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THE EFFECTS OF ENVIRONMENTAL TAXES ON CARBON EMISSIONS: A STUDY ON SELECT EU MEMBER STATES

ÇEVRE VERGILERININ KARBON EMISYONLARI ÜZERINDEKI ETKILERI: SEÇILMIŞ AB ÜYE ÜLKELERI ÜZERINE BIR ARAŞTIRMA

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Abstract

This study investigates the effects that national income, public expenditures, research and development (R&D) investments, and environmental taxes (ET) have on carbon emissions. The variables of national income, the square of national income, public expenditures, R&D, total ET, transport taxes, and energy taxes are used in conjunction with carbon emission data for this analysis. Three distinct models are used herein: Model 1 employs the total ET, model 2 utilises transport taxes, and model 3 makes use of energy taxes. A Dumitrescu-Hurlin causality analysis was employed to investigate the relationship between the variables, which demonstrates that there was a Granger causality from national income, the square of national income, and public expenditures to carbon emissions. However, there was no Granger causality from R&D expenditures to carbon emissions. Finally, there was a one-way Granger causality relationship from total ET, transport taxes, and energy taxes used as ET to carbon emissions. Therefore, this study concludes that R&D investments are important for the development of environmentally friendly production structures and for increasing the importance of these structures in the economy. Finally, the findings emphasise that ET in particular can be effective in reducing carbon emissions within the framework of the Kyoto Protocol and the Paris Agreement

Keyword: Environmental Taxes, Energy Economy, Economic Growth, Panel Data Analysis

JEL Codes: H23, P18, F43, C23

Öz

Bu çalışma, milli gelir, kamu harcamaları, araştırma ve geliştirme (Ar-Ge) yatırımları ve çevre vergilerinin (ET) karbon emisyonları üzerindeki etkilerini araştırmaktadır. Analiz için milli gelir, milli gelirin karesi, kamu harcamaları, Ar-Ge, toplam ET, ulaşım vergileri ve enerji vergileri değişkenleri karbon emisyonu verileri ile birlikte kullanılmıştır. Burada üç farklı model kullanılmaktadır: Model 1 toplam ET'yi, model 2 ulaştırma vergilerini ve model 3 enerji vergilerini kullanmaktadır. Değişkenler arasındaki ilişkiyi incelemek için Dumitrescu-Hurlin nedensellik analizi kullanılmış ve milli gelir, milli gelirin karesi ve kamu harcamalarından karbon emisyonlarına doğru bir Granger nedenselliği olduğu görülmüştür. Ancak, Ar-Ge harcamalarından karbon emisyonlarına doğru bir Granger nedenselliği bulunmamıştır. Son olarak, toplam ET, ulaştırma vergileri ve ET olarak kullanılan enerji vergilerinden karbon emisyonlarına doğru tek yönlü bir Granger nedensellik ilişkisi bulunmuştur. Dolayısıyla bu çalışma, Ar-Ge yatırımlarının çevre dostu üretim yapılarının geliştirilmesi ve bu yapıların ekonomideki öneminin artırılması için önemli olduğu sonucuna varmaktadır. Son olarak, bulgular özellikle ET'nin Kyoto Protokolü ve Paris Anlaşması çerçevesinde karbon emisyonlarının azaltılmasında etkili olabileceğini vurgulamaktadır.

Anahtar Kelimeler: Çevre Vergileri, Enerji Ekonomisi, Ekonomik Büyüme, Panel Veri Analizi

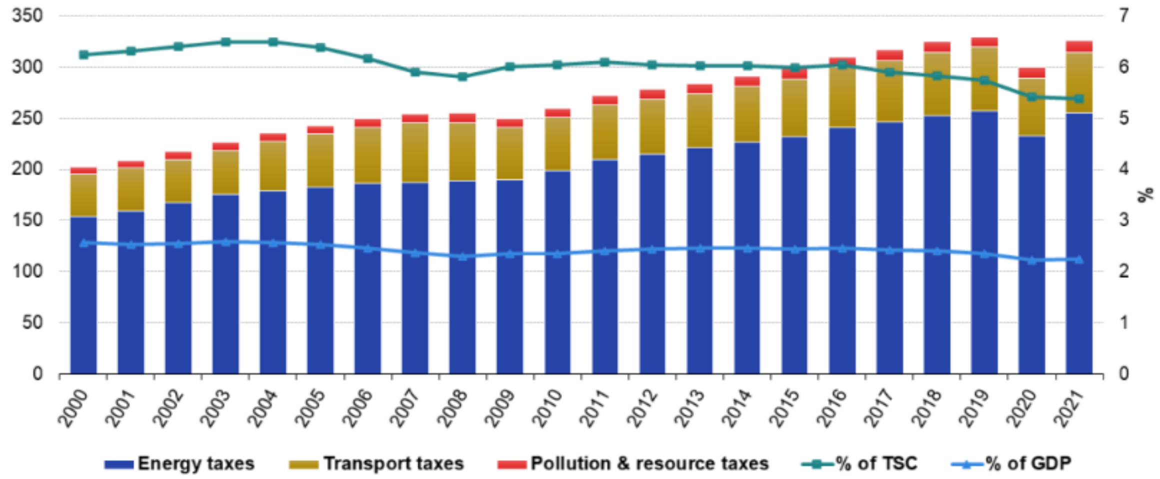
Jel Kodları: H23, P18, F43, C23

1. INTRODUCTION

For the last half-century, environmental problems have been increasing worldwide and have been an obstacle to sustainable development (Liu, et al., 2023). This has made it necessary to take measures against the consumption of natural resources and other factors that cause environmental destruction, with the reduction of carbon emissions (CE) that cause climate change being the particular focus. Accordingly, policies on the consumption of renewable energy sources that reduce environmental damage, zero waste measures, and the need to reduce pollution have started to be implemented. International agreements and world summits have put forth environmental policies to reduce environmental damage, including the 1987 Montreal Agreement that banned the use of chemical products that damage the ozone layer, the world summits held in Rio de Janeiro in 1992 and Johannesburg in 2002, and the 1997 Kyoto Protocol and Paris Agreement that regulates greenhouse gas (GHG) emissions (Baranzini et al., 2000; Ricci, 2007; Rafique et al., 2022). Due to concerns about the harmful effects of global warming, measures to reduce fossil fuel demand were included in the 1997 Kyoto Protocol that was signed by more than 100 countries (Sinn, 2008; Hashmi and Alam, 2019). Furthermore, in the 1990s, a series of initiatives were taken to implement ET reform (ETR) in European Union (EU) member states, starting with the Scandinavian countries. The aim of this reform is to shift the tax burden from the factors of production (labour, capital) to the users of natural resources that cause pollution. In short, it transfers the tax burden from economic ‘goods’ to environmental ‘bads’ (Ekins et al., 2012; Abdullah and Morlay, 2014). Thus, ETR creates a ‘double profit’ potential, in that it allows for environmental improvement as well as economic benefits. Revenues from ET can also be used to reduce the excessive burden of the tax system by reducing distortionary taxes on capital and labour, which will have positive results in terms of employment and investment (Bosquet, 2000; Hassan et al., 2020; Doğan, 2023). Figure 1 details the rates of ET in EU countries, with ET revenue being classified into four categories: energy taxes, transport taxes, pollution taxes, and resource taxes.

Figure 1

Total Environmental Tax Revenue in the EU by Tax Type from 2000–2021

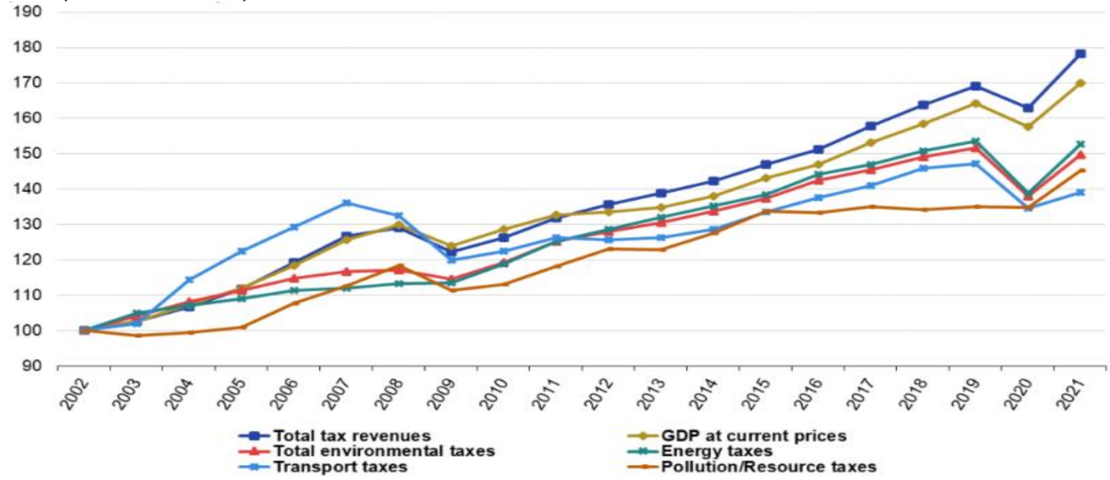


Source: Eurostat, 2023.

This figure delineates the ET and ET revenue by type as both a share of gross domestic product (GDP) and as a percentage of government revenue from taxes and social contributions (TSC). In 2021, EU countries received EUR 325.8 billion from ET, of which the ratio of ET revenues to GDP in EU countries was 2.2%. Moreover, ET revenue accounted for 5.4% of total government revenue from TSC. The EU ET revenues by tax type were distributed as follows: 78% from energy taxes, 18% from transport taxes, and 3.6% from pollution and resource taxes. The energy taxes included taxes on energy products (coal, oil products, natural gas, electricity), and they accounted for more than three-quarters of EU ET. Notably, energy taxes in the EU decreased by 9% between 2019 and 2020 due to the impact of the COVID-19 pandemic. However, these taxes increased by 12% in 2021 (Eurostat, 2023).

Figure 2

GDP Growth; Total Tax Revenue; and Energy, Transport, and Pollution Tax Revenue **in the** EU from 2002–2021 (index 2002=100)

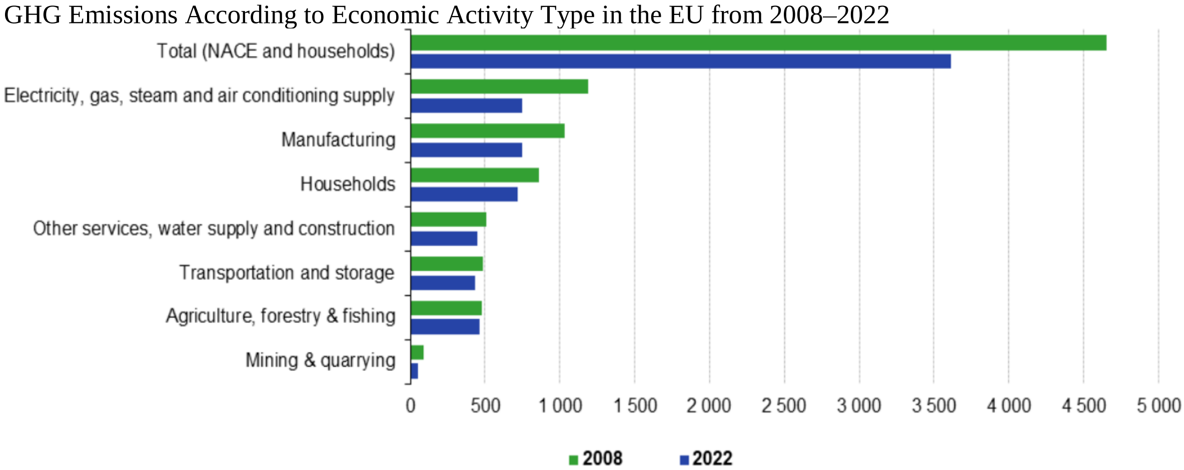


Source: Eurostat, 2023.

Figure 2 summarises the changes in indexed (2002=100) GDP, total tax revenue, energy taxes, transport taxes, and pollution and resource taxes from 2002 to 2021. Overall, the COVID-19 pandemic led to a decline in all ET except pollution and resource taxes. However, this decline started to reverse in 2021, with the total tax revenues in 2021 increasing by 15.3% from 2020. Energy taxes, which accounted for 78% of ET, increased by 13.7% between 2020 and 2021. Lastly, the share of transport taxes in ET increased by 4.5% from 2020 (Eurostat, 2023).

Figure 3

GHG Emissions According to Economic Activity Type in the EU from 2008–2022



Source: Eurostat, 2024.

In 2022, the total GHG emissions in the EU equalled 3.6 billion tonnes of Co2. Between 2008 and 2022, there was a 37% decrease in the level of GHG emissions from electricity, gas, steam and air conditioning supply; a 21% reduction from the manufacturing industry; a 16% decrease from households; and a reduction of 40% from mining and quarrying (Eurostat, 2024). This indicates that there has been a decrease in emission rates due to the implementation of carbon neutral policies in EU countries.

In this context, the aim of this study is to investigate the relationship between CE and ET in selected EU member states. Although many studies have been conducted on the relationship between CE and ET, not enough researchers have investigated the effects of sub-items of ET on carbon emissions. Therefore, this study's investigation of the effects of total ET as well as transport and energy taxes on CE makes a significant contribution to the literature. In the first section of this study, the theoretical framework is outlined. In the second section, a summary of the studies conducted within the scope of the research topic is presented. The third section details the econometric method and the findings obtained. In the last section, the conclusion and evaluations are provided.

2. LITERATURE REVIEW

In traditional economics literature, Pigou (1920) emphasised that taxes are the most appropriate tool to internalise negative externalities. Accordingly, environmental (carbon) taxes are considered to be the most effective method dökmenfor minimising the environmental damage of CE (Freire-González, 2018; He et al., 2021). In addition, ET increase the diversity of green technology and productivity in addition to increasing employment through creating new business areas. Moreover, they are important for enabling nations to achieve their economic growth (EG) targets by encouraging new investments (Rafique et al., 2022). Indeed, many studies have confirmed that ET positively affect EG (Castiglione et al., 2014; Andrei et al., 2016; Gashi et al., 2018; Mirović et al., 2021).fe

The literature indicates that there is a complex relationship between ET and EG. Countries increasing their tax rates generally affects their fiscal policies and leads to positive or negative effects on their national income (Barro, 1990; Widmalm, 1999; Romero-Avila and Strauch, 2008; Idris and Ahmad, 2017; Gashi et al., 2018; Frede and Fahlby, 2012). Acemoglu et al. (2010) examined the effects of tax policies on sustainable growth and intertemporal welfare maximisation. While identifying that efficient tax policies include both carbon taxes and research subsidies, they stated that optimal tax policies can be instituted to avoid the overuse of carbon taxes. Therefore, they asserted that with optimal environmental policies, research and development (R&D) investments should be shifted to cleaner technology and that production should be gradually shifted to cleaner inputs. Furthermore, Dökmen (2012) investigated the relationship between ET and EG in 29 European countries. He found that ET had a positive effect on the states' EG and thus concluded that ET positively affected both the environmental quality and EG of these European countries. Subsequently, when analysing the relationship between ET and EG in European countries between 1995 and 2006 using a panel causality test, Abdullah and Morley (2014) discovered a bidirectional causality relationship between EG and ET. Similarly, Gashi et al. (2018) examined the relationship between taxation and EG in the Kosovo economy between 2007 and 2015, ultimately determining that ET had a positive effect on the nation's EG. Khaerul Azis and Widodo (2019) analysed the relationship between ET and EG for 140 countries and 57 sectors, from which they liuconcluded that ET have negative effects on both the countries' national income and carbon emissions. Additionally, Fan et al. (2019) concluded that ET can stimulate EG, protect resources, and reduce pollution. Ahmad et al. (2021) found that ET improved China's and India's environmental quality, which was determined to be an important driving force for their achieving sustainable EG. Conversely, Hassan et al. (2020) determined that tax revenues negatively affected the EG of 31 countries in the Organization for Co-operation and Development (OECD) while clarifying that the relationship between revenues from ET and EG differed according to whether or not countries had redistribution mechanisms for the revenue obtained from ET. Likewise, Mirović et al. (2022) identified a positive relationship between energy tax, transport tax, and pollution tax revenues and EG in Serbia between 2013 and 2021. Furthermore, Wang et al. (2022) focused on the impact of ET on intensive polluting industries in China. They analysed the data from companies that traded on the stock exchange in the most intensively polluting industries from 2016 to 2020. They used these data to investigate the impact of ET on the economic performance and technological innovation input of intensively polluting industries in China, ultimately determining that ET had a positive effect on China's EG and technological development. In a similar vein, Liu et al. (2023) investigated the relationship between ET, governance, and energy prices in achieving sustainable development in OECD countries, concluding that there was a close relationship between EG and environmental degradation. They also confirmed that the implementation of ET reduced CO2 emissions and improved environmental quality in this context.

Thus, the literature suggests that ET can have a positive impact on technological development, in that they incentivise firms to invest in cleaner and more efficient technologies, stimulate innovation, and contribute to sustainable EG. However, the relationship between ET and technological development is complex and may vary depending on the context and regulatory frameworks in place.

3. METHODOLOGY AND FINDINGS

This study investigated the effects of ET on CE between 1995 and 2020. The data used herein include the carbon emission, national income, government expenditure, and R&D expenditure data obtained from the World Bank database, as well as the total ET, transport taxes, and energy taxes data that were obtained from the Eurostat database. The data from 20 European countries were used, with these countries being determined according to the availability and accessibility of the data. The data are summarised in Table 1.

Table 1
The Study's Variables

Variables	*Representation in the Model*	*Source*
Carbon emissions	lnco2	***World Bank***
National income (2015 USD-based constant prices)	lngdp	***World Bank***
National income squared	lngdp2	-
Government expenditure	lnhk	***World Bank***
R&D expenditure	lnRD	***World Bank***

Total environmental taxes	lntet	***Eurostat***
Transport taxes	lntt	***Eurostat***
Energy taxes	lnet	***Eurostat***

Note. *The data cover the period between 1995 and 2020. All of the data were logarithmically transformed. The data on national income, government expenditure, and R&D expenditure were calculated in USD, while the total ET, transport taxes, and energy taxes were calculated in Euros. The data on the national income squared were calculated by the author based on the GDP data and added to the models.*

The models used in the study were developed using Ahmad et al.'s (2021), liuet al.'s (2022), and Liu et al.'s (2023) models as a basis. The models and hypotheses used in the study are presented below.

Model 1:

$$\mathrm{lnco2_{it}} = \vartheta_{it} + \beta_{1it}\mathrm{lngdp_{it}} + \beta_{2it}\mathrm{lngdp2_{it}} + \beta_{3it}\mathrm{lngov_{it}} + \beta_{4it}\mathrm{lnRD_{it}} + \beta_{5it}\mathrm{lntet_{it}} + \mu_{it} \quad (1)$$

H_0: $\beta_{1it} = \beta_{2it} = \beta_{3it} = \beta_{4it} = \beta_{5it} = 0$

H_1: $\beta_{1it} \neq \beta_{2it} \neq \beta_{3it} \neq \beta_{4it} \neq \beta_{5it} \neq 0$

Model 2:

$$\mathrm{lnco2_{it}} = \varphi_{it} + \theta_{1it}\mathrm{lngdp_{it}} + \theta_{2it}\mathrm{lngdp2_{it}} + \theta_{3it}\mathrm{lngov_{it}} + \theta_{4it}\mathrm{lnRD_{it}} + \theta_{5it}\mathrm{lntt_{it}} + \epsilon_{it} \quad (2)$$

H_0: $\theta_{1it} = \theta_{2it} = \theta_{3it} = \theta_{4it} = \theta_{5it} = 0$

H_1: $\theta_{1it} \neq \theta_{2it} \neq \theta_{3it} \neq \theta_{4it} \neq \theta_{5it} \neq 0$

Model 3:

$$\mathrm{lnco2_{it}} = \gamma_{it} + \delta_{1it}\mathrm{lngdp_{it}} + \delta_{2it}\mathrm{lngdp2_{it}} + \delta_{3it}\mathrm{lngov_{it}} + \delta_{4it}\mathrm{lnRD_{it}} + \delta_{5it}\mathrm{lnet_{it}} + \omega_{it} \quad (3)$$

H_0: $\delta_{1it} = \delta_{2it} = \delta_{3it} = \delta_{4it} = \delta_{5it} = 0$

H_1: $\delta_{1it} \neq \delta_{2it} \neq \delta_{3it} \neq \delta_{4it} \neq \delta_{5it} \neq 0$

In all three models, lnco2 is the dependent variable, and lngdp, lngdp2, lngov, lnRD, lntet, lntt, and lnet are the independent variables. In the models, t = 1, 2,...T is the panel data time period; i = 1, 2,...N is the panel data cross-sectional unit; ϑ_{it}, φ_{it}, and γ_{it} are the fixed parameters; $\beta_{(1,..,4)i}$, $\theta_{(1,...,4)i}$, and $\delta_{(1,...4)i}$ are the slope parameters; and μ_{it}, ϵ_{it}, and ω_{it} are the error terms. If the independent variables representing the models can be used to explain the dependent variable, the H_0 hypothesis will be rejected. However, if the independent variables cannot explain the dependent variable, the H_0 hypothesis will not be rejected.

Whether the models have horizontal cross-section dependence and homogeneous structure was also analysed. Using these results, a unit root test was applied, and the most appropriate estimation method was determined.

3.1. Cross-Section Dependence Test

Breusch-Pegan (1980), Pesaran (2004), and Pesaran et al. (2008) developed horizontal cross-section dependence tests, with Breusch-Pegan's (1980) test being preferred when the N is small and the T is large. Conversely, Pesaran (2004) recommends the use of the CD_{LM} test when the N and T are large and the CD test when the N is large and the T is small. Finally, Pesaran et al. (2008) proposed a bias-corrected LM_{adj} test by adding variance and the mean to the test. As a result of the test statistic calculated in this context, if the H_0 hypothesis is rejected, there is horizontal cross-section dependence. However, if it is not rejected, there is no horizontal cross-section dependence. The formulae used to calculate the LM, CD, CD_{LM}, and LM_{adj} cross-section test statistics herein are presented below (Yerdelen Tatoğlu, 2017: 237–247; Belke and Al, 2019: 309–310):

$$LM = T\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{\rho}_{ij}^2$$

$$CD_{LM} = \sqrt{\frac{1}{N(N-1)}}\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}(T\hat{\rho}_{ij}^2 - 1)$$

$$CD = \sqrt{\frac{2T}{N\,(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \hat{\rho}_{ij}^2$$

$$LM_{adj} = \sqrt{\frac{2}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \hat{\rho}_{ij}^2 \frac{(T-k)\hat{\rho}_{ij}^2 - \mu_{T_{ij}}}{\nu_{T_{ij}}}$$

3.2. Second Generation Unit Root Tests

To obtain consistent results from the data used in the study and the estimated models, it must be determined whether they contain unit roots or not, with these tests comprising unit root and stationarity tests. In unit root tests, the null hypothesis states that the series contains a unit root, while the null hypothesis states that the series does not contain a unit root and is stationary in stationarity tests. Therefore, stationarity tests are those that investigate the existence of a unit root, as well as those showing that the null hypothesis does not contain a unit root and that the process is stationary (Becker et al., 2006: 407).

$$X_{it} = \beta' Z_{it} + \varphi_{it} + \omega_{it} \tag{4}$$

$$\varphi_i = \varphi_{it-1} + \omega_{it} \tag{5}$$

In equation (4), i=1,..., N represents the cross-sectional dimension, and t=1,..., T represents the time dimension. Considering that the term σ_{ui}^2 is the variance of the error term ω_{it}, the null hypothesis of the stationarity test, H_0, states that the null hypothesis is zero for all units, while hypothesis H_1 states that there is a unit root. The hypotheses of the stationarity test are stated as follows (hadri and Rao, 2008: 248; Nazlioğlu et al., 2021: 5):

H_0: $\sigma_{ui}^2 = 0$ The investigated series is stationary.

H_1: $\sigma_{ui}^2 > 0$ The investigated series contains a unit root.

Second generation panel stationarity tests allow for the inclusion of a common factor structure in the error term, as shown in equation (6) (Nazlioğlu et al., 2021:5).

$$\varepsilon_{it} = \varphi_i' F_t + e_{it} \tag{6}$$

$$X_{it} = \beta' Z_{it} + \varphi_{it} + \varphi_i' F_t + \omega_{it} \tag{7}$$

Considering the common factor in equation (6), equation (7) is obtained from equation (4). Bai and Ng (2005) proposed a version of the Fisher test, denoted by $P_{m,PC}$, in which they used the principal components method to identify the common factor F_t term. Furthermore, Hadri and Kurozumi (2012) used the average extended bed cross-section approach in Pesaran's (2007) approach to remove the common factor (Nazlioğlu et al., 2021: 5).

3.3. Dumitrescu-Hurlin Causality Test

The Dumitrescu-Hurlin (2012) causality test is a Granger causality test developed for heterogeneous panel data. The main hypothesis and the null hypothesis are that all 'β_i' are equal to zero, while the alternative hypothesis is that some of the 'β_i' are different from zero. The equation for the Dumitrescu-Hurlin Granger causality test, which was constructed according to the first equation of the panel vector autoregressive model, is detailed below (Tatoğlu, 2017: 154).

$$X_{it} = \theta_i + \sum_{n=1}^{N} \varphi_i^{(n)} X_{it-n} + \sum_{n=1}^{N} \beta_i^{(n)} Y_{it-n} + \omega_{it} \tag{8}$$

In Equation (8), the symbol (n) represents the lag length, the term $\beta_i^{(n)}$ represents the slope, $\varphi_i^{(n)}$ represents the autoregressive parameter, and ω_{it} represents the error term. To test the null hypothesis in equation (8), the presence of causality in each unit was investigated using the average of the Wald test statistics.

$$\overline{W}_{N,T} = \frac{1}{N} \sum_{i=1}^{N} W_{i,T} \tag{9}$$

In this equation, $W_{i,T}$ is the unit-specific Wald test statistic used to test the null hypothesis of unit i. Accordingly, $W_{i,T}$ was calculated as follows (Dumitrescu and Hurlin, 2012: 1453; Tatoğlu, 2017: 155):

$$W_{i,T} = (T - 2K - 1)\left(\frac{\tilde{\omega}_i \Phi_i \tilde{\omega}_i}{\tilde{\omega}_i M_i \tilde{\omega}_i}\right) \quad (10)$$

In Equation (10), $\tilde{\omega}_i$ was normally distributed. Moreover, Φ_i and M_i were the positive definite, symmetric, and idempotent matrices (Dumitrescu and Hurlin, 2012: 1453; Tatoğlu, 2017: 156).

3.4. Results

In panel data analyses, it is important to investigate if there is correlation between units in order to perform model estimations in a credible manner. This is because if there is a horizontal cross-section in the units of the models, unit root tests and estimators that consider the presence of horizontal cross-sections should be used. In addition, the heterogeneous structures of the models should be investigated before estimating them. For this reason, a Swamy S test was used herein to investigate the heterogeneity of the models. This information is presented in Table 2, which indicates that each of the models used did not have horizontal cross-section dependence or a heterogeneous structure.

Table 2
Cross-Section Dependence and Homogeneity Test Results

Models	*Statistic Value*	*Probability Value*
	Model 1	
LM(Breusch, Pegan, 1980)	1123.86	*0.000****
CDlm(Pesaran 2004)	47.91	*0.000****
CD(Pesaran 2004)	22.16	*0.000****
LMadj(Puy, 2008)	47.48	*0.000****
Swamy S Test	*24736.66*	*0.000****
	Model 2	
LM(Breusch, Pegan, 1980)	1166.92	*0.000****
CDlm(Pesaran 2004)	50.11	*0.000****
CD(Pesaran 2004)	24.27	*0.000****
LMadj(Puy, 2008)	49.69	*0.000****
Swamy S Test	*17594.72*	*0.000****
	Model 3	
LM(Breusch, Pegan, 1980)	1076.57	*0.000****
CDlm(Pesaran 2004)	45.48	*0.000****
CD(Pesaran 2004)	20.74	*0.000****
LMadj(Puy, 2008)	46.06	*0.000****
Swamy S Test	*26487.38*	*0.000****

Note. **** Significance at a 1% level.*

Considering that the models used herein had horizontal cross-sectional dependence and heterogeneous structures, the researchers analysed whether the data contained unit roots, for which the WCA unit root test was used, which is a robust estimation against cross-sectional dependence and heterogeneity. These findings indicated that the series were stationary at level values.

Table 3
Hadri-Kurozumi Unit Root Test Results

Variables	W_{CA}
lnco2	-0.002
lngdp	-0.668
lngdp2	-0.662
lngov	-0.292
lnRD	*-0.859*
lntet	*-0.904*
lntt	*-0.425*
lnet	*-0.9*

Note. *WCA; the Hadri-Kurozumi unit root test (2011) considers the model with constant. In this test, the 'Bartlett with Kurozumi rule' is used as the long-run variance estimation method.*

The relationship between the data standing at level value was then investigated using the Dumitrescu-Hurlin Granger causality test. The results from this analysis are presented in Table 3, which shows that in all three models, national income, the square of national income, and public expenditures were the causes of carbon emissions, but there was no causality from R&D expenditures to carbon emissions. In addition, there was Granger causality from the total ET used in model 1, the transport taxes used in model 2, and the energy taxes used in model 3 to carbon emissions.

Table 4

Dumitrescu-Hurlin Panel Granger Causality Test

Direction of Causality	W-Statistic	p-Values	Hypotheses
Model 1			
lngdp → lnco2	6.049	0.007***	H_0 is rejected
lngdp2 → lnco2	0.073	0.006***	H_0 is rejected
lngov → lnco2	4.956	0.049**	H_0 is rejected
lnRD → lnco2	4.495	0.174	H_0 is not rejected
lntet → lnco2	6.644	0.001***	H_0 is rejected
Model 2			
lngdp → lnco2	6.049	0.007***	H_0 is rejected
lngdp2 → lnco2	6.073	0.006***	H_0 is rejected
lngov → lnco2	4.956	0.049**	H_0 is rejected
lnRD → lnco2	4.495	0.174	H_0 is not rejected
lntt → lnco2	5.998	0.000***	H_0 is rejected
Model 3			
lngdp → lnco2	6.049	0.007***	H_0 is rejected
lngdp2 → lnco2	6.073	0.006***	H_0 is rejected
lngov → lnco2	4.956	0.049**	H_0 is rejected
lnRD → lnco2	4.495	0.174	H_0 is not rejected
lnet → lnco2	5.854	0.001***	H_0 is rejected

Note. **** and ** Significance at the 1% and 5% level, respectively.*

4. CONCLUSION AND EVALUATION

To make economic development sustainable and minimise environmental damage, countries have developed new policies on issues such as new energy sources, new technologies, and ET. ET are currently seen as an effective tool for reducing carbon emission rates and positively affecting national economies. Therefore, this study investigated the effects that ET have on CE in 20 EU member states. Herein, data on ET, total ET, transport taxes, and energy taxes were used in three different models. The findings indicate that there was a causality from income, the square of national income, and public expenditure to CE in all three models. However, there was no causality from R&D expenditure to CE in all three models. Therefore, the total ET, transport taxes, and energy taxes, which were considered ET herein, were found to be the cause of carbon emissions.

The analysis of the World Bank data demonstrated that EU countries made the third most CE after China and the United States of America in 2020. Of these nations, Germany, Italy, and France were the most significant contributors to carbon emissions. This indicates that the production structure for CE is an important consideration in the total production in these countries. Conversely, R&D expenditure was not the cause of carbon emissions in all three models, which indicates that the R&D based production structure was not predominantly used in production in the countries analysed herein. In addition, the total ET, transport taxes, and energy taxes were found to be the causes of carbon emissions. Therefore, ET should be the preferred policy instrument to reduce carbon emissions within the framework of both the Kyoto Protocol and Paris Agreement, as they are effective. Consequently, nations need to be incentivised to adopt R&D investments in order to ensure a transition to a production structure that is environmentally friendly in the context of total production. Finally, this research can be expanded on by investigating the long-term relationship between the sub-items of ET, such as transport and energy taxes and carbon emissions, thereby contributing to the literature.

REFERENCES

Abdullah, S. and Morley, B. (2014). Environmental taxes and economic growth: evidence from panel causality tests. Energy Economics, 42, 27-33. https://doi.org/10.1016/j.eneco.2013.11.013

Acemoglu, D., Aghion, P., Bursztyn, L., & Hémous, D. (2010). The environment and directed technical change. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.1668575

Acemoglu, D., Aghion, P., Bursztyn, L., and Hemous, D. (2012). The environment and directed technical change. *Am. Econ. Rev.* 102, 131–166.

Adam B. Jaffe, Karen Palmer; Environmental Regulation and Innovation: A Panel Data Study. *The Review of Economics and Statistics* 1997; 79 (4): 610–619. doi: https://doi.org/10.1162/003465397557196

Ahmad, M. I., Ur Rehman, R., Naseem, M. A., & Ali, R. (2021). Do environmental taxes impede economic growth? A comparison between China and India. *International Journal of Financial Engineering*, *8*(04), 2050023.

Andrei, J., Mieila, M., Popescu, G. H., Nica, E., & Cristina, M. (2016). The impact and determinants of environmental taxation on economic growth communities in Romania. *Energies*, *9*(11), 902.

Bai, Y., and Chen, S. (2022). Empirical study on the impact of environmental regulation on enterprise environmental investment. *Environ. Resour. Ecol. J.* 6 (02).

Baranzini, A., Goldemberg, J., & Speck, S. (2000). A future for carbon taxes. *Ecological economics*, *32*(3), 395-412.

Barro, R. 1990. Government expenditures in a simple endogenous growth model OECD, reports for tax revenues. https://doi:10.1086/261726

Bashir, M., 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), e0242412. https://doi.org/10.1371/journal.pone.0242412

Becker, R., Enders, W., & Lee, J. (2006). A stationarity test in the presence of an unknown number of smooth breaks. *Journal of Time Series Analysis*, *27*(3), 381-409.

Belke, M., & İbrahim, A. L. (2019). Regional Inflation Convergence in Turkey: Evidence from Panel Unit Root Tests. International Journal of Economics and Innovation, *5*(2), 301-323.

Bi, Q., and Yu, C. (2019). Environmental tax and enterprise technological innovation: Promotion or suppression? *Sci. Res. Manag.* 12, 116–125.

Bosquet, B. (2000). Environmental tax reform: does it work? A survey of the empirical evidence. *Ecological economics*, *34*(1), 19-32.

Breusch, T. S., & Pagan, A. R. (1980). The Lagrange multiplier test and its applications to model specification in econometrics. The review of economic studies, 47(1), 239-253. https://doi.org/10.2307/2297111

Castiglione, C., Infante, D., Minervini, M. T., & Smirnova, J. (2014). Environmental taxation in Europe: What does it depend on?. *Cogent Economics & Finance*, *2*(1), 967362.

Cesaroni, F., and Arduini, R. (2001). *Environmental technologies in the European chemical industry*. Pisa, Italy.: Laboratory of Economics and Management. *Working Paper*. 9.

Dogan, M. (2023). Environmental Tax Reform and the European Green Deal: Empirical Evidence from Panel Data Analysis. *International Journal of Public Finance*, *8*(2), 335-352.

Dökmen,G.(2012). Environmental Tax and Economic Growth: A Panel Var Analysıs. Erciyes University Journal of Economics and Administrative Sciences , 0 (40) , 43-65 .

Dumitrescu, E. I., & Hurlin, C. (2012). Testing for Granger non-causality in heterogeneous panels. *Economic modelling*, *29*(4), 1450-1460. https://doi.org/10.1016/j.econmod.2012.02.014

Ekins, P. (2012). Sustainable growth revisited: technology, economics and policy: A contribution to the special section of Mineral Economics 'Resources, energy and eco-innovation'. *Mineral economics*, *24*, 59-77.

Eurostat Statistics Expalained, Air Pollution Statistics (2024). https://ec.europa.eu/eurostat/statistics-explained/index (access date: 05.03.2024).

Eurostat Statistics Expalained, Environmental Tax Statistics (2023). https://ec.europa.eu/eurostat/statistics-explained (access date: 04.03.2024).

Fan, X., Li, X., & Yin, J. (2019). Impact of environmental tax on green development: a nonlinear dynamical system analysis. Plos One, 14(9), e0221264. https://doi.org/10.1371/journal.pone.0221264

Frede, E., Dahlyb, B. 2012. The Impact of Tax Cat on Economic Growth: Evidence Form Canadian Province. National Tax Journal, 65(3), 563-594.

Freire-González, J. (2018). Environmental taxation and the double dividend hypothesis in CGE modelling literature: A critical review. *Journal of Policy Modeling*, *40*(1), 194-223.

Gashi, B., Asllani, G., & Boqolli, L. (2018). The effect of tax structure in economic growth. International Journal of Economics and Business Administration, VI(Issue 2), 56-67. https://doi.org/10.35808/ijeba/157

Hadri, K., & Rao, Y. (2008). Panel stationarity test with structural breaks. *Oxford Bulletin of Economics and statistics*, *70*(2), 245-269.

Hashmi, R., & Alam, K. (2019). Dynamic relationship among environmental regulation, innovation, CO2 emissions, population, and economic growth in OECD countries: A panel investigation. *Journal of cleaner production*, *231*, 1100-1109.

Hassan, M., Oueslati, W., & Rousselière, D. (2020). Environmental taxes, reforms and economic growth: an empirical analysis of panel data. *Economic Systems*, *44*(3), 100806.

He, P., Ya, Q., Chengfeng, L., Yuan, Y., & Xiao, C. (2021). Nexus between environmental tax, economic growth, energy consumption, and carbon dioxide emissions: evidence from china, Finland, and Malaysia based on a Panel-ARDL approach. *Emerging Markets Finance and Trade*, *57*(3), 698-712.

He, Y. M., Luo, Q., and Zhu, X. W. (2018). Environmental regulation, ecological innovation and enterprise competitiveness: An analysis based on data of mineral resources enterprises. *Commer. Res.* 3, 132–137.

https://data.oecd.org/

https://data.worldbank.org/

Idris, M. and Ahmad, T. (2017). Tax revenue and macroeconomic growth in nigeria: a contextual analysis. Asian Journal of Economics Business and Accounting, 3(2), 1-12. https://doi.org/10.9734/ajeba/2017/33362

Khaerul Azis, M., & Widodo, T. (2019). The Impact of Carbon Tax on GDP and Environment.

Liu, H., Zafar, M., Sinha, A., & Khan, I. (2023). The path to sustainable environment: do environmental taxes and governance matter?. Sustainable Development, 31(4), 2278-2290. https://doi.org/10.1002/sd.2505

Mirović, V., Kalaš, B., & Andrašić, J. (2022). Taxation and environmental protection in the function of sustainable growth: the case of serbia. Ecologica, 29(108), 647-652. https://doi.org/10.18485/ecologica.2022.29.108.23

Mirović, V., Kalaš, B., & Milenković, N. (2021). Panel Cointegration Analysis of Total Environmental Taxes and Economic Growth in EU Countries. *Economic Analysis*, *54*(1), 92-103.

Nazlioglu, S., Payne, J. E., Lee, J., Rayos-Velazquez, M., & Karul, C. (2021). Convergence in OPEC carbon dioxide emissions: Evidence from new panel stationarity tests with factors and breaks. *Economic Modelling*, *100*, 105498.

Pesaran, M. H., & Yamagata, T. (2008). Testing slope homogeneity in large panels. Journal of econometrics, 142(1), 50-93. https://doi.org/10.1016/j.jeconom.2007.05.010

Pesaran, M. H. (2004). General diagnostic tests for cross section dependence in panels. Cambridge Working Papers. Economics, 1240(1), 1.

Rafique, M. Z., Fareed, Z., Ferraz, D., Ikram, M., & Huang, S. (2022). Exploring the heterogenous impacts of environmental taxes on environmental footprints: an empirical assessment from developed economies. *Energy*, *238*, 121753.

Ren, G., & Chen, Y. (2023). Is the impact of environmental regulation on enterprise green technology innovation incentives or inhibitions? A re-examination based on the China meta-analysis. *Frontiers in Environmental Science*, *10*, 2705.

Ricci, F., 2007. Channels of transmission of environmental policy to economic growth. Ecol. Econ. 60, 688-69.

Romero, D., Strauch, R. 2008. Publice Finance on long-term growth in Europe: Evidence from panel data analysis. Europen Journal of Political Economy, 24, 172-191.

Sinn, H. W. (2008). Public policies against global warming: a supply side approach. *International tax and public finance*, *15*, 360-394.

Tatoğlu, F. Y. (2017). Panel time series analysis. *İstanbul: Beta* Publishing, (s 352).

Tingbani, I., Salia, S., Hussain, J. G., & Alhassan, Y. (2021). Environmental tax, SME financing constraint, and innovation: evidence from OECD countries. *IEEE Transactions on Engineering Management*.

Wang, Z., Zhu, N., Wang, J., Hu, Y., & Nkana, M. (2022). The impact of environmental taxes on economic benefits and technology innovation input of heavily polluting industries in china. Frontiers in Environmental Science, 10. https://doi.org/10.3389/fenvs.2022.959939

Widmalm, F. (1999). Tax structure and growth. Are some tax better than other? Public choice, Working paper 107, IMF. https://www.jstor.org/stable/30026199

Yerdelen Tatoğlu, F. (2017). Panel Time Series Analysis with Stata Application. Beta Publishing. İstanbul. ss. 356. (3. Baskı 2020).

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