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The Importance of Green Tax in Reducing Carbon Emissions: The Case of G-7 Countries

Karbon Emisyonlarının Azaltılmasında Yeşil Vergilerin Önemi: G-7 Ülkeleri Örneği

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Abstract: Global warming and climate change caused by carbon emissions are accepted as one of the last century's most important environmental and economic problems. In this context, many countries are trying to limit their carbon emissions with new laws and regulations. One of these regulations is green (environmental) taxes. The study examined the role of green taxes in reducing carbon emissions in G-7 countries using the AR(1) Residual Random Effects model for the years 1994-2014. According to the estimation results obtained, it is seen that there is a positive relationship between economic growth and carbon emissions. On the other hand, it is seen that environmental patent applications, environmental taxation, and renewable energy consumption variables have a negative relationship with carbon emissions.

Keywords: Green Taxes, Global Warming, Linear Panel Data Analysis

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Öz: Karbon emisyonlarının yol açtığı küresel ısınma ve iklim değişikliği, son yüzyılın en önemli çevresel ve ekonomik sorunlarından biri olarak kabul edilmektedir. Bu bağlamda birçok ülke yeni yasa ve yönetmeliklerle karbon emisyonlarını sınırlamaya çalışmaktadır. Bu düzenlemelerden biri de yeşil (çevre) vergileridir. Çalışmada G-7 ülkelerinde 1994-2014 yılları için AR(1) Residual Random Effects modeli kullanılarak yeşil vergilerin karbon emisyonlarının azaltılmasındaki rolü incelenmiştir. Elde edilen tahmin sonuçlarına göre, ekonomik büyüme ile karbon salınımı arasında pozitif ilişki olduğu görülmektedir. Öte yandan, çevre ile ilgili patent başvuruları, çevre vergilendirmesi ve yenilenebilir enerji tüketimi değişkenlerinin karbon emisyonları ile negatif bir ilişkiye sahip olduğu görülmektedir.

Anahtar Kelimeler: Yeşil Vergiler, Küresel Isınma, Doğrusal Panel Veri Analizi

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1. Introduction

In recent years, scientists, policymakers, and the business community have frequently discussed environmental degradation and energy consumption. Energy-related greenhouse gas emissions from non-renewable energy sources (coal, oil, petroleum, etc.) are known causes of ecological degradation and global warming. Reducing carbon and greenhouse gas emissions, incompatible with the Sustainable Development Goals, and promoting a low-carbon economy are priorities for developed, developing, and emerging economies. Thus, economic incentives, environmental and carbon taxes, etc. Various policy instruments, such as taxes, have been used in this context.

State and government tax policies, such as environmental taxes and eco-taxes, play an essential role in the energy transition and the prevention of ecological damage. These taxes are crucial in reducing environmental problems such as pollution, ecological footprint, greenhouse gas emissions and climate change. On the other hand, many countries today are adding the goal of sustainable development to their growth targets. In this context, most countries prefer public solutions to reducing environmental degradation and achieving sustainable development goals, as implementing general instruments such as taxes is more practical.

Eco-taxes are one of the macroeconomic tools to support the energy transition. Interest in green taxes has increased in recent years because it is a type of tax that prioritizes environmental concerns in limiting ecological damage. Green taxes are viewed from two perspectives. The first is implementing a tax policy to alter environmentally harmful practices. The second is implementing a tax policy to promote more environmentally friendly practices.

2. The Concept of Eco-Tax (Green Tax) and Its Application in The World

Mass production, population density, and industrial production growth have dramatically increased energy demand. Today, a large part of the increasing energy demand is met by fossil fuels. The carbon emissions released from the extraction and use of fossil fuels form the basis of man-made environmental degradation.

On the other hand, the degradation of air, water, and soil quality negatively affects people's lives and reduces life expectancy worldwide. Environmental degradation is estimated to be responsible for about 40% of deaths worldwide (Pimentel et al., 2007).

Some studies establish a clear link between high temperatures caused by carbon emissions and lower life expectancy (Yu et al., 2019). It is well known that this situation also has implications for the economy. As human life expectancy decreases, people tend to reduce their savings. New practices such as market-based landscaping and pollution permits are emerging to counter environmental degradation and its adverse effects on life expectancy and physical capital.

Both developed and developing countries have created numerous practices and laws in the public sector to reduce negative environmental impacts and ensure economic sustainability. One of these practices is the green tax. They are also referred to as green, pollution, environmental, ecological, and Pigouvian taxes. Green taxes are levied on any practice that may cause corrosion or damage to the environment. These taxes can be levied on the inputs used in each stage of the production process and on the final products and the waste and emissions generated at the end of the process (Gunaydın, 2014:109).

Any tax that promotes the protection of the earth's natural resources and the environment can be considered a green tax. In other words, any tax that limits the negative impacts of fossil fuels can be regarded as a green tax. Green taxes are a policy tool that has attracted the attention of policymakers for some time. Especially since the 1990s, eco-taxes have become a market-based alternative to traditional regulation of corporate or individual pollution (Schaffer, 2021).

Green tax practices were first introduced in developed countries such as the United States, the European Union, Switzerland, New Zealand, Japan, Canada, and South Korea and achieved some success (Levinson, 2007; Wei and Aadlan, 2020: 1033). In addition, the practice of green taxes is relatively new in developing countries such as Ukraine, Mexico, Turkey, Brazil, and Chile. These countries have a green tax on carbon emissions (ICAP, 2019). In addition, China introduced a green tax on air, water, and soil pollutants on January 1, 2018 (Xinhua, 2018).

Environmental taxes are believed to be an economically effective means of discouraging environmentally harmful activities. For example, OECD member countries face a range of ecological sanctions that include improving air quality, protecting water quality, managing solid waste, protecting the ozone layer, and protecting against biodiversity loss. These countries enforce these sanctions through various regulatory tools, including technology-based command-and-control regimes, performance standards, taxes, and other economic incentives. In particular, in recent years, OECD countries have introduced environmental taxes, which play an essential role in environmental policy, and implemented green tax reforms (Ciocirlan and Yandle, 2003; Bolahatoğlu, 2022: 71). In OECD countries, green taxes are mainly divided into three areas: Energy taxes, transport taxes, and pollution and resource taxes. 2022: 72).

Green tax practices are also used in EU member states. For example, Germany introduced a comprehensive green tax reform in the 1990s that included a gradual increase in fuel taxes and new green taxes on natural gas, heating fuels, and household electricity consumption. As a result, carbon dioxide emissions were found to have decreased by an average of 20 million tons in Germany with the help of the Ecological Tax Reform. In addition, the Ecological Tax Reform created around 250,000 additional jobs in Germany. It can be seen that the Ecological Tax Reform is changing the economy and Germany as a society. So much so that the Ecological Tax Reform encourages people to invest in clean energy technologies (DIS, 2022).

Another example of another EU member country that has introduced the application of the eco-tax is Belgium. However, unlike other countries, the scope of the eco-tax in Belgium includes specific excise taxes on products offered for consumption. In other words, the products of Belgian producers are taxed because they harm the environment. Thus, the primary purpose of eco-taxes in Belgium is to change the prices of many products in the Belgian economy, thus changing the consumption behaviour of Belgian consumers and directing them to a more environmentally friendly area (Clercq, 1993).

Looking at eco-taxes as a share of national income, the U.S. has among the lowest tax rates compared to other OECD countries. In this context, the most crucial eco-tax in the U.S. is the fuel tax, considered the most effective tax to prevent negative externalities from pollution in the country. Accordingly, almost all of the income from green taxes in the U.S. consists of the fuel tax (Bolahatoğlu, 2022: 124).

In Turkey, the first of the taxes dealt with under green taxation is the motor vehicle tax. The tax varies depending on the age and size of the vehicle. Another type of tax that falls within the scope of green taxation in Turkey is the special consumption tax. Turkey abolished the fuel tax in 2002 and replaced it with a special consumption tax. The fuel tax depends on the amount of fuel consumed, which affects the emissions of the vehicles. For this reason, some of Turkey's special excise taxes are levied for environmental purposes.

3. Literature Review

The purpose of eco-taxes is not only to raise revenue for the government but also to induce behavioural change so that companies adopt environmentally friendly technologies and consumers prefer less polluting products, thereby reducing environmental damage. For example, a carbon tax could change the structure of production and consumption in favour of more environmentally friendly production and consumption of energy-related products. There are several empirical studies in the economics literature on the effectiveness of the green tax in reducing environmental degradation and carbon emissions. Some support the effectiveness of eco-tax in reducing carbon emissions, while others find no evidence to support the claim that eco-taxes improve environmental quality and reduce carbon emissions. For example, Aydın and Esen (2018) examined whether green taxes reduce carbon emissions in their study for 15 EU member states using a dynamic panel threshold analysis for 1995-2013. The study results show that the effect of green taxes above the threshold on carbon emissions changes from negative to positive. Floros and Vlachou (2005) studied energy demand in the manufacturing sector in Greece and the impact of a green tax, a carbon tax, on carbon emissions using time series for the period 1982-1998. The results show that a carbon tax of $50 per tonne reduces direct and indirect carbon emissions.

Chen et al. (2017) simulated the effect of eco-taxes on reducing emissions and energy savings in a 2012 study for the Guangdong region of China. The results show that when green taxes such as carbon tax and energy tax were implemented, energy consumption decreased by 5.8-11.21%, and carbon emissions decreased by 5.94-11.61% in the Guangdong region. Hao et al. (2021) investigated the effects of eco-tax, human capital and renewable energy on carbon emissions in G-7 countries for the period 1991-2017 using the method CS-ARDL. The study's empirical results show that green taxes, human capital, and renewable energy use reduce carbon emissions.

On the other hand, some studies show that eco-taxes do not positively affect reducing carbon emissions. For example, Hatunoğlu and Tekelli (2007) investigated whether green taxes reduce carbon emissions for 18 EU member states with the 1995-2003 data set using the least squares panel method. The result of the study was that the effect of green taxes on reducing carbon emissions was insufficient, contrary to predictions. Gemechu et al. (2013) measured the environmental impact of green taxes in Spain in 2017 by reducing CO2 emissions. In addition, the study also identified the short-term effects of the eco-tax on consumer prices and the impact on consumer welfare. The results based on the Spanish economy for 2007 show that sectors with a relatively weak environmental profile are burdened with high environmental tax rates. Applying a CO2 tax to these sectors increases output prices and leads to a slight increase in the consumer price index and a decrease in private welfare.

Overall, the analysis shows that environmental taxation cannot simultaneously meet environmental and economic objectives unless there is a way to use public revenues to compensate those adversely affected. Bayar and Şaşmaz (2016) examined the interaction between carbon tax, CO2 emissions, and economic growth in Denmark, Finland, the Netherlands, Sweden, and Norway for the period 1996-2011 using the causality test developed by Dumitrescu and Hurlin (2012). As a result of the study, while no meaningful relationship was found between the carbon tax and the environment, it was found that there is unidirectional causality between economic growth and carbon dioxide emissions.

4. Model and Data Set

4.1. Data Set, Sample and Methodology

The theoretical structure in the study is investigated for the G-7 countries, covering the years 1994-2014. The main reason the study could not be expanded after 2014 is the data constraint. Linear panel regression methods were used as the analysis method in the research. In this context, firstly, specification tests, then tests of deviations from the assumption were made, and parameter estimations were made using the AR(1) Residual Random Effects model.

The sources and explanations of the data for the variables used in the study are given in Table 1. The equation created to test the theoretical structure is shown in equation 1. In the equation, i represent the unit dimension (i=1, 2,…,7), and t represents the time dimension (t=1, 2,...,21). In the study, the Co2 variable, which indicates the carbon emission per capita, was analyzed by taking its logarithm to ensure that it converges to the normal distribution. Therefore, the equation created in this sense constitutes an extended version of the equation used by Loganathan, Shahbaz & Taha (2014). In addition, unlike the theoretical structure established in the mentioned study, since there is no test related to the Environmental Kuznets Curve in this study, the square of per capita income is not included in the analysis.

Tablo 1: Explanations on Variables

Variable	Explanation	Source
Co2	Carbon Emissions Metrics Ton Per Capita (Annual)	World Bank
GDP growth	Gross Domestic Product Growth (Annual %)	World Bank
EnvPatent	Patent Applications Environmentally Related Technologies (Annual)	OECD
EnvTax	Environmentally Related Taxes (Annual %)	OECD
Renew	Renewable Energy Consumption (Annual % of Total Final Energy Consumption)	World Bank

$$LCo2_{i,t} = B_0 + B_1 GdpGrowth_{i,t} + B_2 EnvPatent_{i,t} + B_3 EnvTax_{i,t} + B_4 Renew_{i,t} + u_{i,t} \quad (1)$$

Table 2: Descriptive Statistics on Variables

Variable	Obs	Mean	Std. Dev.	Min	Max
Co2	147	2.298908	.4002769	1.52954	3.018951
GDP growth	147	2.088692	2.232442	-5.696354	6.7
EnvPatent	147	9.416122	2.71014	5.09	15.7
EnvTax	147	1.998095	.7350392	.75	3.6
Renew	147	8.649542	6.432787	.85	22.5

Descriptive statistics for the variables used in the study are shown in Table 2. After the descriptive statistics are displayed, specification tests are analyzed.

4.2. Model Specification and Tests

This section presents the speciation tests for the model used and their results. First of all, tests were conducted to investigate the presence of unit and/or time effects in the model, and then tests were conducted to determine the type of these effects. All test results are shown in Table 3.

Table 3: Specification Tests

Test	Test Statistic	Probability Value
Likelihood Ratio Test (Unit Effect)	439.87	0.000
Likelihood Ratio Test (Time Effect)	0.00	1.000
Score Test (Unit Effect)	6.0e+06	0.000
Score Test (Time Effect)	0.00	1.000
Hausman Test	2.20	0.6991

Robust Hausman Test	0.00	1.0000

The Likelihood Ratio and Score test results for the determination of unit and/or time effects in the model are given in Table 3. Both tests test the validity of the classical model. The Score test is based on the Likelihood Ratio test, preferred in smaller sample groups. In terms of the robustness of the model, both tests were used in the study. The representation of the H_0 hypothesis in the previous tests is shown in equation 2.

$$H_0 = \sigma_\mu = \sigma_\lambda = 0 \tag{2}$$

In equation 2, σ_μ represents the unit effect, σ_λ represents the time effect, and the H_0 hypothesis based on these effects is equal to zero. Therefore, if the hypothesis cannot be rejected, it is concluded that the said effect is present in the model (Tatoğlu, 2021: 182-192). In this context, according to the results in Table 3, the H_0 hypothesis cannot be rejected for time effects in both tests, and it is concluded that there are no time effects in the model. On the other hand, when the test results are analyzed for unit effects, H_0 is rejected for both tests. In summary, it is concluded that there are unit effects in the model.

In the next step, to determine the estimation method to be used in the model, it is necessary to look at the nature of the obtained unit effects. The Hausman test is widely used in the literature to determine whether unit effects have random or fixed effects. The test reveals whether the unit effects are related to the independent variables. If there is no correlation between the unit effect and the independent variables, the random effects estimator is more effective. The H_0 hypothesis tested in the Hausman test is established as there is no correlation between the explanatory variables and the unit effect. The hypothesis in question is included in equation 3.

$$H_0 = X_{it} v_{it} = 0 \tag{3}$$

The Hausman test is consistent in the version in which the basic assumptions of the fixed and random effects models are provided. However, in cases where there are deviations from the premises in the model, the robust Hausman test is used, which produces robust variances. The H_0 hypothesis tested in the robust Hausman test is the same as equation 3 (Tatoğlu, 2021: 195-202).

Both Hausman and robust Hausman test results are given in Table 3. It was concluded that there was no correlation between the unit effect and independent variables in both tests. In this context, random effects estimators should be used in model estimation.

4.3. Deviations From Assumptions and Tests in The Random Effects Model

The results obtained as a result of the specification tests showed that the random effects model is more effective in parameter estimation. However, making an unbiased estimation with the random effects model can only be achieved by fulfilling the model's assumptions. The first of these assumptions specific to random effects models is the orthogonality of independent variables to unit effects. The second is the absence of multicollinearity, indicating a link between the independent variables. The third assumption is that the unit effect error and residual error elements do not change with time, in other words, homoscedasticity. The fourth and final assumption is that there is no autocorrelation between the error terms in the model. As a result of not providing the assumptions regarding the random effects model, biased results are obtained (Tatoğlu, 2021: 123). In this case, various estimation methods can produce robust standard errors without impairing the efficiency of parameter estimations. In this context, the tests for the assumptions of the random effects model are given in Table 4.

Table 4: Tests for Deviations from Assumptions

Test	Test Statistic	Probability Value
Pesaran Cross-Sectional Dependence Test	1.653	0.0983
Levene, Brown & Forsythe Test of Heteroskedasticity (W0)	1.2668046	0.27653559
Levene, Brown & Forsythe Test of Heteroskedasticity (W50)	1.1730275	0.32417032
Levene, Brown & Forsythe Test of Heteroskedasticity (W10)	1.2303509	0.29434636
Baltagi-Wu LBI Autocorrelation Test	1.043952	
VIF	1.35	

The first of these tests for deviations from the assumption is Pesaran's cross-sectional dependence test. According to the results of this test, the H_0 hypothesis that there is no correlation between units in the model cannot be rejected. In this sense, it is understood that there is no correlation between units in the model.

The Levene, Brown & Forsythe test results to test homoscedasticity, another assumption, are shown in Table 3, classified according to various calculation methods such as W0, W50, and W10. According to all test calculations, the H0 hypothesis cannot be rejected, and it is concluded that there is no heteroscedasticity problem in the model.

The result of the Baltagi-Wu LBI autocorrelation test performed for detecting autocorrelation in the model is given in Table 4. Contrary to the cross-sectional dependence and heteroscedasticity tests, the autocorrelation test does not have any primary hypotheses or probability values. As a result of the test, only test statistics are included. If these test statistics are less than 2, it is concluded that AR(1) type autocorrelation exists in the model (Tatoğlu, 2021: 268). In this sense, it is observed that the value obtained as a result of the test is less than 2. In the result obtained, it is found that there is an autocorrelation problem following the AR(1) process in the model.

The test statistics of the VIF factor for multicollinearity, which is a factor that negatively affects the effect of independent variables on the dependent variable, are given in Table 4. Just like in the autocorrelation test, a particular probability value is not obtained in the test in question. However, the fact that the VIF factor is less than ten due to the test statistics obtained means that there is no strong relationship between the independent variables and the explanatory states do not lose their effectiveness (Stine, 1995). In this sense, when the test statistics obtained for the model are examined, it can be interpreted that there is no multicollinearity between the independent variables.

Table 5: Summary of Deviations from the Assumption

Assumption	Status
Cross-Sectional Dependence	-
Heteroscedasticity	-
Autocorrelation	+
Multicollinearity	-

Table 5 shows the summary results of deviations from the assumptions. Based on the results obtained, the estimator used in the model in question should correct the autocorrelation problem and allow estimation without disrupting the parameter estimations.

4.4. AR(1) Residual Random Effects Model Estimation Results

As a result of the tests carried out for deviations from the assumptions, it was observed that there was an autocorrelation problem in the model. In addition, since the unit effects in the model have random effects and other assumptions are provided, parameter estimates are obtained using AR(1) Residual Random Effects Estimator in the study. The method used is a linear parameter estimator that allows estimation in the random effects model by correcting the AR(1) residual deviation. With the error term u_{it}The model error term component makes a parameter estimation following the AR(1) process by including the u_{it-1} period in its content (Tatoğlu, 2021: 353).

Table 6: AR(1) Residual Random Effects Estimation Results

Dependent Variable: LCo2		
Independent Variables:	**Coefficients**	**Probability Values**
GDPGrowth	.0041475	0.003
EnvPatent	-.0088648	0.017
EnvTax	-.1134458	0.000
Renew	-.0170352	0.000
Constant	2.737431	0.000
Normality (Error Term)	0.08	0.9587
Normality (Unit Effect)	5.44	0.0659
R^2: 0.7055	**Wald Statistic:** 79.94	**Prob:** 0.0000

Table 6 shows the parameter estimation results obtained. According to the table, a 1% increase in GDP in the period examined for the G-7 countries increases carbon emissions by 0.004, which is also statistically significant. These results are also compatible with the studies of Atgür (2021), Aydın (2013) and Kasperowicz (2015). These studies state that increases in GDP are one of the reasons for carbon emissions. Increases in economic growth increase energy use in many countries. Since this increase is mainly met from fossil-based energy sources, it will cause deterioration in environmental quality. In this context, the positive relationship between economic growth and carbon emissions is a generally accepted approach in many studies.

Another variable whose effect on carbon emissions is examined in the study is environmental patent applications. A 1% increase in environmental patent applications reduces carbon emissions by 0.008, and this coefficient is also statistically significant. These findings are also compatible with Akyol and Mete (2021). In the study in question, evidence was found that patent applications for preventing climate change reduce carbon emissions. Studies to stop climate change, which have been frequently researched in recent years, have also positively affected the number of skates in this area. In this context, developing technologies to limit carbon emission volumes has become a priority for many countries.

Another variable examined in the model is environmental (green) taxation practices. A 1% increase in environmental taxation practices reduces carbon emissions by 0.003, and this rate is also statistically significant. These results were reported by Floros and Vlachou (2005) and Chen et al. (2017) and are also seen to be compatible with them. Environmental taxes have been increasing in recent years due to both being one of the macroeconomic tools supporting energy transformation and being a tax type that prioritizes environmental concerns in limiting ecological damages. In this context, the reducing effect of the increased environmental taxation on carbon emissions is expected.

Renewable energy consumption is the last variable whose effect on carbon emissions is examined in the study. Accordingly, a 1% increase in renewable energy consumption reduces carbon emissions by 0.017, and the rate is statistically significant. The study findings are also compatible with Çoban (2015). While renewable energy sources are an excellent alternative to fossil-based energy sources, they also play a successful role in preventing environmental deformation.

On the other hand, since the unit effects in the model have a random structure and the established AR (1) Residual, the Random Effects model, is a linear estimator, the linearity of both the error term and the unit effect components were examined. In this sense, the error term is normally distributed in the 99% confidence interval and the unit effect error component in the 95% confidence interval.

The fact that the regression results obtained, which is another diagnostic indicator, have a stable coefficient estimate in the said time interval is an important issue in terms of the validity of the model in all periods. For this reason, whether there is any structural break in the study is investigated with the test developed by Karavias, Narayan & Westerlund (2023). With this test, results regarding the number and location of the relevant structural breaks can be obtained (Tatoğlu, 2021: 297-300). Test results for structural breaks are given below.

Table 7. Karavias, Narayan & Westerlund (2023) Structural Break Test

Date	**Supremum Wald (τ) Statistics**	**Probability Values**
1996	0.36	0.84
2001	3.86	0.02
2004	1.26	0.32
2007	2.24	0.10
2011	10.36	0.00

In order to determine the structural breaks as a result of the test, each break date in the time intervalused in the study was tried. As a result, the break dates giving the minimum breakage residual squares sum were determined and the results are presented in Table 7. As a result of the obtained supremum Wald statistics, the null hypothesis stating that there was no structural break was rejected for the years 2001 and 2011. In other words, it was concluded that there was a structural break in these dates. To test the significance of structural breaks, the break dates determined were modeled with the help of dummy variables in the relevant estimator. The results are shown in Table 8.

Table 8. Significance of Structural Breaks Test

Date	**Coefficient**	**Probability Values**
$Dummy^{2001}$	.0223082	0.100
$Dummy^{2011}$	-.0211977	0.135

According to the findings in Table 8, it was concluded that the structural breaks modeled for both dates were meaningless. As a result, it was observed that AR (1) Residual Random Effects model results did not have any structural changes in the relevant time interval. The coefficient estimates are valid for the 1994-2014 time period.

5. Conclusion

Global warming and climate change are considered one of the last century's most prominent environmental and economic problems. For this reason, new studies are added every day in this field. Carbon emissions are shown as the most significant cause of global warming. On the other hand, carbon emissions are primarily due to the intense use of fossil fuels to meet the energy demand. In this context, many countries are trying to limit their carbon emissions with new laws and regulations. One of these regulations is green (environmental) taxes.

In this study, the role of green taxes in reducing carbon emissions that cause global warming and climate change has been examined using linear panel regression methods for 1994-2014 in G-7 countries. In the study, firstly, the specification tests, then the deviations from the assumption were tested, and parameter estimations were made using the AR (1) Residual Random Effects model.

When the coefficients obtained in the study are examined, it is observed that there is a positive relationship between economic growth and carbon emissions. In this sense, economic growth in the analyzed countries increases carbon emissions and environmental pollution. On the other hand, it is observed that environmental-related patent applications, environmental taxation and renewable energy consumption variables, which are indicators for monitoring environmental quality, have a negative relationship with carbon emissions. In this context, it can be interpreted that environmental-related patent applications and environmental taxation practices, which are expected to reduce harmful emissions, are effective in reducing carbon emissions. Furthermore, the negative relationship between the effect of renewable energy consumption on carbon emissions is also consistent with the energy transformation objectives of the countries within the scope of sustainability.

The optimal use of environmental taxes, an essential instrument in regulating the balance between the environment and the economy, can trigger the spread of technologies that increase environmental quality. In the context of the results obtained, policymakers can reduce environmental pollution with optimal taxation of environmental pollution and contribute to the emergence of environmentally friendly technologies. The world today is in the midst of an energy transition. While consumers demand products that prioritize cleaner environment, manufacturers want to invest more in this area. On the other hand, policy makers should undertake important duties in this field. State and government support is considered important in reducing carbon emissions in various ways and more policies should be developed in this area. Finally, more effective policy proposals can be developed in future studies by examining the relationship between optimal taxation and the spread of environmentally friendly technologies.

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