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An Empirical Assessment from Selected EU Countries

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Synopsis

The relationship between environmental technologies, environmental tax policies and ecological footprint is at the centre of efforts to achieve environmental goals for a sustainable future. In this study, which analyses the relationship between environmental technologies, environmental tax policies, and ecological footprint, the ecological footprint was defined as the dependent variable, while environmental tax, patents on environment technologies, and renewable energy were determined as independent variables. Additionally, gross domestic product, trade openness, and foreign direct investment were included as control variables in the model. The analysis incorporated a sample comprising chosen EU member states, and due to the shared constraint of data availability, annual data spanning the period from 2003 to 2018 were employed. According to the panel cointegration test results, it has been observed that there is a long-term relationship between environmental technologies, environmental tax policies, and ecological footprint. According to the results of the Konya causality analysis, it was concluded that there is a causal relationship between the variables included in

the model and ecological footprint in different countries. In line with the findings obtained from the study, it is recommended that governments make regulations such as environmental taxes and encourage investment in environmental technologies to reduce environmental degradation.

Contents

CHAPTER 1

1. Introduction

Since their existence, humans have continuously utilized environmental and natural assets and as a result, they have been affected by various environmental problems as well as affecting the environment. As human society grows, greenhouse gas emissions are increasing, thus affecting food, lives and other areas, which in turn hinders the socioeconomic activities and quality of life of citizens (Kirikkaleli, 2023: 1). In the process of this interaction between the environment and humankind, uncontrolled destruction of the environment and damage to natural ecosystems as a result of overconsumption of resources threaten the entire life on earth. In this regard, the growing concerns that environmental sustainability cannot be achieved through traditional economic growth models and the increasing sensitivity to possible future environmental crises reveal that the environment and the economy cannot be considered separately from each other. Whereas the resources provided by the environment ensure the continuity and growth of the economic system and social welfare, the wastes generated during the production and consumption of goods and services and the resources used in this process cause serious changes in environmental quality (Esen et al., 2021: 2). This impact of economic policies on the environment has led to intense debates on environmental degradation such as global warming and climate change (Destek and Manga, 2021: 21992).

In recent decades, industrialisation has been one of the main causes of climate change. Besides the rapid growth of industrialisation in the twentieth century, the need for energy has increased significantly with intensive population growth and technological developments. This increasing need for energy has led to the overuse of natural resources and increased the demand for fossil fuels such as oil, coal, and natural gas worldwide (Telatar and Birinci, 2022: 44335). The industrial revolution, which transpired during the eighteenth century, has been linked to the intensified utilization of accumulated capital, consequently fostering elevated rates of economic growth. Nevertheless, this transformative period was also accompanied by the release of deleterious gases, serving as primary contributors to the phenomena of global warming and environmental degradation (Sherif et al., 2022: 32813). Over the course of the previous two decades, greenhouse emissions, global warming, and climate change have occupied a prominent position within the political agenda (Rafique et al., 2022: 1). The primary driver behind climate warming pertains to alterations in atmospheric concentrations of greenhouse gases (GHGs) (Babatunde et al., 2017; Lin and Jia, 2018), notably encompassing carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF_6), as well as the influence of aerosols, land cover changes, and solar radiation (Bernstein et al., 2008).

These indicators are often criticised for not capturing the multifaceted aspects of environmental degradation, although in the past environmental pollution was simply represented by the volume of CO2 and other greenhouse gas emissions. Therefore, Wackernagel and Rees (1998) introduced the ecological footprint (EF), which tends to encompass various aspects of environmental degradation (Murshed et al., 2021: 49969). The concept of "environmental" or "ecological" footprint to measure the total human pressure on the natural environment is used as a general term for different footprint concepts developed over the last two decades (Hoekstra and Wiedmann, 2014: 1114). Compared to carbon emissions, EF is a more comprehensive indicator for detecting environmental degradation as it covers the environment in all its dimensions, including multifaceted environmental indicators such as residential areas, carbon emissions, cropping areas, fishing areas, grazing areas, and forest areas (Telatar and Birinci, 2022: 44336). The impact of production and consumption activities on environmental quality is usually estimated and measured by factors such as carbon dioxide (CO2) and greenhouse gas (GHG) emissions. Nevertheless, it is crucial to have a comprehensive indicator that considers all important aspects of environmental degradation. In this case, EF is considered a very effective indicator to measure the impact of human activities on the ecosystem. The importance of EF as an indicator is that it can take into account the use of human activities in areas such as agriculture, grazing and forest land, together with land development and carbon demand (Javed et al., 2023: 1). In order to improve the quality of the environment and avoid the consequences of environmental degradation, countries aim to reduce EF. To this end, policies related to the use of renewable energy, environmental technologies and environmental taxes are set.

Sustainable environmental quality has been emphasised as a vital part of successful sustainable economic development (Sadorsky, 2011; Bashir et al., 2020). The world has, therefore, made a strong effort to promote the gains of the Fourth Industrial Revolution to realise higher economic growth while maintaining environmental quality (Bilgili et al., 2021). Ecological modernisation theory has formed a dominant paradigm in guiding environmental policies worldwide (Hovardas, 2016). The theory argues that environmental management practices can reduce environmental impacts while providing economic benefits (Murphy and Gouldson, 2000). In this theoretical framework, appropriate environmental legislation or technical correction is defined as a key tool in addressing environmental problems (Guo et al., 2017: 895). Accordingly, this study aims to analyse the relationship between EF and environmental technologies, environmental taxes and renewable energy.

With technological developments, the growth of nations in many aspects, especially the economy, has accelerated. Economic growth allows countries to develop basic infrastructure facilities, reduce poverty and improve the living standards of their citizens. However, development processes also carry some disadvantages, mainly when countries tend to favour artificial luxury over the well-being of the natural environment.

Developing economies sacrifice natural resource reserves to achieve rapid economic growth, leading to serious environmental unsustainability, including environmental degradation, massive solid and industrial waste and other soil, water, and air-related problems (Ahmad et al., 2020: 2). The goal of achieving economic growth has been replaced by the goal of balancing economic, social and environmental sustainability (Chu, 2022b: 515). It is also referred to in the literature as green growth, achieving economic growth without depleting ecological assets in line with sustainable development and reducing environmental pollution for each type of pollution (World Bank, 2012; Koseoglu et al., 2022: 976). Green growth entails supporting economic activities such as reducing energy intensity, clean energy transformation, emission reduction in parallel with economic activities (Guo et al., 2017: 900; Sohag et al., 2019: 1). Green growth discussions mainly emphasise the fact that cleaner production strategies and cleaner supply chains through green technology innovation help to reduce pollution along with EG (Koseoglu et al., 2022: 977).

Climate change constitutes a multifaceted societal issue that implicates the concerted involvement of governments, enterprises, and individuals alike (Xu et al., 2015: 1271). Climate change resulting from the threat of global warming is one of the most important ongoing concerns in the 21st century, bringing about catastrophic climate events that continue to destroy the entire planet (Danish et al., 2017: 855). Accordingly, amidst the ongoing trajectory of energy scarcity and global climate change, there has been a heightened focus within the international community on endeavours pertaining to energy conservation and the mitigation of carbon emissions. Nations across the globe have collectively recognised the imperative of formulating effective energy policies, culminating in the development and implementation of diverse green technologies aimed at fostering sustainable environments (Tsai et al., 2017: 1412). Innovation may perform a vital function in achieving environmental sustainability through the deployment of energy-efficient technologies that sustain economic growth without polluting the environment (Haldar and Sethi, 2021: 2).

Environmental taxes are potentially imposed on goods that have a negative impact on the environment, particularly scarce natural resources. Such taxes can improve environmental quality by motivating the manufacturing sector to develop and adopt efficient technologies or produce environmentally friendly products. Ecological taxes, therefore, help achieve sustainable development by discouraging harmful environmental practices (Shahzad, 2020: 24848; Rafique et al., 2022: 1). Environmental tax policies aim to ensure mental performance, economic equity, and reduced use of resources (including energy use), which in turn helps to achieve various climate change goals such as reducing air emissions, reducing water pollution, posing of wastewater, and so forth (Shayanmehr et al., 2023: 2).

In reducing ecological damage, countries can choose energy efficiency strategies that can contribute to reducing energy consumption; however, these strategies may provide only a limited benefit. The ideal strategy to combat ecological degradation and climate change is to turn to alternative energy sources such as renewable energy sources (Ahmed et al., 2022: 1). However, countries should design and implement comprehensive environmental regulations that can stimulate the transition to green energy and limit waste generation and resource consumption.

Within the context provided, this research makes a noteworthy contribution to the existing literature in three distinct aspects. Firstly, this study environmental technologies, environmental tax policies, and EF in selected EU countries in the occurrence of renewable energy, GDP, trade openness, and foreign direct investment. Since the author has not come across a study in the literature in which these variables are used at the same time, they tended to conduct such research. Secondly, new generation panel data analysis techniques are used as the analysis method. At the end of the analyses conducted by taking cross sectional dependency into account, the relationship between the variables included in the model is examined and discussed on a country basis with the Konya Causality test. Thirdly, the study adopts EF as a surrogate measure for environmental pollution, drawing upon EF's comprehensive framework, which encompasses the amalgamation of soil, air, and water pollution. In contrast, CO_2 emissions exclusively capture pollution associated with energy-related sources. Consequently, this research aligns with contemporary literature guidelines by employing EF as a viable proxy for evaluating environmental pollution. In this context, the theoretical and conceptual framework of the paper is established in the first section, the difference of the study from the literature and its contribution to the literature are explained in the second section, and econometric analyses are carried out in the third section. At last, the findings of the study are interpreted and policy recommendations are developed.

CHAPTER 2

2. Literature Review

The overuse and over time depletion of natural resources has created a wide empirical research area on environmental issues. While they are directly related to the environment and human health, the economic dimension of environmental factors has also begun to take place in the literature. The problem of climate change and threats to human health and sustainable economic development remain the main focus and the biggest challenge facing the contemporary world (Khan et al., 2020). Therefore, in recent years, environmental degradation and its impacts have attracted more attention from academics, researchers, and policy makers. In the literature, carbon emissions and EF are frequently used as a measure of environmental degradation.

Environmental taxes are one of the policy instruments used widely to reduce environmental degradation. Nie et al. (2018) analysed the relationship between environmental taxes and carbon emissions in China using impulse response analysis and variance decomposition and found that environmental tax shocks can reduce carbon emissions. Based on their empirical analyses, Bashir et al. (2020) found that environmental taxes have a negative impact on carbon emissions. Murshed et al. (2021) analysed environmental regulations and environmental sustainability and considered environmental regulations as environmental taxes and environment-related patents as in the OECD database classification. As a result of the analyses, it is found that renewable energy use and environmental regulations jointly reduce EF. In their study on a sample of G7 countries, Doğan et al. (2022) confirmed that environmental taxes effectively reduce emissions and that the marginal effects of environmental taxes on conventional energy consumption, natural resource rent and renewable energy consumption increase statistically significantly with the level of taxation. Similarly, Javed et al. (2023) found that environmental taxes in Italy significantly improve the quality of the environment by reducing the EF. Shayanmehr et al. (2023), who studied the best renewable energy countries, found that environmental tax and renewable energy directly and significantly reduce EF. Furthermore, the findings show that environmental tax plays a leading role in changing the energy structure towards environmentally friendly energies. Meanwhile, some studies in the literature have not found a meaningful relationship between environmental taxes and EF. For instance, Telatar and Birinci (2022), in their study on the Turkish sample, found no long-term effect of environmental taxes on EF and CO_2 emissions. Therefore, the authors state that the environmental tax policy adopted in Turkey does not contribute to preventing or reducing environmental degradation. Similarly, Shayanmehr et al. (2023) found that the relationship between environmental taxes and EF is insignificant in countries with low environmental pollution.

In the meantime, the existing literature has also examined the relationship between technological innovations and EF in terms of environmental sustainability. Sadiq et al. (2022), who examined the relationship between environmental technologies, nuclear energy and globalisation and EF in the ten largest EF countries, found that nuclear energy and environmental technologies contribute to environmental sustainability by reducing the EF. Moreover, the EF has a bidirectional feedback causality with environmental technology. Hussain et al. (2022) argue that the role of renewable energy and environment-related technologies in reducing environmental degradation in BRICS is positive and significant. Chu (2022a) also revealed a long-run relationship between EF and green technologies in his study. He identified the importance of environmental technologies and green energy consumption for sustainable development. Yasmeen et al. (2023) found that environmental technologies significantly reduce energy poverty and EF in E7 economies. Kirikkaleli et al. (2023) find that environmental technology patents are an important determinant of EF in the US and lead to a reduction in ecological deprivation in the long run. In addition, based on the study outputs, they stated that it is possible to resolve the conflicts between the economy and the environment by using technological innovations. Some studies in the literature have not found any relationship between technological innovation and EF. Destek and Manga (2021), for example, who examined the effect of technological innovation on carbon emissions as well as EF in large emerging markets, find that technological innovation is effective in reducing carbon emissions, but does not have a substantial effect on EF.

Another important variable whose relationship with environmental degradation has been analysed in the literature is renewable energy. Similar to environmental taxes and environmental technologies, evidence that renewable energy reduces EF is a common result of many studies in the literature. Danish et al. (2020), in their study on BRICS countries, find that renewable energy reduces the EF and contributes positively to environmental quality. Usman et al. (2020) examine the relationship between renewable energy and EF in the US in the long and short term. Empirical evidence shows that in the long run, renewable energy exerts negative pressure on EF, while in the short run, renewable energy is positively linked to EF. Analysing the relationship between renewable and non-renewable energy, EF and economic growth in the best renewable energy countries, Ansari et al. (2021) demonstrate that economic growth leads to EF. According to the findings, sustaining economic growth is one of the important elements for strengthening the best renewable energy countries, and reducing the EF may negatively affect their economic development. For stabilising the momentum, the deployment of green technologies and the integration of renewable energy are the options that should be preferred by these countries. Analysing the relationship between renewable energy and EF in G7 countries, Radmehr et al. (2022) confirm the existence of a bidirectional link between EF and renewable energy. Accordingly, it is found that an increase in renewable energy consumption leads to a decrease in environmental degradation. In their study covering 120 countries, Li et al. (2022) reveal that global renewable energy will support economic growth while improving the environment. They also conclude that as the rate of urbanisation increases, the negative impact of renewable energy on EF first weakens, then increases and the positive coefficient on the economy continues its growth trend. On contrary, they found that non-renewable energy increases EF although it has a more pronounced positive effect on economic growth.

As can be seen from the studies reviewed in the literature, in order to reduce environmental degradation, governments develop policies to reduce the EF. In this regard, the effects of various variables such as environmental taxes, globalisation, environmental patents, environmental technologies, green technologies, renewable energies on carbon emissions and EF are investigated. This paper differs from the studies in the literature in a few points. Firstly, the sample of the study consists of selected EU countries. To the best of our knowledge, there is not a sufficient number of studies in the literature that focus on EU countries as a sample. Secondly, there are not many studies in the literature that include environmental tax, renewable energy consumption, patents on environment technologies and EF variable in the analyses at the same time. For these reasons, it is thought that the study will contribute to the existing literature.

CHAPTER 3

3. Econometric Methods and Methodology

In the analysis part of the research, the long-run relationship between environmental technologies, environmental tax policies and ecological footprint is tested for selected EU countries (Austria, Belgium, Czechia, Denmark, Finland, France, Germany, Greece, Italy, Luxembourg, Poland, Portugal, Spain, Sweden and Croatia). The main hypothesis of the paper is "*there is a long-run relationship between environmental technologies, environmental tax policies and ecological footprint*". In this context, firstly, the data set and the model of the variables to be used in the light of the hypothesis are introduced; then, the method to be used is determined. Having presented the theoretical and conceptual framework of the tests to be applied within the scope of the method, the findings obtained from the analyses are interpreted.

3.1. Dataset and Model

In the analyses, annual data for the period 2003-2018 are utilised in selected EU countries due to the common data constraint. The main reasons for the selection of this country group are the high growth rate potential of the countries according to World Bank data and the high application rates for environmental technology patent applications according to OECD data. Considering their population densities and market sizes, these countries also stand out in the environmental problems created by global production. The type and amount of energy used in production stages and the environmental policies they will implement are important in the entire planet. For this reason, this country group, which is also at the forefront in global trade, constitutes the sample of the country study.

In the scope of the hypothesis of the research, the variables of the model are determined on the basis of the studies in the literature. In this context, ecological footprint, which is the most frequently used environmental indicator in the literature and known as the most comprehensive environmental indicator because it includes many environmental factors, is determined as the dependent variable. As independent variables, Environmental Tax (ET), Patents on Environment Technologies (PET), Renawable Energy (RE) are included in the model as environmental indicators. Additionally, GDP, Trade Openness (TRD) and Foreign Direct Investment (FDI), which affect the EF in the model, are included in the analyses as control variables. As can be seen in the related literature, all the variables determined in the model setup are the most preferred variables that do not have common data problems. In addition, since all variables in the model except TRD are proportional expressions, they are analysed without taking their logarithms. The logarithmic form of the TRD variable is used. Related variables and necessary explanatory information are given in Table 1.

Table 1. Dataset and Sources

Variables	Definition of Variables	Resources
EF	Ecological Footprint	Global Footprint Network
RE	Renewable energy consumption (% of total final energy consumption)	World Bank
ET	Environmental Tax (% of GDP)	OECD
PET	Patents on environment technologies	OECD
GDP	Growth (annual %)	World Bank
FDI	Foreign direct investment, net inflows (% of GDP)	World Bank
LNTRD	Trade (% of GDP)	World Bank

The model created within the scope of the determined hypothesis is constructed as follows.

$$EF_{it} = \beta_0 + \beta_1 RE_{it} + \beta_2 ET_{it} + \beta_3 PET_{it} + \beta_4 GDP_{it} + \beta_5 FDI_{it} + \beta_6 LNTRD_{it} + \varepsilon_{it}$$

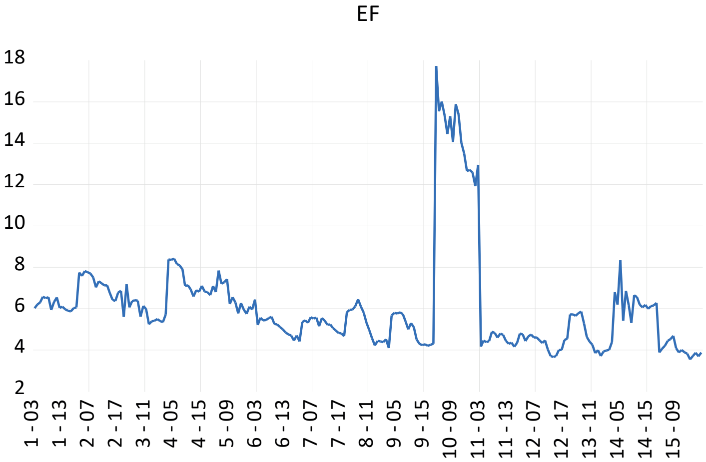
In the model, i=1, 2, 3,....N denotes cross-section data, t=1, 2, 3, ...T denotes the time dimension and ε denotes the error term.

3.2. Econometric Method

The methodological sequence of the study, in which the long-run relationship between environmental technologies and environmental tax policies and the relationship between EF is analysed over selected EU countries, is as follows; Firstly, graphical analysis and descriptive statistics of the variables, Breusch-Pagan (1980)'s CD_{lm1} and Pesaran et al (2008)'s LM_{adj} cross-sectional dependence tests, CADF unit root test developed by Pesaran (2007) to determine the stationarity levels of the variables, The analyses are performed by using the Delta homogeneity test developed by Pesaran and Yagamata (2008) to determine whether the slope coefficients vary across units, the Durbin-Hausman cointegration test developed by Westerlund (2008) to determine the existence of cointegration relationship between variables and Konya (2006) panel causality test for causality test.

3.2.1. Descriptive Statistics and Graphical Analysis of Variables

Before the analyses in econometric studies, it is necessary to interpret the changes and cyclical fluctuations of the variables included in the model over the years and to calculate their descriptive statistics. In this context, the graphical representation of the variables is given in Figure 1.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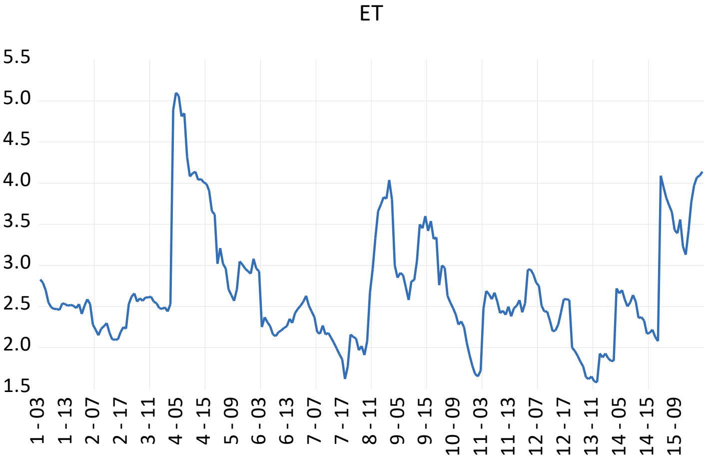
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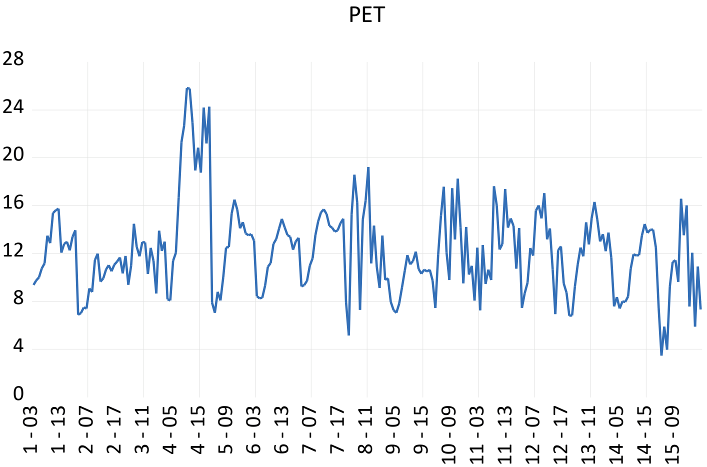
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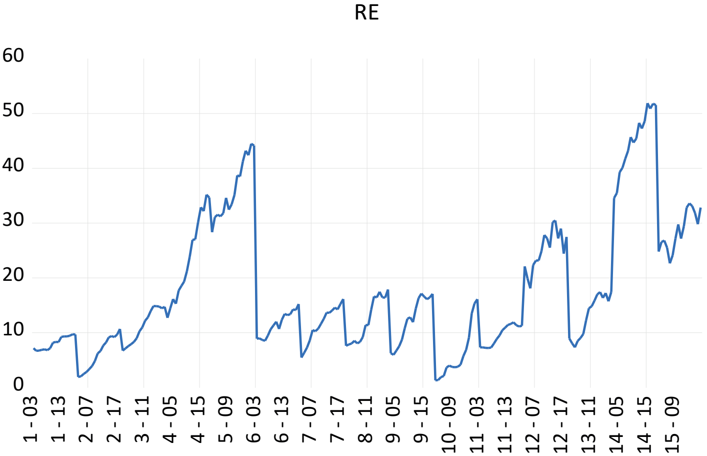
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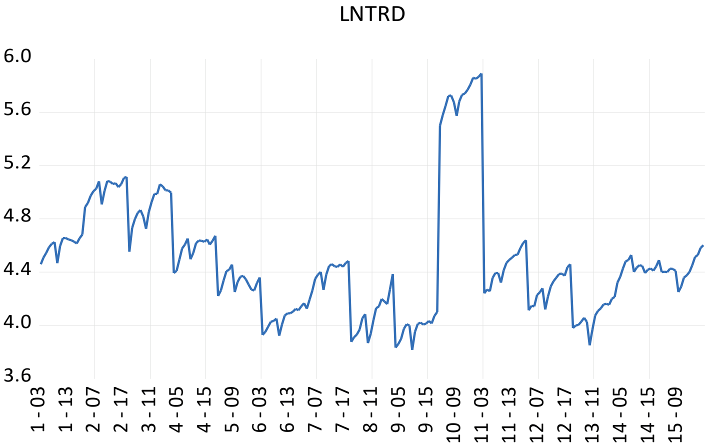
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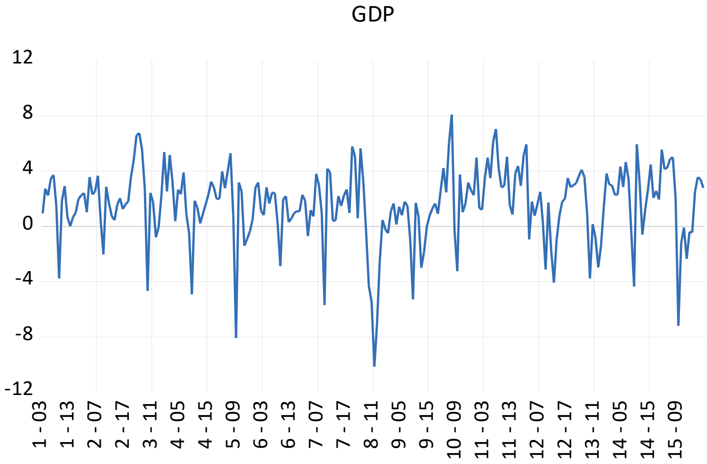
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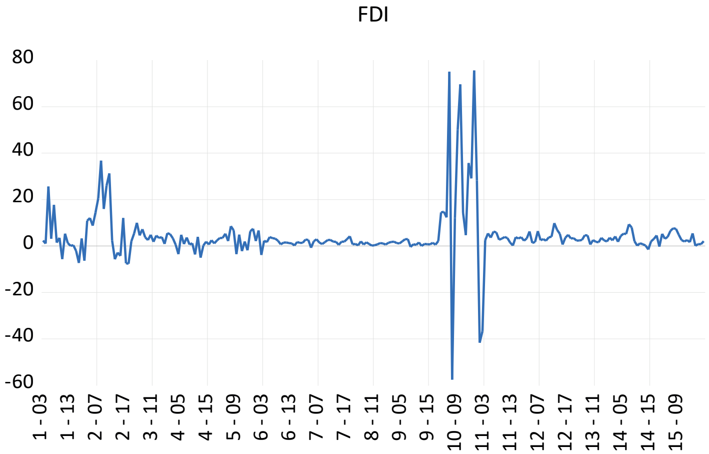

Figure 1. Graphical Representation of Variables

Analysing Figure 1, the highest value of the EF variable is observed in Italy, while other countries fluctuate at the same level. While the highest value in the RE variable is in Denmark, it can be said that there is a continuous fluctuation in other countries. In the PET variable, except for Denmark, the other countries fluctuate around the same level. The RE variable peaks in Denmark and Sweden. In the LNTRD variable, Italy again stands out compared to other countries. When GDP fluctuations are analysed, one can say that it is at the same level in general and that it bottomed out in certain periods only in Greece. Finally, in the FDI variable, it is observed that Luxembourg and Poland stand out from the other countries and peak, while there is no serious divergence in other countries.

Table 2. Descriptive Statistics of the Variables

	Observation	**Mean**	**Max.**	**Min.**	**Standard deviation**	**Skewness**	**Kurtosis**	**Jarque-Bera**
EF	240	6.127725	17.72611	3.548612	2.509035	2.523891	9.739703	709.0370 (0.0000)
ET	240	2.688417	5.100000	1.580000	0.692629	1.154946	4.210829	68.01708 (0.0000)
FDI	240	4.171841	75.63002	-57.5323	11.73261	2.169707	22.16710	3862.082 (0.0000)
GDP	240	1.577070	8.098668	-10.1493	2.702096	-1.07435	5.387270	103.1599 (0.0000)
GTI	240	12.21046	25.83000	3.470000	3.683523	0.858331	4.720105	59.05689 (0.0000)
LNTRD	240	4.484423	5.892815	3.815925	0.451572	1.299742	4.625821	94.00615 (0.0000)
RE	240	17.37912	51.91000	1.280000	12.06600	1.090462	3.323304	48.60957 (0.0000)

Note: Values in brackets indicate probability values.

According to the results of Table 2, it is seen that the series are skewed to the left since the skewness values of all variables except GDP are greater than zero, and the series are pointed since the kurtosis values of all variables are greater than 3.

3.2.2. Cross-Section Dependence Test

In panel data analyses, the existence of a cross-sectional relationship between variables should be examined before analysing hypothesis tests. This is because global issues increase the interdependence of countries day by day. Hence, a positive or negative shock to one of the countries in the sample may also affect other countries due to interdependence. In panel data analyses, first generation tests are used in studies that do not take cross section dependence into account and second generation tests are used in studies that take cross section dependence into account. First generation tests assume that the error terms of the cross-sections forming the panel are independent and that the shock occurring in any cross-section does not affect the others. Therefore, in case of cross-sectional dependence, the use of first generation tests will lead to biased results.

Since the time dimension (T=16) is larger (T>N) than the cross-sectional dimension (N=15), the cross-sectional dependence is analysed with the help of Breusch-Pagan (1980) CD_{lm1} test and Pesaran et al. (2008) (LM_{adj}) test and the findings are shown in Table 3.

Table 3. Cross-Section Dependence Results

Variables	**CD Tests**	**CD_{lm1} (BP, 1980)**	**CD_{lm2} (Pesaran, 2004)**	**CD (Pesaran, 2004)**	**LM_{adj} (Pesaran et al., 2008)**
EF	T statistic	734.0021*	43.0021*	24.9960*	42.9052*
	Probability Value	0.0000	0.0000	0.0000	0.0000
ET	T statistic	524.6860*	28.9610*	7.7089*	28.4610*
	Probability Value	0.0000	0.0000	0.0000	0.0000
FDI	T statistic	164.0927*	4.0777*	4.9487*	3.5778*
	Probability Value	0.0002	0.0000	0.0003	0.0000
GDP	T statistic	875.6217*	53.1779*	28.6990*	52.6779*
	Probability Value	0.0000	0.0000	0.0000	0.0000
GTI	T statistic	563.7069*	31.6537*	19.6561*	31.1537*
	Probability Value	0.0000	0.0000	0.0000	0.0000
LNTRD	T statistic	1037.2240*	64.3296*	30.6339*	63.8296*
	Probability Value	0.0000	0.0000	0.0000	0.0000
RE	T statistic	1358.3650*	86.4904*	36.6835*	85.9904*
	Probability Value	0.0000	0.0000	0.0000	0.0000

***Note:** *, ** and *** indicate that the coefficients are significant at 1%, 5% and 10% levels, respectively.*

According to the results of Table 3, all variables included in the model are statistically significant at 1% significance level. This result indicates the existence of cross-sectional dependence. In other words, there is cross-sectional dependence between countries and the result obtained is also compatible with the global world today and a shock effect that may affect one of the countries may also affect other countries. In conclusion, a policy change in environmental technologies and environmental tax policies of one of the countries included in the analysis can be interpreted as affecting other countries as well.

3.2.3. Panel Unit Root Test Results

Unit root tests are generally performed to avoid the problem of spurious regression. Granger and Newbold (1974) emphasise in their study that analyses with unit rooted series will not show real results. What is important in panel data analyses is whether the countries included in the analyses are independent of each other. In this context, unit root tests in panel data analyses consist of first generation and second generation tests. While first generation stationarity analyses disregard cross-sectional dependence, second generation stationarity analyses take cross-sectional dependence into account.

Since cross-sectional dependence is observed in the study, CADF unit root test, one of the second generation unit root tests developed by Pesaran (2007), is employed. The main reasons for choosing the CADF unit root test can be stated as follows;

- Considering the countries included in the model and the time dimension, it gives consistent results for cases where T>N. In the study, the cross-sectional dimension is N=15. The time dimension is T=15. Since T>N, the most preferred CADF unit root test in the literature is used.

- A test statistic value is calculated for all units forming the panel in the analyses, and then the CIPS (Cross Sectionally Augmented IPS) test statistic is calculated for the entire panel by taking the arithmetic mean of these tests.
- In the CADF test, the ADF regression is augmented with lagged cross-sectional averages. Thus, the regression model established with CADF is reduced to the OLS estimation of the regression specified in equation 1 (Pesaran, 2007: 269).

$$\Delta y_{it} = a_i + b_i y_{i,t-1} + c_i \bar{y}_{t-1} + d_i \Delta \bar{y}_t + e_{it}$$

The CADF and CIPS test statistic values obtained after the CADF unit root tests are compared with the critical table values in Pesaran's article, which are generated by Monte Carlo simulations, and the hypotheses for stationarity are tested. Here, if the calculated CADF and CIPS test statistic values are greater in absolute value than the critical table values, the null hypothesis (there is a unit root in the series) is rejected and the alternative hypothesis (there is no unit root in the series) is accepted for the relevant unit-panel (Pesaran, 2007: 265-312).

In the study, the CADF unit root test for the overall panel and the cross-sectional units forming the panel is analysed with the Fixed and Fixed-Trend Model and the results are presented in Table 4 and Table 5 with the Pesaran (2007) critical table values.

Table 4. CADF Unit Root Test Model Results with Constant

Country	EF	ΔEF	ET	ΔET	FDI	ΔFDI	GDP	ΔGDP	GTI	ΔGTI	LNTRD	ΔLNTRD	RE	ΔRE
Austria	-1.357	-3.68**	-2.27	-2.97	-5.41*	-3.53***	-2.66	-3.16***	-0.08	-1.55	-1.62	-3.38***	-0.76	-4.20**
Belgium	-1.72	-2.22	-3.08***	-3.48***	-4.31**	-3.35***	-1.78	-4.00**	-2.44	-3.57**	-1.81	-3.93**	-1.24	-4.04**
Czech Republic	-1.45	-2.16	-3.18***	-3.84***	-1.73	-4.55**	-0.83	-1.96	-1.08	-1.84	-3.20***	-4.48**	-0.36	-2.38
Denmark	-1.39	-2.86	-0.99	-2.82	-2.13	-4.00**	-3.15***	-4.83*	-3.31***	-4.44**	-3.26***	-3.41***	-1.73	-2.83
Finland	-1.27	-3.08***	-1.55	-2.79	-2.42	-2.26	-0.25	-4.28**	-1.58	-2.29	-2.71	-3.12***	-3.57**	-5.02*
France	-1.56	-3.01	-1.59	-2.25	-2.01	-3.11***	-1.28	-4.41**	-2.66	-3.11***	-1.90	-2.43	-1.55	-3.50***
Germany	-1.04	-2.27	-1.17	-2.88	-2.12	-2.55	-2.41	-4.17**	-2.24	-2.41	-1.58	-2.76	-1.73	-4.53**
Greece	-1.61	-2.83	-1.54	-1.77	-2.65	-2.23	-1.38	-2.06	-1.65	-2.28	-1.47	-4.92*	-1.43	-2.81
Italy	-1.89	-4.04**	-2.5	-3.96**	-8.35*	-5.30*	-3.44***	-5.94*	-1.12	-2.97	-1.30	-1.95	-1.56	-3.89**
Luxemburg	-1.33	-2.20	-3.59**	-4.95*	-5.10*	-3.13***	-1.98	-2.89	-0.55	-1.65	-1.48	-2.38	-1.59	-3.52***
Poland	-1.57	-2.68	-2.45	-3.83**	-1.07	-3.13***	-1.75	-2.34	-1.66	-2.30	-4.28**	-4.66*	-0.75	-1.19
Portugal	-1.29	-2.56	-2.13	-2.96	-2.7	-1.73	-2.59	-6.07*	-2.02	-2.44	-3.13***	-4.73*	-1.58	-2.21
Spain	-1.95	-3.09***	-2.86	-2.85	-2.99	-3.39***	-1.36	-3.02	-3.44***	-3.93**	-1.89	-3.38***	-2.04	-2.86
Sweden	-2.27	-6.84*	-1.97	-3.64**	-2.64	-5.66*	-2.92	-7.05*	-2.26	-2.65	-2.31	-3.92**	-2.12	-3.73**
Croatia	-2.73	-4.45**	-2.15	-5.11*	-2.18	-2.94	-1.71	-3.40***	-1.63	-1.98	-2.09	-4.54**	-1.24	-5.52*
CIPS statistic	-1.63	-3.20*	-2.14	-3.64**	-2.19**	-3.39*	-1.97	-3.97**	-1.85	-2.63*	-2.27***	-3.60*	-1.55	-3.48*

NOTE: 1) CADF table critical values for the model with constants: %1: -4.65 %5: -3.57 %10: -3.08

CIPS table critical values: %1: -2.52 %5: -2.28 %10: -2.16

2) The signs (*), (**) and (***) indicate stationary at 1%, 5% and 10% significance levels, respectively.

3) Lag lengths are chosen according to the Schwarz information criterion.

Table 5. CADF Unit Root Test Model Results with Constant and Trend

Country	EF	ΔEF	ET	ΔET	FDI	ΔFDI	GDP	ΔGDP	GTI	ΔGTI	LNTRD	ΔLNTRD	RE	ΔRE
Austria	-2.65	-3.57	-2.14	-2.85	-4.01***	-3.41	-2.97	-3.07	0.54	-2.32	-2.04	-3.16	-3.78***	-4.08***
Belgium	-1.93	-1.88	-2.84	-3.30	-3.31	-3.36	-1.68	-3.84***	-1.34	-3.57	-2.43	-3.62	-2.19	-4.77**
Czech Republic	-2.24	-1.73	-2.85	-3.55	-2.10	-5.57*	-0.25	-2.24	0.05	-2.68	-3.17	-4.11***	-0.37	-3.64***
Denmark	-1.05	-2.70	-2.61	-2.86	-1.56	-5.25**	-5.41**	-4.43**	-2.74	-4.24**	-3.04	-3.12	-1.18	-3.67***
Finland	-0.87	-2.77	-2.07	-2.99	-2.18	-2.25	-2.66	-3.90***	-2.30	-2.13	-2.60	-2.81	-3.08	-5.33**
France	-1.12	-2.97	-1.91	-2.14	-3.94***	-2.72	-5.18**	-4.07***	-2.77	-2.96	-1.99	-2.00	-2.08	-3.22
Germany	-0.82	-2.11	-1.36	-3.23	-2.76	-2.58	-4.34**	-4.01***	-2.36	-2.26	-1.57	-2.43	-3.78***	-4.18**
Greece	-2.24	-2.61	-1.62	-2.00	-2.59	-2.15	-1.31	-2.82	-1.49	-2.92	-3.68***	-4.41**	-3.36	-2.60
Italy	-3.54	-3.72***	-3.85***	-3.92***	-6.22*	-4.82**	-3.27	-7.49*	-0.96	-4.89**	-2.17	-1.43	-2.55	-3.80***
Luxemburg	-0.95	-1.92	-4.06***	-4.59**	-4.02***	-2.81	-2.39	-2.66	-0.45	-2.63	-1.06	-2.75	-1.61	-3.73***
Poland	-1.49	-2.27	-2.35	-3.52	-1.80	-2.88	-1.87	-2.18	-1.19	-2.24	-4.01***	-4.24**	-0.26	-2.35
Portugal	-1.11	-2.25	-2.42	-2.66	-2.24	-1.62	-4.44**	-5.65*	-1.37	-2.33	-3.31	-4.27**	-1.35	-2.28
Spain	-1.86	-2.79	-2.72	-2.62	-2.76	-3.06	-3.15	-2.77	-3.67***	-3.63***	-2.74	-2.93	-2.44	-2.82
Sweden	-4.58**	-6.39*	-2.12	-3.47	-3.58	-5.15**	-4.30**	-6.59*	-2.07	-2.42	-2.75	-3.44	-1.79	-4.50**
Croatia	-2.61	-4.58**	-2.46	-6.02*	-2.49	-2.80	-2.07	-3.43	-1.19	-1.98	-2.56	-4.12***	-3.50	-5.92*
CIPS statistic	-1.94	-2.95**	-2.49	-3.32*	-3.04**	-3.36*	-2.59	-3.94*	-1.55	-2.88**	-2.64	-3.26*	-2.19	-3.79*

NOTE: 1) CADF table critical values for Model with Constant and Trend: %1: -5.46 %5: -4.17 %10: -3.63

CIPS table critical values: %1: -3.09 %5: -2.83 %10: -2.69

2) The signs (*), (**) and (***) indicate stationary at 1%, 5% and 10% significance levels, respectively.

3) Lag lengths are chosen according to the Schwarz information criterion.

Looking at the results of Table 4 and Table 5, it is seen that all variables except FDI are unit rooted at level. When differentiated, all variables are stationary at different significance levels. The FDI variable, in contrast, is stationary at the 5% level of significance at the level, but when it is differentiated, it can be said that the degree of significance is strengthened and it becomes stationary at the 1% level. The results show that all variables are stationary at I(I) level according to the CADF unit root test model with constant. When country-based statistical values are analysed, it is seen that each country has different unit root results on the basis of variables. Nevertheless, the fact that all variables in the panel become stationary when all variables are differenced shows that the variables are I (I) in the Durbin-Hausman cointegration test, which is the cointegration test to be used in the next section of the study, and that the sufficient condition for the analysis is met.

3.2.4. Homogeneity Test

In panel data analysis methods, it is required to decide whether the coefficients of the variables assumed to have a long run cointegration relationship are homogeneous or not. The homogeneity test examines whether the change in one of the countries affects the other countries at the same level. The homogeneity of the slope coefficients in the panel cointegration equation is investigated with the help of $\tilde{\Delta}$ (delta) and $\tilde{\Delta}\ adj$ (adjusted delta) tests developed by Pesaran and Yagamata (2008). Delta test is valid for large samples and Delta adj test is valid for small samples. In the homogeneity test, the null hypothesis (H_0) is interpreted as "slope coefficients are homogeneous" and the alternative hypothesis (H_1) is interpreted as "slope coefficients are heterogeneous". If the result of the homogeneity test reveals that the slope coefficients are heterogeneous, the long-run relationship between the variables is investigated with the second generation cointegration test that takes this situation into account.

The homogeneity test results of the variables are presented in Table 6.

Table 6. Homogeneity Test Results

Test Statistics	Statistic Value	Probability Value
Delta_tilde	6.990*	0.000
Delta_tilde_adj	9.886*	0.000

Note: *, ** and *** indicate that the panel coefficients are heterogeneous at 1%, 5% and 10% significance levels, respectively.

According to the homogeneity test results in Table 6, the H_0 hypothesis based on the homogeneity of the coefficients in the Delta test is rejected at 1% significance level and it is decided that the coefficients are heterogeneous. This reveals that the effect of a change in the variables included in the model on the EF differs from country to country.

3.2.5. Panel Cointegration Test Results

Following the determination of the stationarity degrees of the variables, cointegration relationship should be examined for the existence of a long-run relationship. The existence of a long-run relationship in panel data analyses is performed with the methods most frequently used in Pedroni (1999), Pedroni (2007), Westerlund

(2008), Westerlund and Edgerton (2007) studies in the literature. However, as in unit root tests, cross-sectional dependence must be considered in cointegration analyses. Otherwise, problems such as accepting the hypothesis that there is a cointegration relationship when there is no cointegration relationship may be encountered. Due to this problem, the Durbin-Hausman analysis developed by Westerlund (2008), which takes into account the cross-section dependence, is used in this study. There are several reasons for using the Durbin - Hausman test developed by Westerlund (2008). The most important advantage of the test is that it is a second generation panel cointegration test that accounts for cross-sectional dependence. It also allows independent variables to be I(0) or I(I) while the dependent variable must be I(I) (Westerlund, 2008: 205). In addition to these, the Durbin-Hausman cointegration test allows both the parameters in the panel to be the same (homogeneous) across units and the parameters to differ (heterogeneous) across units. *DH Panel* test statistic is used if the parameters are homogeneous across units, and *DH Group* test statistic is used if the parameters are heterogeneous.

According to the results of the Delta test developed by Pesaran and Yamagata (2008), the coefficients are heterogeneous. Therefore, it can be stated that DH Group test statistical results will give more reliable results in the cointegration test. Durbin-Hausman cointegration test results are reported in Table 7.

Table 7. Durbin-Hausman Cointegration Test Results

Test Statistics	**Statistic Value**	**Probability Value**
Durbin-H Group Statistic	17.780*	0.000
Durbin-H Panel Statistic	18.526*	0.000

Note: *, ** and *** indicate that there is a long-run relationship between the variables at 1%, 5% and 10% significance level, respectively.

Since it is determined that it would be more appropriate to use group statistics in the study according to the result that the slope coefficients change and the variables are heterogeneous in Table 7, the results of Durbin-H Group statistics are used. When the probability values of the Durbin-H Panel statistic are analysed, it is concluded that there is a long-run relationship between the variables since it is less than 0.05. Therefore, it is concluded that there is a long-run relationship between environmental technologies and environmental tax policies and EF in selected EU countries. This outcome shows the importance of determining the long-run relationship of the variables, since the effects of the practices aimed at improving environmental quality will manifest themselves in the long run.

3.2.5. Kónya Causality Test

Kónya (2006) developed the test that examines the existence of causal relationships between variables by using the Seemingly Unrelated Regressions (SUR) estimator introduced to the literature by Zellner (1962). One of the advantages of this test is that since the panel is assumed to be heterogeneous, causality tests can be applied separately for the countries belonging to the panel. Another important advantage of this test is that it is not necessary to apply unit root and cointegration tests since country-specific critical values are generated. If the Wald statistic calculated for each country after applying the test is greater than the critical values at the significance level, the null hypothesis “there is no causality between the variables” is rejected. In other words, when the Wald statistic is greater than the critical value, it is concluded that there is causality between the variables.

Table 8. Kónya Causality Results

Country	H_0: EF $\nrightarrow$ ET			
		Critical Values		
	Wald Statistics	%1	%5	%10
Austria	1.015	558.555	281.446	197.822
Belgium	6.739	1075.562	277.557	228.337
Czech Republic	1.19	784.784	367.501	206.426
Denmark	132.066	2169.455	300.027	259.045
Finland	64.826	738.96	357.703	189.048
France	57.297	1650	401.663	221.762
Germany	141.325	1220.322	445.414	273.231
Greece	166.182	1574.476	430.835	273.226
Italy	5.315	1439.013	395.224	213.131
Luxemburg	169.616	1203.391	605.776	287.201
Poland	48.181	2037.409	248.578	191.525
Portugal	6.249	1860.49	388.407	227.482
Spain	159.019	846.243	424.211	239.321
Sweden	83.149	2336.902	390.162	261.626
Croatia	50.251	526.87	266.898	210.101

Country	H_0: ET $\nrightarrow$ EF			
		Critical Values		
	Wald Statistics	%1	%5	%10
Austria	0.873	1100.36	204.553	178.782
Belgium	86.732	327.019	194.719	168.141
Czech Republic	97.746	731.741	222.271	186.454
Denmark	164.26	1824.478	333.929	205.539
Finland	162.376***	460.096	168.463	151.827
France	15.3	524.856	209.896	163.744
Germany	128.232	597.484	213.281	158.9
Greece	150.996	797.171	229.532	185.39
Italy	146.114	460.815	226.091	160.201
Luxemburg	64.605	298.215	218.685	158.736
Poland	76.197	1010.297	254.639	177.086
Portugal	18.679	858.86	255.592	192.659
Spain	111.379	479.747	210.656	187.661
Sweden	158.289	559.566	236.165	169.713
Croatia	161.142	667.452	465.991	192.331

Country	H_0: EF $\nrightarrow$ FDI			
		Critical Values		
	Wald Statistics	%1	%5	%10
Austria	463.249***	1197.194	568.521	199.071
Belgium	401.41***	859.771	459.068	238.875
Czech Republic	19.419	1410.857	867.943	228.584
Denmark	2.512	1764.358	556.017	206.964
Finland	109.964	1331.678	283.386	197.794
France	27.85	1524.055	294.243	184.597
Germany	29.246	1090.75	578.548	354.203
Greece	314.805***	882.559	420.567	221.993
Italy	1.999	859.367	606.852	322.508
Luxemburg	355.585***	1179.06	378.136	202.666
Poland	402.287**	1898.828	198.14	159.098
Portugal	10.234	1144.608	435.771	199.592
Spain	204.257	719.837	454.905	229.965
Sweden	460.959***	6355.758	502.057	293.098
Croatia	460.261**	1004.123	328.695	173.553

Country	H_0: FDI $\nrightarrow$ EF			
		Critical Values		
	Wald Statistics	%1	%5	%10
Austria	6.37	847.592	309.156	198.626
Belgium	16.468	1004.58	316.587	195.467
Czech Republic	224.041**	289.352	209.373	157.988
Denmark	114.505	564.153	354.756	244.386
Finland	145.203	2188.739	549.11	252.458
France	204.766***	366.787	216.808	184.212
Germany	174.233	3966.529	713.821	230.352
Greece	184.316	1307.882	339.458	199.182
Italy	56.595	2550.482	412.591	209.499
Luxemburg	0.092	561.374	266.626	184.507
Poland	167.901	1245.8	477.44	231.755
Portugal	28.953	443.799	363.148	187.644
Spain	68.875	567.92	336.07	246.259
Sweden	231.499***	729.334	260.093	208.746
Croatia	5.865	1872.881	405.742	314.068

Country	H_0: EF $\nrightarrow$ GDP			
		Critical Values		
	Wald Statistics	%1	%5	%10
Austria	113.495	1688.92	541.575	270.228
Belgium	110.973	1615.956	374.741	214.624
Czech Republic	113.768	2583.267	630.494	283.747
Denmark	77.232	541.811	231.396	174.188
Finland	136.065	540.301	362.257	246.439
France	66.827	1661.354	371.902	228.96
Germany	114.435	2574.391	723.603	361.353
Greece	140.444	1306.829	401.528	301.713
Italy	23.605	1297.749	421.538	198.909
Luxemburg	0.199	4591.092	803.736	397.482
Poland	38.051	2831.622	364.33	169.622
Portugal	91.173	891.29	367.981	245.027
Spain	111.686	983.784	426.725	197.663
Sweden	7.392	2381.36	304.856	245.135
Croatia	51.982	751.492	559.931	349.486

Country	H_0 : GDP $\nrightarrow$ EF			
		Critical Values		
	Wald Statistics	%1	%5	%10
Austria	47.094	5964.387	161.019	143.519
Belgium	43.67	227.834	165.716	147.476
Czech Republic	46.086	325.262	217.441	158.377
Denmark	34.916	282.895	203.703	149.26
Finland	46.848	677.892	287.246	150.012
France	46.496	504.613	283.667	154.937
Germany	42.644	348.047	214.132	154.774
Greece	46.497	1294.092	258.451	166.434
Italy	46.401	559.792	213.969	163.905
Luxemburg	46.468	851.813	355.094	186.676
Poland	46.785	261.297	202.603	159.949
Portugal	46.336	748.094	184.342	145.239
Spain	45.601	2579.685	232.141	146.429
Sweden	34.639	305.959	170.664	149.574
Croatia	46.655	491.193	248.528	170.904

Country	H_0: EF $\nrightarrow$ GTI			
		Critical Values		
	Wald Statistics	%1	%5	%10
Austria	75.448	3226.479	340.081	184.254
Belgium	114.156	1539.973	618.141	303.147
Czech Republic	10.753	3027.462	583.129	213.452
Denmark	102.565	385.272	205.846	157.749
Finland	129.511	823.959	456.506	221.47
France	128.529	1345.665	397.399	228.685
Germany	60.878	1622.452	307.232	191.833
Greece	131.77	10550.9	434.06	242.833
Italy	99.466	2612.794	837.743	275.268
Luxemburg	136.151	11128.58	436.297	267.38
Poland	98.502	5201.076	645.767	250.951
Portugal	40.73	2526.079	442.097	262.46
Spain	133.53	3407.133	644.223	309.187
Sweden	112.39	1856.644	468.862	193.007
Croatia	120.92	1542.612	840.449	402.456

Country	H_0 : GTI $\nrightarrow$ EF			
		Critical Values		
	Wald Statistics	%1	%5	%10
Austria	145.748	1202.983	188.696	168.381
Belgium	103.159	355.683	197.358	151.208
Czech Republic	134.886	698.304	171.444	149.659
Denmark	110.132	1070.355	254.357	164.501
Finland	66.372	604.629	230.853	151.151
France	90.707	1865.407	229.545	177.09
Germany	69.98	545.644	221.476	156.427
Greece	95.148	1371.747	168.301	143.955
Italy	125.476	463.064	203.185	150.904
Luxemburg	110.263	1337.242	167.589	149.624
Poland	117.709	574.404	249.6	150.521
Portugal	55.518	2360.254	244.722	186.682
Spain	87.759	435.981	156.162	140.349
Sweden	74.921	546.608	257.566	169.173
Croatia	18.53	1525.752	184.462	163.051

Country	H_0: EF $\nrightarrow$ LNTRD			
		Critical Values		
	Wald Statistics	%1	%5	%10
Austria	-217.324	1184.789	335.24	235.517
Belgium	-77.475	709.524	340.68	231.335
Czech Republic	-54.245	3566.956	432.161	268.384
Denmark	-42.258	694.198	352.507	193.318
Finland	-43.897	881.825	259.505	199.811
France	-36.51	460.191	355.856	239.709
Germany	-33.148	1138.66	287.911	256.812
Greece	-37.534	2064.329	686.271	230.442
Italy	-34.812	2615.966	350.87	247.745
Luxemburg	-33.119	831.603	457.448	272.843
Poland	-33.636	2351.303	448.494	247.482
Portugal	-35.966	701.791	310.45	153.808
Spain	0.056	599.459	257.114	193.07
Sweden	-48.819	804.806	395.921	209.413
Croatia	4.508	4816.394	326.01	238.294

Country	H_0 : LNTRD $\nrightarrow$ EF			
		Critical Values		
	Wald Statistics	%1	%5	%10
Austria	-11.279	5366.87	260.806	166.49
Belgium	-2.378	3740.937	507.029	131.149
Czech Republic	-57.765	1749.152	508.918	213.237
Denmark	-200.27	3327.695	440.465	230.081
Finland	163.444	11508.6	553.663	254.344
France	-108.441	1222.937	191.318	138.454
Germany	92.942	3561.116	448.661	163.414
Greece	13.977	3192.899	626.961	223.069
Italy	-115.789	3563.923	708.76	279.765
Luxemburg	48.874	1695.495	504.855	147.388
Poland	-12.502	10561.72	491.727	295.269
Portugal	38.017	2566.102	373.803	90.083
Spain	67.314	11975.28	840.831	110.912
Sweden	40.626	12708.97	540.415	199.036
Croatia	32.182	5147.159	936.76	151.489

Country	H_0: EF $\nrightarrow$ RE			
		Critical Values		
	Wald Statistics	%1	%5	%10
Austria	82.66	713.856	381.109	188.466
Belgium	0.804	709.515	181.398	105.1
Czech Republic	12.374	482.637	260.715	119.017
Denmark	1.26	4033.082	288.604	122.574
Finland	2.33	903.283	186.699	108.857
France	1269.465**	2877.194	280.727	144.36
Germany	425.159**	743.502	296.417	139.255
Greece	282.341***	1757.558	449.257	99.572
Italy	305.013***	3265.7	1375.428	303.349
Luxemburg	330.099*	283.632	160.689	122.676
Poland	-895.046*	417.803	130.026	82.925
Portugal	233.676**	375.677	113.421	81.274
Spain	9.475	263.043	166.127	101.041
Sweden	0.855	1836.975	250.782	119.664
Croatia	0.712	1789.951	187.48	70.408

Country	H_0 : RE $\nrightarrow$ EF			
		Critical Values		
	Wald Statistics	%1	%5	%10
Austria	107.199***	137.11	126.192	80.294
Belgium	71.645	467.053	157.725	81.551
Czech Republic	125.59***	857.545	219.633	118.497
Denmark	32.997	495.252	182.468	93.871
Finland	74.561	166.805	130.261	91.875
France	8.913	2688.062	262.654	140.958
Germany	11.049	324.175	163.992	104.36
Greece	8.521	508.495	166.798	114.379
Italy	21.614	811.804	248.87	147.014
Luxemburg	14.847	656.033	158.24	96.237
Poland	101.678	975.582	382.625	146.896
Portugal	187.151***	3065.942	474.634	153.367
Spain	17.382	1195.293	326.255	141.532
Sweden	1.049	1413.697	248.736	74.523
Croatia	4.083	516.25	228.814	123.852

Note:* *, ** *and* *** *indicate that there is causality from the first variable to the second variable at 1%, 5% and 10% significance level, respectively.

According to Table 8, where the results of Konya Causality analyses are reported collectively;

- The relationship between environmental taxes (ET) and ecological footprint (EF) is identified at the 10% level in Finland.
- There is a relationship between ecological footprint (EF) and foreign direct investment (FDI) at 5% significance level in Poland and Croatia, and at 10% significance level in Austria, Belgium, Greece, Luxemburg and Sweden.
- There is a unidirectional relationship from foreign direct investment (FDI) to ecological footprint (EF) at 5% significance level in Czech Republic, 10% significance level in France and Sweden.
- The relationship from ecological footprint (EF) to renewable energy (RE) is found at 1% significance level in Luxemburg and Poland, 5% in France, Germany and Portugal, and 10% in Greece and Italy.
- A unidirectional causality relationship from renewable energy (RE) to ecological footprint (EF) is detected at 10% significance level in Austria, Czech Republic and Portugal.

No causality relationship is detected between other variables.

Conclusion and Policy Implications

Today, increasing environmental concerns have accelerated businesses' and governments' search for environmentally friendly solutions. In this context, environmental technologies and tax policies stand out as the cornerstone of sustainability efforts. Environmental technologies provide innovative solutions that minimise environmental impacts, while environmental tax policies offer economic incentives to promote environmental responsibilities and offset adverse effects. The combination of these two factors supports businesses' efforts to reduce their ecological footprint while also contributing to ensuring social and economic sustainability.

Environmental technologies include innovative solutions that enable efficient use of natural resources, increase energy efficiency, and minimise waste generation. While these technologies help businesses reduce their environmental impact, they also provide a competitive advantage and support economic growth. Adopting these technologies helps companies reduce costs and achieve environmental sustainability through energy efficiency while narrowing their ecological footprint. Environmental taxes aim to reduce environmental damage, raising the cost of pollution and rewarding environmentally friendly behaviour. These policies can be implemented in various ways, such as carbon taxes that encourage reducing fossil fuel use or waste taxes that aim to reduce waste generation. Environmental tax policies accelerate the adoption of environmental technologies and help reduce the ecological footprint by directing businesses and individuals to more sustainable alternatives.

This study aims to examine the long-term relationship between EF and environmental technologies and environmental taxes. Accordingly, while EF was determined as the dependent variable, environmental technologies, Patents on environmental technologies and renewable energy were included in the model as independent variables.

According to the panel cointegration test results, a long-term relationship was determined between environmental technologies, environmental taxes, and ecological footprint. According to the results of the Konya causality analysis, it was found that there is a causal relationship between the variables included in the model and the ecological footprint in different countries included in the analysis. The findings obtained from these analyses are consistent with the results reported in the studies by Bashir et al. (2020), Danish et al. (2020), Murshed et al. (2021), Sadiq et al. (2022), Hussain et al. (2022), Radmehr et al. (2022), Shayanmehr et al. (2023), and Kirikkaleli et al. (2023).

In light of the findings of our study, it is suggested that governments make moves on environmental taxes, environmental technologies and renewable energy to reduce environmental degradation. First, the implementation of environmental taxes can represent an effective approach to creating a lower ecological footprint environment. For instance, tax reductions, exemptions, or supplementary financial incentives may be provided to businesses actively engaged in green technological innovations to mitigate the adverse impacts of conventional production technologies. Second, incremental tax policies can be used as a policy measure to prevent investment in high energy-consuming projects. Accordingly, financial institutions can help support projects that will increase energy efficiency by providing low-interest financing. Third, the impact of environmental technologies on EF implies the need for initiatives to promote green technology through the regulatory restructuring of financial markets. Fourth, the substitution of conventional energy sources with renewable alternatives has the potential to mitigate the extent of environmental degradation in the selected European Union countries. Finally, to facilitate the adoption of cleaner technologies aimed at EF reduction, the government should establish licensing protocols and offer financial assistance to energy companies pursuing such projects, thereby addressing their concerns. In this context, leveraging existing collaborative frameworks among government, the public, and private entities, the state can safeguard the integrity of public goods, including but not limited to natural resources such as mines and forest reserves.

This study is subject to certain limitations that may serve as a catalyst for the development of future research endeavours. As a result of constrained data accessibility, the temporal scope of this study is confined to a duration of 16 years. Future studies could consider employing more extensive datasets encompassing diverse global regions, potentially yielding disparate outcomes. In conclusion, the expansion of this study to incorporate supplementary variables, such as political risk, economic policy uncertainty, green finance, and institutional quality, within diverse case studies holds the potential to make noteworthy contributions to the existing literature.

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