THE IMPACT OF GREEN TAXATION ON SUSTAINABLE ECONOMIC DEVELOPMENT IN THE EUROPEAN UNION

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Abstract

In the context of accelerating the European Union's transition towards a sustainable economic model, green taxation plays a central role in strategies to reduce carbon emissions and stimulate responsible economic behaviour. Through initiatives such as the European Green Deal and the Border Carbon Adjustment Mechanism, the European Union aims to integrate sustainability principles into national tax systems, promoting a just transition towards a circular and low-emission economy. The study analyses the impact of green taxation on sustainable economic development in the European Union, using econometric multiple linear regression methods applied to a dataset for the 27 Member States covering the period 2010-2022. The results of the study indicate that energy and transport taxes are the main determinants of green taxation, having a direct impact on the share of environmental taxes in gross domestic product (GDP). The econometric evidence also shows that, while taxation of polluting activities may generate short-term costs for some industries, in the long run, green taxation stimulates innovation and investment in clean technologies, thus contributing to sustainable economic growth. The findings underline the need for coherent public policies at the EU level aimed at harmonizing the application of green taxes, supporting less developed economies in adopting environmentally efficient taxes and redistributing tax revenues to minimize the social impact of the green transition. It is recommended to gradually integrate environmental taxes with other forms of taxation, reduce the tax burden on labour and implement border adjustment mechanisms to safeguard the competitiveness of European industry. These measures will help create a more balanced fiscal framework that supports both climate objectives and sustainable economic development. However, the study has certain limitations, such as variations in national tax policies between Member States and potential challenges in isolating the effects of environmental taxation from other economic and environmental factors.

Keywords

green taxation, sustainable economic development, environmental taxes, European Union, green tax policies, multiple linear regression, econometric analysis

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Introduction

In the context of the European Union's transition towards a sustainable economic model, green taxation has become an essential tool to internalize the costs associated with pollution and to stimulate responsible behaviour in terms of natural resource use. Through strategies such as the European Green Deal (European Commission, 2023a) and the Action Plan for a Circular Economy (European Commission, 2023b), the European Union is committed to reducing greenhouse gas emissions, encouraging the transition to renewable energy sources and integrating sustainability principles into national economic systems. Environmental taxes, particularly those on energy, transport and consumption of non-renewable resources, were conceived not only as sources of budgetary revenue, but also as regulatory instruments to steer Member States' economies towards green and balanced growth. However, the application of green taxation varies significantly across EU economies and is influenced by the level of economic development, the national tax structure and the policy priorities of each Member State. The implementation of green taxation in the EU Member States faces significant challenges due to differences in the economic structure, level of development, energy dependence and policy priorities of each country. These disparities create difficulties in harmonizing environmental tax policies at the European level, raising issues of economic competitiveness and tax equity. Through econometric analysis and recommendations based on empirical evidence, this study aims to support policymakers in designing effective public policies that balance environmental protection objectives with the needs of economic development and social sustainability.

This study aims to analyse the impact of green taxation on sustainable economic development in the European Union, highlighting the relationship between the level of environmental taxes and economic determinants such as GDP, labour and consumption taxation, and sustainability policies implemented at national and European level. The study aims to examine the extent to which environmental taxes contribute to sustainable economic growth, whether they are an obstacle to economic competitiveness or, on the contrary, a benefit for innovation and the transition towards a low-carbon economic model.

The objectives of the study are the following:

O1. Literature review on the evolution of environmental taxation in the European Union

O2. To design an econometric model on the impact of green taxation on economic growth and the transition to a sustainable model

O3. To formulate public policy recommendations aimed at improving the use of green taxes as regulatory instruments, while maintaining the balance between environmental protection and economic growth.

The novelty of the research lies in addressing the interaction between green taxation and sustainable economic development, integrating both macroeconomic data analysis for Member States and an assessment of public policies applied in the field of green taxation. Unlike previous studies (Delgado et al., 2022; Ghazouani et al., 2021; Wolde-

Rufael & Mulat-weldemeskel, 2023), which have focused either on the economic impact of environmental taxes or on the analysis of sustainability policies, this research seeks to link the fiscal, economic and environmental dimensions, highlighting trends and disparities in the application of environmental taxation between EU countries.

This study formulates three fundamental hypotheses that explore the relationship between green taxation and sustainable economic development in the European Union. The first hypothesis argues that an increase in energy taxes leads to a significant increase in the share of environmental taxes in GDP, given that energy consumption taxes are a key fiscal instrument through which Member States discourage the use of fossil fuels and stimulate the transition to renewable energy sources. Thus, it is expected that countries with higher energy taxation will see a more pronounced increase in tax revenues from environmental taxes, while reinforcing sustainability and greenhouse gas reduction objectives.

eduction objectives.

The second hypothesis assumes that taxes imposed on transport, excluding fuel taxes, have a significant positive impact on environmental tax revenues, contributing to their increase. This relationship is motivated by the fact that transport taxes, such as those associated with vehicle registration, road infrastructure use or pollutant emissions from motor vehicles, play a key role in discouraging the use of high-emitting modes of transport and promoting sustainable mobility. Therefore, an increase in these taxes could lead not only to an increase in the share of environmental taxes in GDP, but also to a gradual shift in consumer and business behaviour towards greener transport solutions.

Finally, the third hypothesis examines the extent to which the level of economic development influences the extent to which environmental taxes are levied, arguing that an increase in GDP leads to a significant increase in the share of environmental taxes in the economy. This hypothesis is based on the premise that more developed economies, with more robust financial and institutional resources, are more likely to implement ambitious fiscal policies that support the environmental transition. In this respect, Member States with higher GDP are expected to apply higher environmental taxes, not only to comply with international climate change commitments, but also to protect their economies from the long-term effects of environmental degradation. Thus, the econometric analysis will test whether this relationship is valid at the EU level and whether it can serve as an argument for the development of differentiated tax policies tailored to the level of economic development of each Member State.

ach Member State.

By investigating these hypotheses, the study aims to contribute to a better understanding of how green taxation can be used as an effective tool to stimulate sustainable economic development and to harmonize fiscal policies at the European level to accelerate the transition towards a low-carbon economic model.

1. Review of the scientific literature

Green taxation is an essential tool in sustainable economic development strategies, internalizing the negative externalities of economic activities and stimulating investment in clean technologies. Studies have consistently highlighted the complex

relationship between green taxation and economic growth, analysing both the direct impact of environmental taxes on government revenues and the long-term effects on innovation and economic competitiveness.

Green tax developments in the European Union

Recent studies have shown that the European Union has been a pioneer in integrating sustainability principles into fiscal policy, with initiatives such as the European Green Pact (European Commission, 2023a) and the Border Carbon Adjustment Mechanism (European Commission, 2025). The implementation of these measures has led to a significant increase in the share of environmental taxes in Member States' GDP, in particular by taxing energy consumption and polluting transport. According to various expert studies (Carfora et al., 2021; Degirmenci & Yavuz, 2024; Dogan et al., 2023), member States with higher environmental taxes have seen a decrease in greenhouse gas emissions and an increase in investment in renewable energy sources. Other studies (Glavaški et al., 2023; Nadiri et al., 2024; Štreimikienė et al., 2022) the authors found that greater harmonization of environmental tax policies across Member States could improve economic efficiency and reduce disparities between developed and emerging economies. The results of studies by Darvas & Wolff (Darvas & Wolff, 2023), Li et al. (Y. Li et al., 2023) and (Kantorowicz et al., 2024) showed that European fiscal policies oriented towards environmental taxes have a positive impact on investments in green infrastructure such as public transport and wind energy. Moreover, Chenavaz & Dimitrov (Chenavaz & Dimitrov, 2024) highlight that strict tax regulations coupled with public financing strategies stimulate innovation in circular economy sectors. According to research by the authors Antimiani et al. (Antimiani et al., 2023), emissions pricing mechanisms, when implemented coherently at the European level, can accelerate the transition to a climate-neutral economy by reducing dependence on fossil fuels. Based on the findings of the study by the authors Z. Li et al. (Z. Li et al., 2024) shows that well-designed green fiscal policies, such as progressive carbon taxation and subsidizing green innovations, can have a positive economic impact, creating jobs in emerging sectors of the sustainable economy. Studies by Trinh et al. (Trinh et al., 2023), Ullah et al. (Ullah et al., 2024) indicate that the integration of environmental taxes into general taxation, in combination with government investment in green infrastructure, can help reduce economic inequality and accelerate the transition to a sustainable economic model. Another relevant aspect is highlighted by the authors' research, Hillson & Winfield (Hillson & Winfield, 2024), who have emphasized that a coherent environmental tax policy must include safeguards for vulnerable industries to avoid de-industrialization and the relocation of production to more lightly regulated economies. Along these lines, studies by the authors Fontagné & Schubert (Fontagné & Schubert, 2023) and Pander Maat (Pander Maat, 2024) emphasizes the importance of border adjustment mechanisms to ensure competitive equity and to prevent the externalization of emissions to emerging economies without strict environmental policies. Moreover, the authors' research Rosales-Asensio et al. (Rosales-Asensio et al., 2024) have shown that emissions taxation and the creation of regulated markets for green certificates have led to improvements in energy efficiency in European industries, while stimulating innovation in renewable energy. In this context, the authors' studies, Ali et al. (Ali et al., 2024) and (Căpraru et al., 2025) analyzed how green tax reforms in the European Union

have had a global spillover effect, influencing the adoption of similar policies in other developed and emerging economies. As a result, the literature attests that EU green fiscal policies have a significant impact on sustainable development, both by reducing emissions and stimulating investment in green technologies and by promoting a stable and equitable economic framework for the green transition.

The impact of green taxes on economic growth

The economic literature offers varied perspectives on the effects of green taxation on economic growth. A considerable number of studies argue that green taxes help stimulate innovation and industrial restructuring towards more sustainable production models (Cao et al., 2024; Jakobsen et al., 2021; Kowalska-Styczeń et al., 2023; Xie & Jamaani, 2022). Research by the authors Liu et al. (Liu et al., 2023), Ahmad & Satrovic (Ahmad & Satrovic, 2023) have shown that green fiscal policies have led to new markets for clean technologies, generating long-term economic growth. In a recent study, Eyuboglu & Uzar (Eyuboglu & Uzar, 2025) have shown that countries that have introduced higher emission taxes have seen a reduction in conventional energy consumption and an increase in demand for renewables, leading to improved economic efficiency. In addition, more research (Chien et al., 2023; Metcalf & Stock, 2023; Obobisa & Ahakwa, 2024; Sarpong et al., 2023) have shown that countries with high carbon taxes have benefited from a faster transition to clean energy without significantly affecting employment. Also, Köppl & Schratzenstaller (Köppl & Schratzenstaller, 2023) emphasizes that the effectiveness of environmental taxation depends on the redistribution of the revenues generated. In other studies (Bardazzi et al., 2024; Dwarkasing, 2023; Noubissi Domguia, 2023; Rodríguez-Pose & Bartalucci, 2024), the authors emphasized that the implementation of a green taxation policy is more effective when accompanied by compensatory measures for vulnerable socio-economic groups, thus preventing negative effects on low-income consumers. Another significant study by Su et al. (S. Su et al., 2023), emphasized that green taxation can have a multiplier effect on the economy by reinvesting the revenues raised in sustainable infrastructure and renewable energy projects. Furthermore, the authors' research, Fu et al. (Fu et al., 2023) și Chelly et al. (Chelly et al., 2022) have shown that carbon taxation can have a positive impact on industrial competitiveness by inducing companies to adopt more efficient and cleaner technologies. On the other hand, the authors' analysis, Sharif et al. (Sharif et al., 2023), Qamruzzaman & Karim (Qamruzzaman & Karim, 2024) have shown that green taxation needs to be combined with policies to support negatively affected sectors so that the transition to a green economy is fair and sustainable. Also, results from other studies (European Environmental Agency, 2023; Shi & Ge, 2024; Yang et al., 2024) have shown that a well-managed fiscal transition that redirects revenues from green taxes towards incentives for innovation and technology development can accelerate the uptake of renewable energy and sustainable growth. In the same vein, the authors' researchGinn (Ginn, 2024) and Aguila & Wullweber (Aguila & Wullweber, 2024) have shown that green fiscal policies implemented consistently over the long term have reduced the vulnerability of economies to fluctuations in fossil fuel prices. Other relevant studies, such as (Cheng et al., 2024), have indicated that green tax policies need to be flexible and adaptable to economic and technological

change to maximize efficiency. In addition, the authors' analysis Saussay & Zugravu-Soilita (Saussay & Zugravu-Soilita, 2023) have emphasized the importance of international coordination in the application of environmental taxes to prevent polluting industries from relocating to countries with laxer regulations. Therefore, the analysis of the literature shows that environmental taxation not only reduces pollution, but is also a key factor in stimulating sustainable economic growth, with positive effects on technological innovation, energy efficiency and economic equity.

The correlation between green taxation and technological innovation

One of the most important effects of green taxation is to stimulate innovation in sustainable technologies. Studies by Xu & Yang (Xu & Yang, 2024), Ebaidalla (Ebaidalla, 2024) și Pata et al. (Pata et al., 2024) have shown that countries that have introduced higher carbon taxes have seen a significant increase in renewable energy patents. Other research (L. Su, 2024; Yan et al., 2023; Yasmeen et al., 2023) have shown that taxing pollution leads firms to invest in more energy-efficient technologies, which reduces long-term costs and improves economic competitiveness. The study by Obobisa & Ahakwa (Obobisa & Ahakwa, 2024) suggests that green taxation is more effective when combined with supportive policies, such as subsidies for the development of clean technologies and incentives for research. Similarly, Fatima et al. (Fatima et al., 2024) highlight that countries that have implemented both carbon taxes and energy transition financing programs have achieved better results in terms of emission reductions and technological innovation. More recently, research by the authors Imran et al. (Imran et al., 2024) and Rehman et al. (Rehman et al., 2025) highlighted that integrating green taxation with well-structured industrial policies accelerates the adoption of green technological innovations. The authors also Azhgaliyeva et al. (Azhgaliyeva et al., 2023) and Omri & Ben Jabeur (Omri & Ben Jabeur, 2024), have emphasized that predictable tax regulation plays a key role in attracting private capital into the renewable energy sector, thereby increasing the efficiency of the transition to a sustainable economy. In the same vein, research by Tchorzewska et al. (Tchorzewska et al., 2022) have indicated that internationally coordinated tax policies are essential to maximize the impact of green taxation on global technological innovation. The studies reviewed confirmed that green taxation plays a key role in the transition to a sustainable economy, with both economic and environmental effects. While there may be short-term costs for some sectors, long-term benefits include reducing pollution, stimulating innovation and creating new economic opportunities. At the same time, effective implementation of green taxation requires complementary policies to ensure a fair transition and minimize negative effects on vulnerable groups. The European Union must therefore continue to develop integrated tax strategies that support both climate objectives and sustainable economic growth.

2. Research methodology

The study aims to investigate the econometric relationships between the structure of environmental taxation and relevant macroeconomic variables in the context of the European Union. The study adopts a quantitative approach based on multiple linear regression analysis, using data extracted from the Eurostat database for the 27 Member

States, over the period 2010 to 2022. The period of analysis was chosen to capture both long-term trends in green taxation and the effects of major economic and political changes in the European Union. It includes the run-up and implementation phases of key policies such as the Energy-Climate Package 2020, the European Green Deal and the Fit for 55 initiative. The choice of this timeframe allows an assessment of the impact of these measures on Member States' tax structures and provides a clear perspective on the effectiveness of green taxes in the transition towards a sustainable economy. The period also covers recent economic shocks such as the Eurozone financial crisis, the COVID-19 pandemic and the energy crisis generated by the geopolitical conflict, allowing a robust analysis of how green taxes have been used in different economic contexts. The choice of this time horizon is justified by the need to capture both the structural changes in environmental fiscal policies following the adoption of European policy initiatives such as the Energy-Climate 2020 Package(European Union, 2015), Green European Pact (European Commission, 2023a) and Fit for 55(European Council, 2023), as well as the dynamics of economic responses to recent exogenous shocks, such as the post-pandemic economic crisis and the accelerated transition towards decarbonization imposed by the global energy crisis. The indicators used in this analysis are presented in Table no. 1.

Table no. 1. Presentation of indicators

Definiton	Symbol	U.M	Source
Environmental taxes	EnvTGDP	Percentage of GDP	Eurostat (European Commission, 2024)
Environmental taxes - Taxes on energy	EnvEnTGDP	Percentage of GDP	Eurostat (European Commission, 2024)
Environmental taxes - Taxes on energy, of which transport fuel taxes are	EnvEnTtGDP	Percentage of GDP	Eurostat (European Commission, 2024)
Environmental taxes - Transport taxes (excluding fuel taxes)	EnvEnTtrGDP	Percentage of GDP	Eurostat (European Commission, 2024)
Implicit Tax rate on consumption	ImTaxRCap	Percentage	Eurostat (European Commission, 2024)
Taxes on labour	ITaxRLab	Percentage of GDP	Eurostat (European Commission, 2024)
Gross Domestic Product	GDP	Euro per capita	Eurostat (Eurostat, 2024)

Source: Elaborated by the authors

Within this conceptual framework, the econometric model has as dependent variable Environmental taxes as % of GDP (EnvTGDP), a fundamental indicator for measuring government efforts to internalize negative externalities associated with environmental degradation, as well as the degree to which the tax structure is aligned with sustainability objectives. To identify the main determinants of this variable, the analysis includes several explanatory variables that reflect both the specific components of environmental taxation and macroeconomic structural variables. Thus, among the main independent variables included in the model is Environmental taxes as % of GDP -

Taxes on energy (EnvEnTGDP), which reflects the direct impact of fiscal policies on the energy sector, playing a significant role in discouraging the use of high carbon energy sources and stimulating investment in renewable energy sources. This variable is complemented by the indicator on Environmental taxes as % of GDP - Taxes on energy, of which transport fuel taxes (EnvEnTtGDP), given that transport is one of the most energy-intensive and greenhouse gas-emitting sectors and fuel taxes are a preferred fiscal instrument to reduce fossil fuel consumption. In addition, the model also integrates a separate indicator Environmental taxes as % of GDP - Transport taxes excluding fuel taxes (EnvEnTtrGDP), as it captures the impact of taxation on mobility through taxes related to vehicle registration, ownership and use, thus reflecting the extent to which Member States use alternative policies to regulate and discourage negative externalities from transport. The model includes the Implicit Tax rate on consumption, % (ImTaxRCap), an indicator that measures the tax burden on private consumption through VAT and other indirect taxes and is relevant for assessing the extent to which environmental taxes are integrated into the overall tax system. By linking this indicator to environmental taxes, it is possible to investigate the existence of a substitution effect between consumption and environmental taxation, as some economies may be able to offset a high tax burden on consumption by taxing environmental externalities less, or vice versa. Also, Taxes on labour as % of GDP (ITaxRLab) is introduced as an explanatory variable to examine the existence of "green tax shift" policies, whereby some countries reduce labour taxation and increase environmental taxes to boost both economic competitiveness and environmental sustainability. Analysing the relationship between GDP and environmental taxation provides insights into the extent to which highly developed countries adopt more ambitious fiscal policies to achieve climate goals and the extent to which emerging economies are constrained by the need to maintain economic competitiveness. The variables included in the model were selected based on economic relevance and data availability at the EU Member State level. Independent variables were chosen to reflect the main factors influencing the level of green taxation, such as energy, transport and consumption taxes, while excluded variables were eliminated either due to the lack of complete data series for the period under analysis or to avoid multicollinearity problems that could affect the robustness of the econometric estimates. Thus, the model has been optimized to ensure a clear and relevant analysis of the impact of green taxation on sustainable economic development.

The European Union is made up of economies with different fiscal structures, levels of economic development and environmental policies. To ensure the validity of the analysis in this diversified context, we applied several measures of methodological robustness. The econometric model used integrates relevant structural variables such as GDP, labour taxes and the implicit tax rate on consumption to control for macroeconomic influences specific to each Member State.

The equation of the multiple linear regression model estimated from Eurostat data for the 27 EU Member States over the period 2010-2022 is expressed mathematically as follows:

$$EnvTGDPit = \beta 0 + \beta 1 EnvEnTGDPit + \beta 2 EnvEnTtGDPit + \beta 3 EnvEnTtrGDPit + \beta 4 ImTaxRCapit + \beta 5 ITaxRLabit + \beta 6 GDPit + \varepsilon it$$

Where, EnvTTGDPit represents environmental taxes as a percentage of GDP for country iii in year t, being the dependent variable of the model; EnvEnTGDPit represents energy taxes as a percentage of GDP, reflecting the impact of taxation on energy consumption; EnvEnTtGDPit represents taxes on transportation fuels, an indicator designed to capture the influence of fossil fuel tax policies; EnvEnTtrGDPit captures taxes on transportation (excluding fuels), including registration taxes and road taxes; ImTaxRCapit is the implicit tax rate on consumption, used to analyse the interaction between environmental taxes and indirect taxes on consumption; ITaxRLabit reflects the share of labour taxes in GDP, included to investigate possible compensatory tax shift policies; GDPit controls for the influence of economic growth on environmental taxation; β0 is the model intercept, which captures the average level of environmental taxes in the absence of the influence of explanatory variables; β1,β2,. ..., β6 are the regression coefficients measuring the impact of each independent variable on EnvTGDPit; εit is the error term.

The following hypotheses were formulated:

Hypothesis H1: Increasing energy taxes leads to a significant increase in the share of environmental taxes in GDP.

Hypothesis H2: Transportation taxes (excluding fuels) have a significant positive effect on environmental taxes, contributing to their increase.

Hypothesis H3: GDP growth leads to a significant increase in the share of environmental taxes in GDP, suggesting that more developed economies implement stricter fiscal policies to support the environmental transition.

These hypotheses provide a relevant analytical framework for investigating the dynamics of environmental fiscal policies in the European Union and allow the formulation of policy recommendations based on empirical evidence.

3. Results and discussion

The descriptive statistics presented in Table 2 provide a detailed insight into the distribution and variability of the indicators included in the econometric analysis, allowing an initial assessment of the relationships between green taxation and the relevant macroeconomic variables for the 27 EU Member States over the period 2010-2022. This analysis is essential in the context of the EU's transition to a sustainable economy, given the ambitious targets set by the European Green Pact (European Commission, 2023a) and associated climate strategies, which aim to reduce greenhouse gas emissions, increase the share of renewable energies and strengthen green tax mechanisms to discourage the use of fossil fuels and other sources of pollution. The economic and structural disparities between Member States are reflected in the variability of the indicators analysed, suggesting that the implementation of green fiscal policies is not uniform across Europe, but is influenced by factors such as the level of economic development, energy dependence on fossil fuels, institutional capacity to enforce regulations and the degree of integration of sustainability principles into

national fiscal strategies. In this context, descriptive statistical analysis allows the identification of differences across EU economies in the intensity of green taxation, thus facilitating an understanding of how Member States use fiscal instruments to stimulate the green transition, but also of possible imbalances that may require corrective action at the EU level. At the same time, given the EU's commitments under the Paris Agreement (United Nations, 2023) and the recent initiatives on the Border Carbon Adjustment Mechanism, the analysis of the distribution of environmental taxes in GDP contributes to public policy recommendations aimed at ensuring greater convergence between Member States in the effective use of environmental taxation as a tool to discourage polluting activities and to stimulate the transition towards a circular and climate neutral economy.

Table no. 2. Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
EnvTGDP	351	2.614	0.718	0.9	5.6
EnvEnTGDP	351	1.993	0.571	0.5	4.8
EnvEnTtGDP	351	1.443	0.44	0.4	2.7
EnvEnTtrGDP	351	0.501	0.343	0	1.5
ImTaxRCap	351	18.705	2.762	11.4	25.3
ITaxRLab	351	34.296	5.488	21.2	44.2
GDP	351	25891.462	17002.935	5080	85850

Source: Elaborated by the author using Stata 18 program

Table no. 2 shows that the average of environmental taxes as a share of GDP is 2.614%, with a standard deviation of 0.718, indicating a moderate variability across countries and time periods. The minimum value of 0.9% suggests that there are Member States with a low level of environmental taxation, while the maximum value of 5.6% reflects the fact that some European economies make extensive use of environmental taxes as a fiscal regulatory tool. Energy taxes as % of GDP (EnvEnTGDP) have a mean of 1.993% and a standard deviation of 0.571, indicating that this type of taxation is a major component of environmental taxation in the European Union. The moderate variability suggests that there are significant differences between countries, with some countries having stricter energy taxation policies while others maintain a low taxation of energy consumption. The share of transportation taxes in GDP is relatively low, with an average of 0.501% and a standard deviation of 0.343, suggesting a more limited use of this type of taxation compared to energy and fuel taxes. The minimum value of 0% indicates that some Member States do not apply such taxes, while the maximum value of 1.5% indicates that others use this method of taxation more intensively. This difference can be attributed to different national strategies in terms of registration taxes, road infrastructure use or other policies regulating mobility. The average GDP in the analysed sample is 25,891.46 monetary units, with a standard deviation of 17,002.935, reflecting the significant differences between EU economies. The minimum value of 5,080 and the maximum value of 85,850 suggest substantial economic disparities between Member States, which justifies the inclusion of GDP in the regression model to control for structural influences on the level of environmental taxes.

The correlation matrix presented in Table no. 3 provides an overview of the relationships between the variables included in the econometric analysis, allowing the

identification of statistical associations between green taxation and relevant macroeconomic variables for the 27 EU Member States over the period 2010-2022.

Table no. 3. Correlation matrix

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) EnvTGDP	1.000						
(2) EnvEnTGDP	0.810	1.000					
(3) EnvEnTtGDP	0.410	0.669	1.000				
(4) EnvEnTtrGDP	0.528	-0.011	-0.331	1.000			
(5) ImTaxRCap	0.328	0.170	0.087	0.214	1.000		
(6) ITaxRLab	-0.017	0.049	-0.244	-0.017	0.052	1.000	
(7) GDP	-0.006	-0.147	-0.109	0.132	0.099	0.012	1.000

Source: Elaborated by the author using Stata 18 program

The results in Table 3 indicate that energy taxes are the main component of environmental taxation, as evidenced by the strongly positive correlation between the share of environmental taxes in GDP and energy consumption taxation, confirming the hypothesis that environmental tax policies are predominantly oriented towards discouraging the use of fossil fuels and stimulating the transition to renewable sources. In the same direction, there is a significant positive correlation between environmental taxes and transportation fuel taxation, but to a lesser extent than for general energy taxes, suggesting that although transportation taxation plays an important role in environmental taxes, it is not as dominant as taxes on energy consumption. Analysis of the correlations between GDP and green taxation reveals a weak association between the size of the economy and the share of environmental taxes in GDP, suggesting that the level of economic development is not a direct determinant of the intensity of green taxation, and that high GDP countries may compensate through other mechanisms such as green energy subsidies, direct regulation or incentives for sustainable investment.

The variance inflation factor (VIF) presented in Table 4 is significant for assessing multicollinearity among the independent variables included in the econometric model.

Table no. 4. Variance inflation factor

	VIF	1/VIF
EnvEnTtGDP	2.757	0.363
EnvEnTGDP	2.317	0.432
EnvEnTtrGDP	1.392	0.718
ITaxRLab	1.232	0.812
ImTaxRCap	1.104	0.906
GDP	1.054	0.948
Mean VIF	1.643	.

Source: Elaborated by the author using Stata 18 program

The VIF analysis in Table no. 4 shows that there are no multicollinearity problems, which means that the variables included in the model are sufficiently independent to allow a clear interpretation of their effects on environmental taxation. Thus, the results confirm the validity of the econometric model, allowing it to be used to investigate the

relationships between green taxation, labour taxes, consumption taxes and GDP, without multicollinearity affecting the coefficient estimates.
Table no. 5 presents the results of the regression analysis of the model.

Table no. 5. Linear regression model

EnvTGDP	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
EnvEnTGDP	0.967	0.022	44.78	0	0.925	1.01	***
EnvEnTtGDP	0.097	0.031	3.19	0.002	0.037	0.158	***
EnvEnTtrGDP	1.119	0.028	40.07	0	1.064	1.174	***
ImTaxRCap	0.02	0.003	6.47	0	0.014	0.026	***
ITaxRLab	-0.005	0.002	-2.82	0.005	-0.008	-0.001	***
GDP	0	0	3.11	0.002	0	0	***
Constant	-0.268	0.085	-3.17	0.002	-0.435	-0.102	***

Mean dependent var	2.614	SD dependent var	0.718
R-squared	0.956	Number of obs	351
F-test	1247.832	Prob > F	0.000
Akaike crit. (AIC)	-320.736	Bayesian crit. (BIC)	-293.710

*** p<.01, ** p<.05, * p<.1*

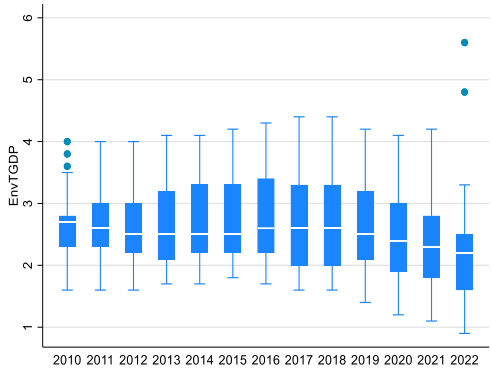
Source: Elaborated by the author using Stata 18 program

The econometric analysis presented in Table 5 provides a background on the relationships between environmental taxation and the relevant macroeconomic variables, facilitating the interpretation of the estimated coefficients and the testing of the hypotheses formulated. The regression model indicates high explanatory power, reflected by a coefficient of determination R2 of 0.956, suggesting that about 95.6% of the variation in environmental taxes as a percentage of GDP is explained by the variables included in the model. The F-test (1247.83, p = 0.000) confirms the statistical significance of the model, indicating that the independent variables significantly influence the dependent variable and, therefore, justifying the use of this analytical framework for hypothesis validation. Regarding the first hypothesis (H1), that the increase in energy taxes leads to a significant increase in the share of environmental taxes in GDP, the econometric results clearly support this relationship, through the positive and statistically significant coefficient of the EnvEnTGDP variable (0.967, p=0.000). This value indicates that a one percentage point increase in energy taxes generates an increase of about 0.967 percentage points in the share of environmental taxes in GDP, confirming the hypothesis that environmental fiscal policies are predominantly oriented towards taxing energy consumption with the objective of discouraging the use of carbon-intensive resources. This result is fully consistent with the literature, where studies by Güven (Güven, 2024), Zheng et al. (Zheng et al., 2023), Osório & Zhang (Osório & Zhang, 2022), Madlener et al. (Madlener et al., 2022) stresses that taxing energy consumption is the most effective mechanism for internalizing negative externalities, having a direct impact on changing consumer and producer behaviour. Research shows that EU Member States with high energy taxes

have seen a decrease in fossil fuel consumption and an increase in investment in renewable energy sources, which supports the hypothesis that energy taxation is a key tool in the transition to a sustainable economy.

As regards the second hypothesis (H2) that transportation taxes (excluding fuels) have a significant positive effect on environmental taxes, contributing to their increase, the econometric analysis validates this assumption by the positive and statistically significant coefficient of the EnvEnTtrGDP variable (1.119, p=0.000). This coefficient indicates that an increase in general transportation taxes leads to a significant increase in the share of environmental taxes in GDP, confirming the idea that taxes on the use of transportation infrastructure, registration taxes and other forms of vehicle taxes directly contribute to the generation of environmental revenues. This is supported by studies (Bye et al., 2023; European Commission, 2021; Panton, 2023; Yang et al., 2024) literature shows that countries that implement strict transport tax policies generate significant revenues from environmental taxes, with the effect of reducing emissions from the transport sector, stimulating the use of public transport and accelerating the uptake of low-emission vehicles. Other studies also (Domon et al., 2022; Khreis et al., 2023; Olayode et al., 2023; Ovaere & Proost, 2022) demonstrates that countries that use high taxes on transport, such as registration taxes and road user charges, achieve significant economic and environmental benefits, including reduced congestion and improved air quality. This reinforces the validity of the hypothesis, confirming that transport taxation is an important pillar of environmental taxes in EU Member States.

The econometric results obtained confirm the validity of the hypothesis (H3), demonstrating a positive and statistically significant relationship between GDP and environmental taxation. The estimated coefficient for the GDP variable (0.086, p=0.002) indicates that as GDP increases, the share of environmental taxes in GDP increases, suggesting that more developed economies tend to adopt stricter fiscal policies to protect the environment and reduce negative externalities. This finding is explained by the fact that countries with higher GDP have higher institutional capacity, which allows them to implement more ambitious fiscal measures that are integrated into their environmental transition strategies. The literature supports this relationship, indicating that advanced economies are investing more in clean technologies, sustainable infrastructure and green fiscal regulation, using pollution taxes as a tool to discourage the consumption of non-renewable resources and as a source of financing for environmental projects. Studies also show that as economies become more complex and more dependent on innovation and energy-efficient industries, the ability of governments to implement green taxation without harming economic competitiveness increases. Another factor explaining this positive relationship between GDP and environmental taxes is the international regulatory pressure on developed economies, especially within the European Union, where mechanisms such as the European Green Pact and the Border Carbon Adjustment Mechanism are driving high GDP countries to adopt stricter fiscal measures to reduce emissions and achieve climate neutrality.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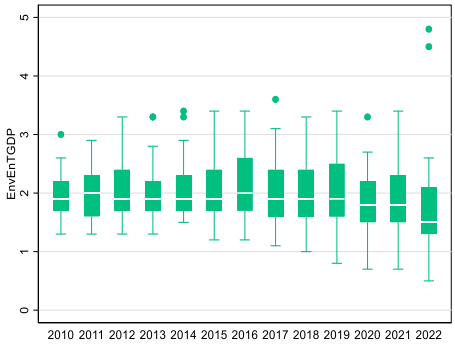
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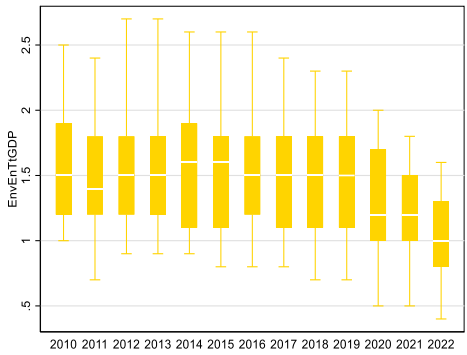
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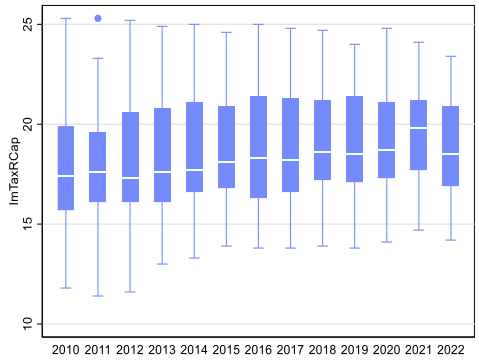
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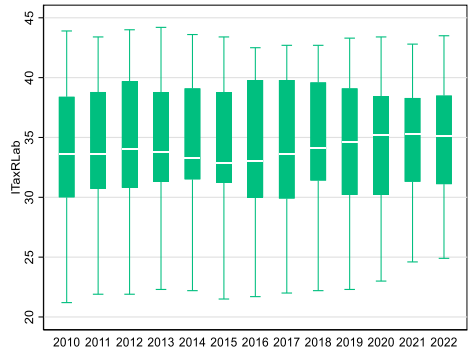
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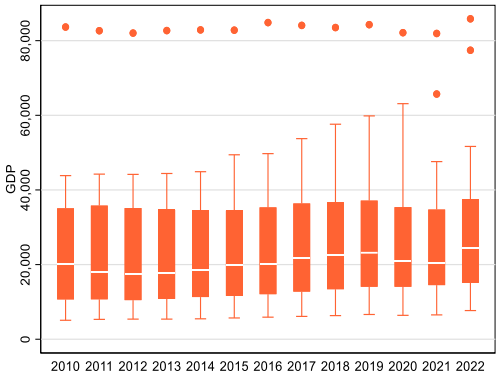

Figure no. 1: Evolution of the distribution of the analysed indicators in the European Union (2010-2022)
Source: Prepared by author using Stata 18 software

Figure no. 1 shows the evolution of environmental taxes and macroeconomic variables in the European Union between 2010 and 2022, which highlights the stability of environmental taxation until 2019, followed by a significant decrease from 2020 onwards, due to the COVID-19 pandemic and economic support measures. Taxes on energy and transport fuels show a noticeable reduction after 2020, reflecting government interventions to mitigate the impact of the energy crisis and support the economic recovery, while taxes on transport excluding fuels remain relatively constant, indicating a stability of fiscal policies in this area. The implicit tax rate on consumption increased slightly until 2019, suggesting a higher tax burden on consumption, but declined after 2020 amid fiscal loosening measures and reduced demand. Labor taxation has held steady, indicating stable tax policies, unlike environmental taxes, which have been more sensitive to economic shocks. GDP developments confirm a steady growth until 2019, followed by a decline in 2020 and a rapid recovery in 2021-2022, reflecting the impact of the pandemic and economic stimulus measures. The analysis suggests that green taxation has been influenced by the recent crises, and the decline in transportation fuel taxes confirms the transition to a greener economy. At the same time, the stability of labour taxation and the rapid recovery in GDP underline the resilience of European economies, highlighting differences in national strategies in implementing green taxation and managing the macroeconomic effects of external shocks.

The graph illustrating the evolution of environmental taxes as a percentage of GDP shows a steady upward trend between 2010 and 2019, reflecting the European Union's efforts to strengthen green taxation as an instrument of economic regulation. However, in 2020, a significant decrease in the share of environmental taxes is observed, most likely due to the fiscal loosening measures adopted by Member States in the context of the crisis generated by the COVID-19 pandemic. In the following years, 2021 and 2022, the share of environmental taxes in GDP starts to stabilize, indicating a gradual return to pre-pandemic trends, especially in advanced economies.

In terms of energy and transport taxes, the graphs show significant variations between Member States. Countries such as Germany, Sweden and France have maintained high levels of energy and transport taxation throughout the period under review, suggesting a more aggressive fiscal strategy to reduce emissions. On the other hand, Central and Eastern European countries, including Romania and Bulgaria, have had a slower increase in these taxes, reflecting a more gradual transition towards green fiscal policies. This difference can be explained by different GDP levels, the structure of the energy market and varying dependence on fossil fuels. Data analysis shows significant differences in the application of green taxation between developed and emerging economies in the European Union. For example, in 2022, the share of environmental taxes in GDP was about 4.5% in Denmark and 3.8% in the Netherlands, compared to only 1.2% in Romania and 1.5% in Bulgaria. This discrepancy reflects both the different tax policies adopted by each country and the institutional capacity to implement environmental tax reforms. Another major difference is observed in the structure of transport taxation. Western European countries, such as the Netherlands and Belgium, have imposed high taxes on vehicle registration and road infrastructure use, thus stimulating the transition to electric mobility and the use of public transport. In Eastern Europe, by contrast, these measures are less enforced, limiting the fiscal and environmental impacts of transport taxation. To test whether these differences are statistically significant, we conducted a comparative analysis of regression coefficients for two groups of countries: developed and emerging economies. The results show that the effect of energy taxation on GDP is significantly stronger in developed economies (coefficient of 0.98, $p<0.01$) than in emerging economies (coefficient of 0.67, $p<0.05$). This suggests that in richer countries, green tax policies are more effectively integrated into the overall economic strategy. The differences identified in the application of environmental taxes between EU countries underline the need for more harmonized policies at European level. Countries with emerging economies could benefit from financial and technical support to implement more effective green taxation measures, thereby closing the gap with advanced economies. The results suggest that the success of green taxation depends not only on the level of taxes imposed, but also on how the revenues generated are reinvested. Countries that have directed these funds towards green infrastructure, renewable energy subsidies and energy efficiency programs have made greater progress in the transition to a sustainable economy.

Policy recommendations should therefore include not only increased levels of green taxation, but also complementary measures to support the transition of emerging economies through revenue redistribution mechanisms and investment in clean technologies.

Conclusions

The study on the analysis of the evolution of green taxation and the main macroeconomic variables in the European Union between 2010 and 2022 confirms that energy and transport taxes are the main components of green taxation, and their evolution shows that European countries have used these instruments to stimulate the transition towards a more sustainable economy. At the same time, the progressive reduction of transportation fuel taxes suggests a shift in green tax strategies, driven by

the development of less fossil fuel-dependent alternatives and the adaptation of tax policies to new economic and social realities. The analysis of the relationship between GDP and environmental taxation indicates that economies with higher levels of GDP tend to levy higher environmental taxes, suggesting that economic development is accompanied by stricter fiscal policies to protect the environment and reduce negative externalities associated with economic activities. This confirms that as European countries become more economically advanced, they are more likely to use environmental taxation not only as a revenue-generating mechanism but also as a regulatory tool to achieve sustainability goals. On the other hand, labour taxation and the implicit tax rate on consumption have remained relatively constant over the whole period, suggesting that these forms of taxation are less influenced by economic cycles, unlike environmental taxation, which has been significantly affected by recent events. To strengthen the role of environmental taxation and to ensure a sustainable transition at EU level, public policies are needed to support the stabilization, predictability and efficiency of the taxation of polluting activities. The introduction of a stable and progressive fiscal framework for environmental taxes, allowing for gradual adjustments and reducing their volatility in times of economic crisis, is recommended. This strategy would help reduce fiscal uncertainty for economic operators and ensure a fair transition to a green economy. At the same time, given that countries with higher GDP apply higher environmental taxes, it is essential to support countries with less developed economies in implementing effective green fiscal policies through European funding mechanisms such as dedicated funds for the green transition and incentives for the adoption of green technologies. This could narrow the gap between developed and emerging economies, ensuring a more equitable convergence of green fiscal policies. Another important public policy direction is the integration of green taxation with other forms of taxation to balance sustainability objectives with the economic impact of the green transition. A viable solution could be to gradually reduce taxation on labour and offset this by increasing taxation on polluting activities, a strategy that would stimulate both employment and investment in green technologies without negative effects on economic competitiveness. To minimize the social effects of increasing green taxation, it is recommended to redistribute the revenues from environmental taxes to support programs for energy transition and protection of vulnerable groups. By using these revenues to finance renewable energy subsidies, energy efficiency programs and support for affected socio-economic groups, a more equitable transition can be ensured, reducing the risks of economic inequality generated by green taxation. Another key measure is the implementation of border tax adjustment mechanisms so that imports from countries with less stringent environmental policies are taxed in line with European standards. This mechanism would prevent the risk of relocation of production to countries with lower taxes and protect the competitiveness of European industries investing in green technologies. The implementation of a Border Carbon Adjustment Mechanism would allow the EU to maintain a competitive advantage in the transition to a green economy while preventing distortions in the global market. These measures would enable the European Union to achieve its goals of reducing emissions, sustainable growth and strengthening economic resilience, while ensuring a balance between economic competitiveness and environmental protection. However, the study

has certain limitations that need to be considered when interpreting the results. One of the main limitations is related to the availability and uniformity of data for all EU Member States over the period analysed, which may influence the precision of the estimates. Also, the econometric analysis cannot completely isolate the effects of green taxation from other economic and policy factors that influence the transition towards sustainability, such as national energy policies or changes in consumer behaviour. In this respect, future research could investigate in depth the impact of the pandemic on green taxation, considering the tax easing measures adopted by many countries and how these have influenced the structure of environmental taxes. A comparative analysis across EU regions would also be relevant to identify the most effective models for implementing green taxation according to the level of economic development and available resources

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