econometrics 54:159-178
29. Lai X, Liu Z, Luo S (2020) Assessment on the effectiveness of environmental regulation in China-evidence from a panel data analysis. Environmental Science and Pollution Research 27:37363-37376. https://doi.org/10.1007/s11356-020-08583-w
30. Li H, Peng W (2020) Carbon tax, subsidy, and emission reduction: analysis based on DSGE model. Hindawi. Complexity. https://doi.org/10.1155/2020/6683482.
31. Lin B, Jia Z (2018) The energy, environmental and economic impacts of carbon tax rate and taxation industry: a CGE based study in China. Energy 159:558-568. https://doi.org/10.1016/j.energy.2018.06.167

32. Lin B, Li X (2011) The effect of carbon tax on per capita CO2 emissions. Energy Policy 39:5137–5146. https://doi.org/10.1016/j.enpol.2011.05.050
33. Liu C, He LY (2010). KSS unit root test of nonlinearity an nonstationarity in China's agricultural future markets. Physics Procedia 3:1753-1756. https://doi.org/10.1016/j.phpro.2010.07.015
34. Liu M (2019) The impact of environmental taxon low-carbon transition. International Journal of Business and Social Science 10(1):95-105. https://doi.org/10.30845/ijbss.v10n1p12
35. Lo MC, Zivot E (2001) Threshold cointegration and nonlinear adjustment to the law of one price. Macroeconomic Dynamics 5:533–576. https://doi.org/10.1017.S1365100500000456
36. Meng S, Siriwardana M, McNeill J (2013) The environmental and economic impact of the carbon tax in Australia. Environ Resource Econ 54:313–332. https://doi.org/10.1007/s10640-012-9600-4
37. Metcalf GE, Weisbach D (2013) Carbon taxes. Encyclopedia of Energy, Natural Resource and Environmental Economics 1:9-14. https://doi.org/10.1016/B978-0-12-375067-9.00126-1
38. Miller SJ, Vela MA (2013) Are environmentally related taxes effective? Inter-American Development Bank Working Paper Series No. IDB-WP-467:1-23
39. Morley B (2012) Empirical evidence on the effectiveness of environmental taxes. Applied Economics Letters 19:1817–1820. https://doi.org/10.1080/13504851.2011.650324
40. Niu T, Yao X, Shao S, Li D, Wang W (2018) Environmental tax shocks and carbon emissions: an estimated DSGE model. Structural Change and Economic Dynamics 47:9–17. https://doi.org/10.1016/j.strueco.2018.06.005
41. OECD (2011) Environmental taxation: a guide for policy makers. https://www.oecd.org/env/toolsevaluation/48164926.pdf. Accessed 14 September 2021
42. OECD (2021) Environmental tax. https://data.oecd.org/envpolicy/environmental-tax.htm. Accessed 10 May 2021
43. Phillips PCB (1987) Time series regression with a unit root. Econometrica 55(2):277-301. https://doi.org/10.2307/1913237
44. Rafique MZ, Fareed Z, Ferraz D, Ikram M (2021) 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
45. Rees WE (1992) Ecological footprints and appropriated carrying capacity: What urban economics leaves out. Environment and Urbanization 4(2):121-130. https://doi.org/10.1177/095624789200400212
46. Robinson PM (1994) Efficient Tests of Nonstationary Hypotheses. Journal of the American Statistical Association 89(428):1420-1437. https://doi.org/10.2307/2291004
47. Saleem N, Shujah-ur, Jun Z (2019) The impact of human capital and biocapacity on environment: Environmental quality measure through ecological footprint and greenhouse gases. Journal of Pollution Effects & Control 7(2). https://doi.org/10.35248/2375-4397.19.7.237

48. Sarıgül SS, Topçu AB (2021) The impact of environmental taxes on carbon dioxide emissions in Turkey. International Journal of Business & Economic Studies 3(1):43-54.
49. Sasmaz, M. U. (2016). Validity of double dividend hypothesis in EU-15 countries. Global Journal on Humanites & Social Sciences [Online] 04:30-36. http://sproc.org/ojs/index.php/pntsbs. Accessed 14 September 2021
50. Shahzad U (2020) Environmental taxes, energy consumption, and environmental quality: theoretical survey with policy implications. Environmental Science and Pollution Research 27:24848-24862. https://doi.org/10.1007/s11356-020-08349-4
51. Sun Y, Mao X, Liu G, Yin X, Zhao Y (2020) Modelling the effects of energy taxes on ecological footprints transfers in China's foreign trade. Ecological Modelling 431. https://doi.org/10.1016/j.ecolmodel.2020.109200
52. Tamura H, Nakanishi R, Hatono I, Umano M (1996) Is environmental tax effective for total emission control of carbon dioxide? systems analysis of an environmental-economic model. IFAC Proceedings Volumes 29(1):5435-5440. https://doi.org/10.1016/S1474-6670(17)58546-8
53. Tamura H, Hotehama M, Tomiyarna S, Hatono I (1999) On environmental tax for total emission control of carbon dioxide. IFAC Proceedings Volumes 32(2):5782-5787. https://doi.org/10.1016/S1474-6670(17)56987-6
54. Tekin A, Şaşmaz MÜ (2016) Küreselleşme sürecinde ekolojik riskleri azaltmada çevresel vergilerin etkisi: Avrupa Birliği örneği. Yönetim ve Ekonomi 23(1):1-17. https://doi.org/10.18657/yecbu.20984
55. Telatar, O. M. (2016). The effects of foreign portfolio investments on Turkish economic growth: a nonlinear approach. 18th International Scientific Conference on Economic and Social Development-Building Resilient Society. Zagreb, Croatia. 9-10 December: 616-622.
56. Topal MH (2017) Çifte kazanç hipotezinin OECD ekonomileri için testi: panel eşbütünleşme ve nedensellik analizi. The Journal of International Scientific Researches 2(4):1-20. https://doi.org/10.23834/isrjournal.284627
57. UN (2020) The sustainability development goals report 2020. https://unstats.un.org/sdgs/report/2020/. Accessed 27 September 2021
58. Ulucak R, Danish, Kassouri Y (2020) An assessment of the environmental sustainability corridor: Investigating the non-linear effects of environmental taxation on CO2 emissions. Sustainable Development 28:1010–1018. https://doi.org/10.1002/sd.2057
59. Vera S, Sauma E (2015) Does a carbon tax make sense in countries with still a high potential for energy efficiency? comparison between the reducing-emissions effects of carbon tax and energy efficiency measures in the Chilean case. Energy 88:478-488. https://doi.org/10.1016/j.energy.2015.05.067
60. Wackernagel M (1994) Ecological footprint and appropriated carrying capacity: a tool for planning toward sustainability. Dissertation, University of British Columbia
61. Wackernagel M, Rees WE (1996) Our ecological footprint: reducing human impact in the earth. New Society Publishers. https://doi.org/10.5070/G31710273

62. Wolde-Rufael Y, Mulat-Weldemeskel E (2021) Do environmental taxes and environmental stringency policies reduce CO_2 emissions? evidence from 7 emerging economies. Environmental Science and Pollution Research 28:22392-22408. https://doi.org/10.1007/s11356-020-11475-8
63. World Bank (2016) The cost of air pollution-strengthening the economic case for action. The World Bank and Institute for Health Metrics and Evaluation. University of Washington, Seattle. https://openknowledge.worldbank.org/bitstream/handle/10986/25013/108141.pdf?sequence=4&isAllowed=y. Accessed 27 September 2021
64. Zahra S, Khan D, Nouman M (2021) Fiscal policy and environment: a long-run multivariate empirical analysis of ecological footprint in Pakistan. Environmental Science and Pollution Research. https://doi.org/10.1007/s11356-021-15665-w.