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The Impact of Tax Policies on the Environment as a Global Public Good: Co-integration Test Results

Vergi Politikalarının Küresel Bir Kamu Malı Olan Çevre Üzerindeki Etkisi: Eş-bütünleşme Testi Sonuçları

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Abstract

Tax policies play a significant role in achieving environmental protection and sustainable development goals. Environmentally sensitive taxation methods are implemented to reduce negative impacts on the environment. Such taxation policies contribute to the conservation of natural resources and increase environmental awareness and responsibility. This article aims to identify the long-term effects of environmental taxes, urban population growth, and renewable energy consumption on the ecological footprint in Türkiye, given the importance of the subject. Therefore, in this study, the ecological footprint, which is the most important indicator of environmental degradation, was used as the dependent variable, while environmental tax, urban population growth rate, and renewable energy were used as independent variables. The stationarity of the variables in the analysis was tested with the ADF and PP unit root tests, and whether the variables were related in the long term was investigated with the Johansen cointegration test. According to the long-term FMOLS, DOLS, and CCR estimation results obtained after determining the cointegration relationship, a negative relationship was found between the ecological footprint variable and environmental taxes and renewable energy, while a positive relationship was found between the ecological footprint and urban population growth. These findings indicate that environmental taxes and the use of renewable energy are effective in reducing the ecological footprint, while urban population growth may disrupt ecological balance. Therefore, the effectiveness of environmental policies should be increased, and strategies related to urban population growth should be developed.

Keywords: *Sustainable Environment, Tax Policies, Ecological Footprint, Cointegration Test*

JEL Classification: *H23, K32, C01*

Öz

Vergi politikaları, çevreyi koruma ve sürdürülebilir kalkınma hedeflerine ulaşmada önemli bir rol oynamaktadır. Çevre üzerindeki olumsuz etkileri azaltmak için çevreye duyarlı vergilendirme yöntemleri uygulanmaktadır. Bu tür vergilendirme politikaları, hem doğal kaynakların korunmasına katkı sağlamakta hem de çevresel bilinç ve sorumluluğu artırmaktadır. Bu makale kapsamında konunun önemine binaen Türkiye'de çevre vergileri, kentsel nüfus artışı ve yenilenebilir enerji tüketiminin ekolojik ayak izi üzerindeki uzun dönemli etkisi tespit edilmeye çalışılmıştır. Bu sebeple çalışmada çevresel tahribatların en önemli göstergesi olan ekolojik ayak izi bağımlı değişken olarak, çevre vergisi, kentsel nüfus artış oranı ve yenilenebilir enerji ise bağımsız değişken olarak kullanılmıştır. Çalışmanın analizinde değişkenlerin durağanlığı ADF ve PP birim kök testleriyle sınanmış, değişkenlerin uzun dönemde ilişkiye sahip olup olmadığı ise Johansen eşbütünleşme testiyle araştırılmıştır. Eşbütünleşme ilişkisinin tespiti sonrasında gerçekleştirilen uzun dönem FMOLS, DOLS ve CCR tahmin sonuçlarına göre, ekolojik ayak izi değişkeniyle çevre vergileri ve yenilenebilir enerji arasında negatif bir ilişki, ekolojik ayak izi ile kentsel nüfus artışı arasında ise pozitif bir ilişki bulunmuştur. Bu bulgular, çevre vergilerinin ve yenilenebilir enerji kullanımının ekolojik ayak izini azaltmada etkili olduğunu gösterirken, kentsel nüfus artışının ekolojik dengeyi bozabileceğine işaret etmektedir. Bu nedenle, çevre politikalarının etkinliği artırılmalı ve kentsel nüfus artışıyla ilgili stratejiler geliştirilmelidir.

Anahtar Kelimeler: *Sürdürülebilir Çevre, Vergi Politikaları, Ekolojik Ayak İzi, Eş-bütünleşme Testi*

JEL Sınıflandırması: *H23, K32, C01*

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1. Introduction

Today, many policy proposals continue to be presented within the scope of combating climate change. Here, it is essential first to identify the components that pollute the environment and take measures accordingly. In Türkiye, as in the whole world, radioactive pollution is a factor that causes environmental destruction. Apart from these, other factors cause environmental destruction (air, water, soil, noise pollution, and solid waste) (Fisunoğlu, 1985). As a matter of fact, since all these situations also have an economic dimension, there is a need for both international and national environmental reforms and policy proposals in this regard.

Policy proposals in the finance literature cover a wide range of topics, from reducing greenhouse gas emissions to promoting renewable energy sources, from increasing energy efficiency to implementing regulatory measures such as carbon tax. In this context, the use of financial instruments has become a critical issue that is intensively discussed in academic circles in order to increase the effectiveness of climate change policies. Fiscal instruments include various financial instruments such as carbon trading systems, subsidies, tax incentives, and green bonds, and the effective use of these instruments plays a critical role in achieving sustainable development goals.

From a different perspective, the idea of "Ecological Tax Reform" has effectively increased the importance of environmental taxes. The "Ecological Tax Reform," which envisages the widespread use of fiscal instruments within the environmental policy framework, has two main pillars. One of the main pillars of this reform is reducing state aid for economic activities that cause environmental damage. The other pillar is to shift the tax burden on labor, capital, and commercial activities to environmentally harmful economic activities. The Ecological Tax Reform aims to penalize environmentally harmful economic activities by reducing fiscal aid to these activities or introducing new taxes while relatively reducing the tax burden on labor, capital, and commercial activities (Ferhatoğlu, 2003).

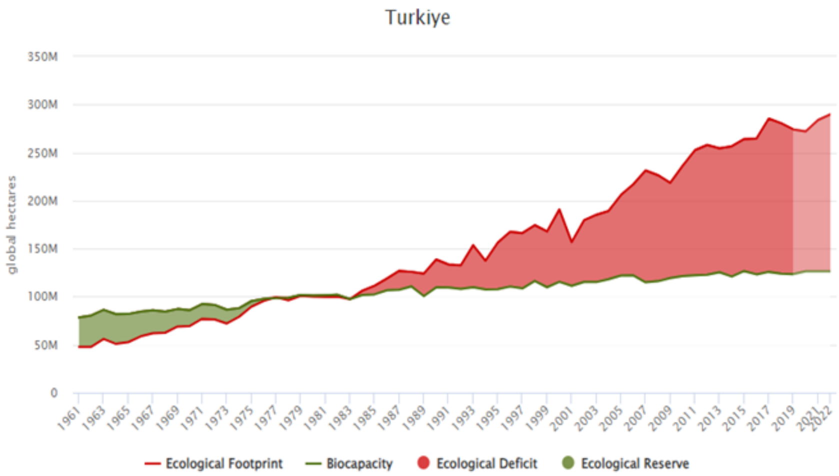
The "ecological footprint", which has lately been used as a variable in studies on the environment as an international public good, constitutes the basic framework of this study. Ecological footprint represents the area of biologically productive land and water needed to produce the resources consumed and dispose of the wastes produced by an individual, community, or activity, considering recent technology and resource control. The Ecological Footprint is described in international hectares . In other words, the ecological footprint is a tool that measures the biological area used by a person to meet all their needs. Biological capacity indicates the capacity to given geographical area to construct renewable natural resources. Two main factors determine the biological capacity of a region: firstly, the area of agricultural land, grassland, fishing grounds, and forests within the region's borders; secondly, how productive these land or water areas are. Biological capacity, like ecological footprint, is calculated in area units and expressed in global hectares (WWF, 2012: 8).

Many factors that cause environmental pollution have been mentioned in the previous paragraphs of the study, and variables have been selected in this context. The motivation of this study is to determine the effect the currently applied environmental taxes and other variables used in the study (ecological footprint, urban population growth rate, and renewable energy) have on the ecological footprint. In particular, the limited number of studies involving the ecological footprint variable shows that there is still a developing literature. In this context, the study aims to contribute to the literature. In this framework, the study starts with the introduction and continues with the conceptual framework, literature, data set, methodology, and findings. Finally, the study is concluded with the conclusion where the findings are evaluated, and policy recommendations are presented.

2. Conceptual Framework

As mentioned before, the ecological footprint is employed as the dependent variable in this study, while environmental tax, urban population growth rate, and renewable energy are utilized as independent variables. In this section, the conceptual framework for these variables will be presented. Ecological footprint is a parameter that measures our dependence on nature. The ecological footprint method provides a systematic approach to natural resource accounting based on supply and demand at global, regional, local, and individual levels (Wackernagel et al., 1997). The Global Global Footprint Network (GFN) shares quantitative data on ecological footprint. Figure 1 represents the global hectares of ecological footprint, biocapacity, ecological deficit, and ecological reserve in Türkiye for the years 1961-2022; Figure 2 represents the global hectares per capita of ecological footprint, biocapacity, ecological deficit, and ecological reserve in Türkiye for the years 1961-2022.

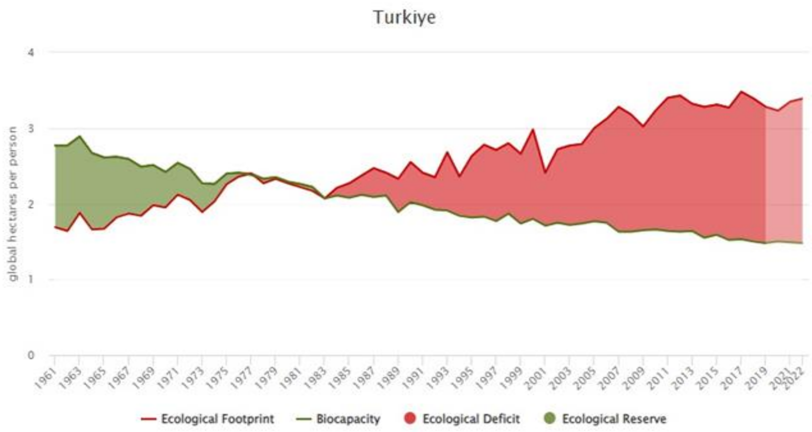
Figure 1. Ecological Footprint, Biocapacity, Ecological Deficit, and Ecological Reserve in Türkiye (in Global Hectares) (1961-2022)



Source: Global Footprint Network (GFN), 2023.

Figure 1 shows Türkiye's ecological footprint, biocapacity, ecological deficit, and ecological reserves between 1961 and 2022. During this period, it is possible to explain Türkiye's total biocapacity and ecological footprint data in detail. As of 1961, Türkiye's biocapacity was 76.4 million global hectares (kha), and its ecological footprint totaled 44.4 million kha. Türkiye's biocapacity was more significant during this period than its ecological footprint, so an ecological reserve existed. However, by 1980, Türkiye's ecological reserve was shrinking, and an ecological deficit was gradually emerging. The biocapacity totaled 94.1 million kha at that time, while the ecological footprint increased to 93.7 million kha. By 2016, biocapacity had reached 114.3 million kha, while the ecological footprint increased dramatically to 266.9 million kha. This shows that the ecological deficit is becoming more pronounced, and the pressure on Türkiye's natural resources is increasing. By 2022, this ecological deficit is observed to increase even further. While the total biocapacity is 126.1 million kha, the ecological footprint has reached 289.7 million kha. This shows that Türkiye's biocapacity needs to be improved to meet the resources consumed and waste generated and that the country is on an ecologically unsustainable path.

Figure 2. Ecological Footprint, Biocapacity, Ecological Deficit, and Ecological Reserve per Capita in Türkiye (in Global Hectares per Capita) (1961-2022)



Source: Global Footprint Network (GFN), 2023.

Figure 2 shows Türkiye's ecological footprint, biocapacity, ecological deficit, and ecological reserves per capita in global hectares between 1961 and 2022. In 1961, Türkiye's total biocapacity was 2.86 global hectares per capita (gha), and its ecological footprint was 2.48 gha per capita. In this period, Türkiye's biocapacity was higher than its ecological footprint, and therefore, an ecological reserve was available. In 1980, it was seen that the ecological reserve shrunk, and the ecological deficit started. At this date, while the biocapacity was 2.48 gha per capita, the ecological footprint increased to 2.46 gha. By 2016, biocapacity had dropped to 1.55 gha per capita, while the ecological footprint had increased dramatically to 3.31 gha. This shows that the ecological deficit is becoming more pronounced, and the pressure on Türkiye's natural resources is increasing. By 2022, this ecological deficit is observed to increase even further. While the biocapacity is 1.5 gha per capita, the ecological footprint has reached 3.2 gha. Therefore, this situation shows that Türkiye's biocapacity needs to be improved to meet the resources consumed and waste generated, and it reveals the importance of environmental policies.

Environmental taxes, one of the cornerstones of the study, are one of the independent variables. The environmental taxes currently applied in Türkiye consist of the Environmental Cleaning Tax, Plastic Bag Tax, Motor Vehicles Tax, and Special Consumption Tax within the scope of the central government budget. A tax that has been discussed in recent years is the Carbon Tax. However, it has yet to enter into force. It is a controversial issue whether these taxes have been introduced or will be introduced for environmental protection or financial purposes. In this regard, the budget realization statistics published by the Ministry of Treasury and Finance on the taxes applied in Türkiye include the collection amounts related to environmental taxes. The high level of special consumption tax on petrol and derivatives is especially striking in these amounts. However, in addition to tax policies, central public institutions, extraordinary provincial administrations, and municipalities with a population of more than 5000 make environmental expenditures. It would be appropriate to say that public expenditures are made in many environmental areas, from water services to wastewater management services, from soil and groundwater protection services to noise reduction (Biyan & Gök, 2014: 292).

From another point of view, the relationship between urban population growth and renewable energy consumption variables is critical in understanding modern economic and environmental dynamics. Urban population growth leads to an increase in energy demand and, thus, fossil fuel consumption. This is associated with the increasing dependence on fossil fuels for transport, industry, and housing needs that come with urbanization. However, increasing fossil fuel consumption also brings environmental problems and greenhouse gas emissions. From a different perspective, the shift towards renewable energy sources contributes to environmental sustainability by reducing fossil fuel dependence and increasing energy security in the long run (Kongbuamai et al., 2020; Freire-González, 2018; Zhou et al., 2020).

Within the framework of all these explanations, it can be said that the study's variables are vital in finding solutions to environmental problems. Understanding the relationship between these variables and determining their impact directions is the main principle of this study.

3. Literature Review

The current literature indicates that usage of renewable and non-renewable energy, pollutants like CO2 and other greenhouse gases, and ecological footprint variables, which have been included in recent studies, are important indicators of environmental damage. Since ecological footprint is used as the dependent variable and environmental tax, urban population growth rate and renewable energy are used as independent variables in this study, studies that examine the effect of all independent variables on ecological footprint separately or that include economic variables in addition to other environmental indicators will be summarised under this heading.

Rafique et al. (2022), in their panel data analysis study with the data of 29 OECD countries for the years 1994-2016, found that the factors affecting the ecological footprint, in the long run, are economic growth, environmental tax, energy consumption, urbanization, foreign direct investments, renewable energy (solar, wind, etc.) and industrialization. The study revealed an inverse relationship between environmental taxes and the ecological footprint. These findings are also supported by studies conducted by (Ulucak & Khan, 2020; Usman et al., 2020; Majeed et al., 2021 and Sharma et al., 2021). Contrary to the findings of other studies, Al-Mulali et al. (2016) and Shayanmehr et al. (2023) found a positive relationship between environmental taxes and ecological footprint. In the study, eight dynamic panel data models with ecological footprint as the explained variable were constructed using 1980-2009 annual data for 58 countries (developed and developing countries). The results of the study indicate that environmental taxes increase the ecological footprint. Shayanmehr et al. (2023), in a study covering some country groups, including Türkiye, analyzed the data for 1994-2018 using the panel data analysis method. According to the results of this study, which investigates the impact of environmental taxes on ecological footprint, environmental taxes increase ecological footprint. This finding reveals that contrary to expectations, environmental taxes could be more effective in ensuring ecological sustainability and increasing the ecological footprint instead of decreasing it. This result suggests that essential issues need to be reviewed in the implementation and design of environmental taxes. Telatar and Birinci (2022) tried to determine the impact of environmental taxes on Türkiye's ecological footprint and CO2 emissions. Data for the years 1994-2019 were analyzed using the non-linear cointegration test. As a result of the study, it was found that environmental taxes do not affect ecological footprint and CO2 emissions in the long run. On the other hand, Lin and Moubarak (2014) and Telatar and Birinci (2022) are the studies in which causality between environmental taxes and ecological footprint was not found. Lin and Moubarak (2014) found no causality between environmental taxes and ecological footprint using a time series analysis of data from 1977-2011 in China. Telatar and Birinci (2022) tried to determine the effect of environmental taxes on Türkiye's ecological footprint and CO2 emissions. Data for the years 1994-2019 were analyzed using the non-linear cointegration test. As a result of the study, it was found that environmental taxes do not affect ecological footprint and CO2 emissions in the long run. Chambers and Guo (2009) took ecological footprint as an environmental variable and analyzed its effect on GDP. Within the scope of the study, 1961-2001 data for 93 countries were used and analyzed using the panel GMM method. The study revealed that utilizing natural resources does not stimulate economic growth. Ulucak and Erdem (2017) investigated the connection between the ecological footprint and economic growth. A distinction was made between developed and developing countries in the study where the panel data method was used. The study found that the impact of environmental factors on output is more pronounced in developing countries. In this respect, the study differs from the study by Chambers and Guo (2009), who conclude that the ecological footprint is more important and influential than other factors of production, especially for developing countries. The authors thought the difference between the two studies was due to the sample, time dimension, and methodology (Ulucak & Erdem, 2017: 138).

4. Data, Methodology and Empirical Findings

4.1. Data

In the study conducted to determine factors (environmental tax, urban population, and renewable energy) that affect the ecological footprint in Türkiye in the long run, the data of the variables cover the period 1994-2022 and consist of annual observations. The ecological footprint used in the study was obtained from the Global Footprint Network, environmental tax from the OECD, urban population, and renewable energy consumption from the World Bank database. The analysis of the study was carried out using the Eviews program. Explanations about the variables are given below.

Table 1. Variables

Variables	Symbol	Explanations
Ecological Footprint	EcoFoot	Change of ecological footprint
Environmental Tax	ETax	The percentage of total tax revenues derived from environmental taxes.
Urban Population	UrbanPop	Urban population growth rate
Renewable Energy	ReEnergy	The proportion of renewable energy in the overall energy consumption.

4.2. Methodology

Time series analysis is an approach based on the variable's past behavior to be predicted to make predictions (Kennedy, 2006: 350). A non-stationary variable in a time series indicates that it includes unit root. If variable is non-stationary, effect of any shock or policy change on the variable will be permanent. If it is understood that the series are non-stationary at level levels, their stationarity can be ensured by applying the differencing process. With the rationalization process, the problem of spurious regression is eliminated, and the analysis results become more reliable (MacKinnon, 1991: 266-267).

The stationarity problem in time series has led to inconsistent study results. Hence, the extended Dickey-Fuller unit root test, which removes autocorrelation by adding lagged values of dependent variables as independent variables to the model, and the Philips-Perron (PP) test, which is a nonparametric method to control the high degree of correlation in time series, have been developed in the economic literature (Yalçınkaya et al., 2018: 9).

Dickey-Fuller's (1979-1981) unit root test is frequently preferred to investigate whether a variable series is unit-rooted or not. The regression equations developed for the ADF test, which is used to investigate the series' stationarity, are as follows (Dickey & Fuller, 1981:1057-1072).

$$\Delta X_t = \beta_0 + \beta_1 X_{t-1} + \sum_{i=1}^{k} \lambda_i \Delta X_{t-i} + u_t \tag{1}$$

$$\Delta X_t = \beta_0 + \beta_1 X_{t-1} + \beta_2 trend + \sum_{i=1}^{k} \lambda_i \Delta X_{t-i} + u_t \tag{2}$$

Unit root test proposed by Phillips and Perron includes nonparametric corrections. The equation for the test is,

$$\Delta y_t = \alpha y_{t-1} + \chi_t{}'\delta + \varepsilon_t \tag{3}$$

is determined as. Here, $\alpha = \varrho - 1$, and xt is the deterministic component denoting "constant" or "constant and trend". In the Phillips-Perron test, nonparametric corrections are made to calculate the test statistic. Therefore, a Therefore, the asymptotic distribution of the Phillips-Perron test statistic is not affected by autocorrelation (Çağlayan & Saçaklı, 2006: 124).

Taking the differences in the series eliminates the effect of the shocks the variables have been exposed to in the past periods and causes the long-run relationships between the variables to disappear. Thus, cointegration analysis suggests that even if the series of economic variables are non-stationary, a stationary linear combination of these series may exist, which can be determined econometrically. Therefore, the existence of a long-run relationship between variables can be determined by cointegration analysis (Tarı, 2005: 405-406).

Although the cointegration concept and test developed by Engle-Granger is practical because it is based on a single equation and the ECM method is used, it has some things that could be improved. For example, in a bivariate system, a cointegration relationship may be found in the equation of one variable. In contrast, no such relationship may be observed in the equation of the other variable. This may create uncertainty in the relationship between variables. Johansen developed a method that allows the estimation and testing of all different cointegration relationships between sets of variables. This approach is used when the number of cointegrations that may arise between a set of variables is one or more than one (Tarı, 2015: 425-426).

Traditional cointegration tests have been replaced by advanced methods like FMOLS (Hansen & Phillips, 1990), CCR (Park, 1992), and DOLS (Stock & Watson, 1993) estimators. This shift is due to issues with endogeneity and the difficulty in interpreting long-run coefficients. FMOLS, DOLS, and CCR are particularly useful for analyzing non-stationary series at their level values, as the resulting coefficients from these methods elucidate the relationships between variables, facilitating interpretation (Erdoğan et al., 2018: 46).

In this study, time series cointegration analysis is utilized. To perform the cointegration analysis, the variables were first subjected to ADF and PP unit root tests. After the non-stationarity was determined, the VAR(2) model with the appropriate lag was constructed. Before proceeding to cointegration analysis, whether the VAR(2) model with appropriate lag level was determined to satisfy the stability conditions (no autocorrelation, no changing variance, and characteristic polynomial roots less than one). After determining whether there is a long-run relationship between the variables through the VAR(2) model with the Johansen cointegration test, the long-run estimation results are obtained with the help of FMOLS, DOLS, and CCR.

The model of the study;

$$EcoFoott = \alpha 0 + \beta 1ETaxt + \beta 2UrbanPopt + \beta 3ReEnergyt + \varepsilon t$$

In the above equation, α represents the constant term, β represents the slope coefficients, and ε represents the error terms.

4.3. Empirical Findings

Information on the characteristics of data employed this investigation is given below.

Table 2. Descriptive Statistics

	EcoFoot	**ETax**	**UrbanPop**	**ReEnergy**
Mean	3.054	2.771	2.174	15.574
Median	3.180	3.090	2.270	14.120
Maximum	3.480	4.000	2.735	24.050
Minimum	2.360	1.080	1.255	11.400
Std. Dev.	0.323	0.807	0.401	3.633
Skewness	-0.567	-0.506	-1.018	0.848
Kurtosis	2.121	2.229	3.105	2.456
Jarque-Bera	2.487	1.959	5.031	3.836
Probability	0.288	0.375	0.080	0.146

Considering the analysis period, the EcoFoot variable's median, mean, minimum, and maximum values are 3.180, 3.054, 2.360, and 3.480, respectively. The ETax variable's median, mean, minimum, and maximum values are 3.090, 2.771, 1.080, and 4.000, respectively. The UrbanPop variable's median, mean, minimum, and maximum values are 2.270, 2.174, 1.255, and 2.735, respectively. The ReEnergy variable's median, mean, minimum, and maximum values are 14.120, 15.574, 11.400, and 24.050, respectively.

The stationarity of the variables used in the study was examined through unit root tests (ADF-PP), and the findings of these tests are presented below.

Table 3. Unit Root Test Results

Variables	ADF		PP		Result
	Const.	Const. and Trend	Const.	Const. and Trend	
EcoFoot	-2.247 (0.195)	-2.442 (0.139)	-2.196 (0.211)	-2.875 (0.140)	Non-stationary
Δ EcoFoot	-7.927 (0.000)	-7.830 (0.000)	-9.317 (0.000)	-9.378 (0.000)	Stationary
ETax	-2.278 (0.185)	-1.782 (0.686)	-2.272 (0.187)	-1.585 (0.773)	Non-stationary
Δ ETax	-6.093 (0.000)	-7.362 (0.000)	-6.093 (0.000)	-7.809 (0.000)	Stationary
UrbanPop	-1.622 (0.457)	-2.706 (0.241)	-0.457 (0.885)	-1.222 (0.886)	Non-stationary
Δ UrbanPop	-3.025 (0.045)	-3.356 (0.032)	-3.186 (0.028)	-3.642 (0.034)	Stationary
ReEnergy	-2.601 (0.105)	-0.617 (0.969)	-1.932 (0.154)	-1.925 (0.614)	Non-stationary
Δ ReEnergy	-5.724 (0.000)	-6.909 (0.000)	-6.557 (0.000)	-13.110 (0.000)	Stationary

Note: Values in parentheses show probability values. The symbol 'Δ' indicates the difference operation.

The findings of the unit root test (ADF and PP) indicate that all variables have a unit root at their level values; therefore, these variables are not stationary at their levels. When the unit root test (ADF and PP) is applied again by taking the first-order differences of the non-stationary variables, the null hypothesis is rejected. Thus, it is observed that the variables become stationary when their first-order (I1) differences are taken.

Before proceeding with the cointegration analysis, the Vector Autoregressive (VAR) model with the appropriate lag should be determined. The determination of appropriate lag level to be used in VAR model is carried out using information criteria. The VAR model appropriate lag value results using various information criteria are given in Table 4 below.

Table 4. VAR Model

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-111.9679	NA	0.4278	7.6645	7.8046	7.7093
1	15.4134	220.7942	0.0001	-0.2275	0.3329	-0.0482
2	31.6381	24.8779*	0.0001*	-0.7092*	0.2716*	-0.3954*

Note: '*' indicates the delay length selected by the relevant criteria.

In Table 4, all information criteria indicate that appropriate lag level is two. Before proceeding with the cointegration analysis, the VAR(2) model with the appropriate lag level should be checked to see whether it satisfies the stability conditions (no autocorrelation, no changing variance, and characteristic polynomial roots less than one). Then, the cointegration test can be performed using the VAR model with the appropriate lag that satisfies the stability condition.

Table 5. Stability Condition Tests of VAR (2) Model

LM Autocorrelation Test Result			
Lag	LR Statistics	Probability	Decision
1	21.473	0.171	no autocorrelation
White Heteroscedasticity Test Result			
	Chi-Square Statistics	Probability	Decision
	160.363	0.477	no heteroscedasticity
Characteristic Polynomial Roots			
Roots	Modulus		
0.762572 - 0.275305i	0.810746		
0.762572 + 0.275305i	0.810746		
0.769288 - 0.011837i	0.769379		
0.769288 + 0.011837i	0.769379		
-0.312688 - 0.390155i	0.499995		
-0.312688+0.390155i	0.499995		
0.493670	0.493670		
-0.397677	0.397677		

When the stability condition tests of the VAR (2) model with the appropriate lag level in Table 5 are analyzed respectively, it is found that there is no autocorrelation in the VAR(2) model; it does not have to change variance. The characteristic polynomial roots are less than 1. Therefore, all the criteria required to proceed to the Johansen cointegration test are met by the VAR (2) model. Findings of cointegration test are given below.

Table 6. Cointegration Results

Number of Equations	Eigenvalue Values	Trace Stat.	Critic. Value(%5)	Prob.
r=0	0.763275	64.03004	54.07904	0.0050
r≤1	0.485675	25.12690	35.19275	0.3926
r≤2	0.141459	7.174620	20.26184	0.8858
r≤3	0.107033	3.056564	9.164546	0.5702

According to the Johansen cointegration test results in Table 6, there is one cointegrated vector between EcoFoot, ETax, UrbanPop and ReEnergy variables.

After the Johansen cointegration test, FMOLS, DOLS and CCR methods were used to estimate coefficients of relationships between EcoFoot, ETax, UrbanPop and ReEnergy variables. The findings of the estimation are given below.

Table 7. Estimation Results

Variables	FMOLS		DOLS		CCR	
	Coeff.	**Prob.**	**Coeff.**	**Prob.**	**Coeff.**	**Prob.**
ETax	-0.143886	0.0171	-0.166247	0.0500	-0.150516	0.0318
UrbanPop	0.187702	0.0962	0.280059	0.0400	0.177916	0.0863
ReEnergy	-0.075924	0.0029	-0.073982	0.0413	-0.085958	0.0058
Constant	4.083370	0.0000	4.021969	0.0005	4.323616	0.0000
Trend	0.011159	0.0299	0.006912	0.0777	0.007747	0.0416

FMOLS estimations reveal a negative relationship between the EcoFoot and ETax variables at 5% confidence level. This indicates that when ETax increases by one unit, the EcoFoot variable decreases by 0.143 units. There is a positive relationship between the EcoFoot and the UrbanPop variables at a 10% confidence level. Therefore, when UrbanPop increases by one unit, the EcoFoot variable increases by 0.187 units. There is a negative relationship between EcoFoot and ReEnergy variables at a 1% confidence level. This indicates that a one-unit increase in ReEnergy decreases EcoFoot by 0.075 units.

DOLS estimates reveal a negative relationship between EcoFoot and ETax at the 5% confidence level. In other words, a one-unit increase in ETax decreases EcoFoot by 0.166 units. A positive relationship exists between the EcoFoot and the UrbanPop variables at a 5% confidence level. This positive relationship also shows that when UrbanPop increases by one unit, the EcoFoot variable increases by 0.280 units. There is a negative relationship between the EcoFoot and the ReEnergy variables at a 5% confidence level. In other words, one unit increase ReEnergy decreases EcoFoot variable by 0.073 units.

CCR estimations reveal inverse relationship between EcoFoot variable and ETax variable at the 5% confidence level. Therefore, one-unit increase ETax decreases EcoFoot variable by 0.150 units. A positive relationship exists between the EcoFoot and the UrbanPop variables at a 10% confidence level. In other words, a one unit increase UrbanPop increases EcoFoot by 0.177 units. There is a negative relationship between the EcoFoot and the ReEnergy variables at a 1% confidence level. In other words, one-unit increase ReEnergy decreases EcoFoot variable by 0.085 units.

Conclusion and Recommendations

Sustainable environmental policies have become a crucial issue in today's world. Taxes introduced in this context help reduce environmental damage and encourage the use of renewable energy. Moreover, the financing obtained from these taxes constitutes an essential source for achieving sustainable environmental goals. This study aims to analyze the long-run impact of environmental taxes, urban population, and renewable energy consumption on the ecological footprint in Türkiye. The study uses a dataset covering the period 1994-2022.

In the analysis of the study, firstly, the stationarity of the variables was tested with ADF and PP unit root tests, and long-run relationship between variables, which were found to be non-stationary at their level values, was examined with the Johansen cointegration test. As a result of the cointegration test, it was found that there is a cointegration relationship between ecological footprint, environmental taxes, urban population, and renewable energy consumption in Türkiye. According to the long-run FMOLS, DOLS, and CCR estimation results, a statistically significant negative relationship was found between ecological footprint, environmental taxes and renewable energy consumption. It is revealed that increases environmental taxes and renewable energy consumption reduce ecological footprint. These findings also support the studies by Rafique et al. (2022), Ulucak and Khan (2020), Majeed et al. (2021), Usman et al. (2020) and Sharma et al. (2021). From the estimation results, a statistically significant positive relationship was found between the ecological footprint and the urban population variable. It is concluded that increases in urban population increase the ecological footprint.

Environmental taxes alone are insufficient to solve environmental problems, and other fiscal instruments should be integrated and harmonized. In addition, to increase the effectiveness of environmental taxes, individuals should be made environmentally conscious, and their voluntary compliance should be encouraged by raising awareness of this issue. In this way, the effectiveness of fiscal instruments can be increased, and sustainable environmental management can be ensured for future generations. In addition, fossil fuel consumption should be limited by increasing renewable energy resources to prevent radioactive pollution that causes environmental damage.

Making future recommendations on the impact of ecological footprint on taxation is essential for both environmental sustainability and economic policies. Taxing businesses and individuals according to the amount of carbon they produce through carbon taxation can be an incentive to reduce carbon emissions. It would also accelerate the transition to renewable energy sources by reducing the use of fossil fuels. In addition, providing tax breaks and subsidies for low-carbon and zero-emission products and technologies can encourage consumers and producers towards more environmentally friendly options. In addition, to prevent the overuse of natural resources, integrating taxes based on the use of these resources into the system can limit the use of natural resources.

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