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Do energy and environmental taxes stimulate or inhibit renewable energy deployment in the European Union?

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A R T I C L E I N F O

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A B S T R A C T

The modern lifestyle and economic development of the European Union countries are closely connected to high energy consumption and environmental pollution. Renewable energy has arisen as one solution to this problem, even though the obstacles and challenges regarding the deployment of renewable energy lie in high costs, technology and legislation. The investigation of the determinants of renewable energy has become very attractive and popular because of the Sustainable Development Goals and COP26 targets. Therefore, this paper aims to explore the role of energy taxes and environmental taxes in addition to that of economic and environmental indicators in renewable energy development for the panel of EU countries by applying reliable and robust econometric techniques to the annual data from 1995 to 2019. The empirical results suggest that an increase in economic growth and oil prices supports renewable energy while environmental taxes and energy taxes have a negative impact on renewable energy deployment in EU countries. Thus, it is crucial to reform the structure of taxes to support the use of renewable energy. In addition, increasing environmental taxes to transform EU countries into energy-efficient economies will require additional EU policy adjustments.

1. Introduction

Nowadays, all European Union (EU) countries have problems with climate change, pollution and fossil fuel burning. For this reason, they are transforming their energy production by using more and more renewable energy sources. In order to decarbonize EU economies and to stimulate economic development, renewable energy plays a key role. Hence, the share of renewable energy in gross final energy consumption in the EU-27 has more than doubled in the last 15 years. In 2020, renewables accounted for 22.1% of energy consumed in the EU, about 2% points above the 2020 target of 20% [1]. In 2020 the highest share of renewable energy was recorded in Sweden (60%), ahead of Finland (44%) and Latvia (42%). On the other hand, the lowest share of renewable energy was recorded in Malta (11%), followed by Luxembourg (12%) and Belgium (13%) [1]. In the following year, the share of renewables increased by only 0.1% points [2]. Looking at the absolute values, the greatest growth was in the heating sector thanks to biomass and heat pumps, and in electricity generated from solar energy. The potential benefits of renewable energy include a decline in GHG emissions, diversion of energy supplies and decreased reliance on fossil fuel markets (particularly oil and gas). All of this can also boost employment in the EU by creating jobs in new 'green' technologies. On the other hand, the reason for the low use of renewable energy lies in high initial costs of investing in renewables while fossil fuels are still subsidized. Moreover, the investment, both public and private in renewable energy should be supported by governments to reach the optimal level. Therefore, the energy sector and energy policies are evolving to enable the transition to clean energy. In order to hasten the process, the EU has presented an ambitious plan, i.e., the European Green Deal. In addition, the plan is to achieve the 2030 Agenda for Sustainable Development, in which energy is a particular focus of Sustainable Development Goal (SDG) 7 - Ensure access to affordable, reliable, sustainable and modern energy for all. The plan consists of eight key areas, and building and renovating in an energy- and resource-efficient way is one of them. As a result, this will promote the extended use of renewable energy, greater energy efficiency and the use of various economic and financial instruments to preserve and expand the EU's natural carbon sinks. In addition, the target of the 2030 climate campaign is to effectuate a 55% overall reduction in emissions (where the majority of greenhouse gas emissions come from buildings at more

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than 60%) and energy consumption by 14% [3]. The benefits of achieving this target are not only a climate neutral continent by slowing down global warming and mitigating its effects, but it will also create additional jobs and support small- and medium-sized enterprises. According to the EU package “A Clean Planet for all” [4], energy taxation, carbon pricing schemes and revised subsidy structures play a critical role in achieving the climate neutrality target. In particular, the future energy taxation framework braces the transition to clean energy, provides sustainable and fair growth and also reflects social equity deliberations. Based on all the indicators, we can see that although the EU has achieved certain goals, they are not yet sufficient to move the process forward. Therefore, the link between the SDGs and gross domestic product (GDP) should be more emphasized. The UN has defined 17 global challenges, called SDGs, to achieve sustainable development. Many of these challenges have to do with the environment and climate change, with renewable energy playing an important role. To achieve the defined goals, GDP growth is an important determinant. In the literature, there is no consensus among researchers that higher GDP as an indicator of national prosperity will lead to the defined goals of the SDGs. In addition [5], concluded that with higher GDP growth, there was a greater impact on the environment and climate change. In addition, to achieve SDG 8 - decent work and economic growth, in the middle of GDP growth, hinder the achievement of environmental goals. Therefore, alternative SGDs should be implemented.

To enable the transition to climate neutrality and sustainable development, the EU can intervene with various tax policy instruments. One of the most important instruments is the environmental tax. As a fiscal policy instrument, environmental taxes impact resource consumption or emission levels by increasing the price of products that have a certain negative impact on the environment. The main objective of these taxes is to revise market prices in a way that internalizes environmental damage and to provide environmental effectiveness, economic efficiency and lower energy intensity. This can be seen in the change in consumer behavior caused by the increased price of goods and services from polluters to buying and consuming cleaner energy sources. In addition, environmental taxes generate government revenues that can be used to address environmental problems and motivate taxpayers to enhance production for social or economic purposes. Based on the Eurostat methodology, there are four types of environmental taxes. These are energy taxes, transport taxes, pollution taxes and resource taxes. In addition, this type of taxes moves consumers to shift their consumption patterns in a cleaner and more sustainable direction, which is the main goal of European Green Deal plan. In 2020, the EU-27 governments collected environmental tax revenues amounting to € 299.9 billion. That represents 2.2% of the EU’s GDP and 5.4% of total government revenue from taxes and social contributions in the EU. The highest shares were recorded in Slovenia (12.3%), Latvia (10.1%) and Bulgaria (9.9%), while the lowest shares were in Germany (4.1%), Slovakia (4.0%) and Luxembourg (3.5%) [6]. By observing each type of environmental taxes individually, more than three-quarters (77.2%) of the total revenues in 2020 were collected as energy taxes. This is far ahead of the taxes on transport (19.1%) and pollution and resources (3.7%) [6]. The highest share of energy taxes as a percentage of taxes and including social contributions were recorded in the Bulgaria (8.74%), Latvia (8.05%) and Greece (7.06%) [6]. This is good indicator which represents the significance of green taxes in state budget revenues and their accomplishment in implementing green budget reforms. Nevertheless, this should be considered with caution. For example, the low revenues could indicate a low tax rate or be the result of high tax rates that have had the effect of changing the behavioral consumption patterns regarding the related products or activities. On the other hand, the high tax revenues could indicate low tax rates that incentivize non-residents to purchase taxed products across a border after the implementation of high excise duties. As an overall effect, the benefits of environmental and energy taxes or ’green’ taxes are related to double dividends such as economic growth, the reduction of environmental impact and a shift of tax structures from taxes on labor and income to environmental and resource taxes [7]. Moreover [8], found that environmental taxes are the most important determinant of CO_2 emission reduction. Later [9–12], similarly concluded that CO_2 emissions decrease with the increase of environmental taxes. The difference between environmental and energy taxes lies first in their design and objective and second in the collection of tax revenues. For example, environmental taxes aim to reduce negative environmental impacts and combat climate change. On the other hand, energy taxes account for a significant portion of the final prices consumers pay for their energy. The second difference is in the collection of tax revenues. In 2020, three quarters, or 77.2%, of EU environmental tax revenues were collected through energy taxes. The explanation for this lies in the inclusion of CO_2 emissions, as these are usually levied on energy products, and the auctioning of tradable allowances. Nevertheless, both types of taxes have the same purpose - to protect the environment.

Following the ambitious plan of the EU to become a climate neutral continent by 2050, the purpose of this paper is to emphasize the importance and meaning of energy and environmental taxes, or so called ’green taxes’, on renewable energy development. The main motivation for this paper is to present whether energy and environmental taxes promote or inhibit the development of renewable energy in EU countries. The EU countries were selected because they need to promote renewable energy development in order to achieve the goals of the European Green Deal as well as to support Sustainable Development Goals and COP26 targets. Therefore, the main objective of this paper is to investigate the relationship between energy and environmental taxation in addition to economic and environmental indicators and renewable energy consumption for EU countries over the period 1995–2019. There are two fundamental contributions. First, this is the first paper that empirically demonstrates the impact of energy and environmental taxes on renewable energy development in EU countries. The second reason was to overcome the lack of studies, especially at the EU level, on the relationship between energy and environmental taxes and renewable energy and to provide some new empirical evidence and policy implications. The other contribution is to apply novel econometric methods that are strong with regard to the issues of heteroscedasticity and cross-sectional dependence. In line with the motivation and objective of the paper, our research question is:

- Do energy and environmental taxes stimulate or inhibit renewable energy deployment in EU countries and to what extent?

The structure of the paper consists of the following sections. After a brief introduction, the main literature on energy and environmental taxes and renewables and the literature gap are presented. The third section describes the model, data, and methodology, while the fourth section presents the empirical results. The conclusions and policy recommendations are provided in the last section.

2. Review of the existing literature

The concerns regarding climate change has forced the EU government to hasten the process of transitioning to green and sustainable development. This is only possible with the adequate economic instruments and financial resources. Hence, Kosonen and Nicodeme [13] emphasized that fiscal instruments alone or in combination with other market-based instruments play an important role in achieving EU energy and environmental goals. Therefore, the scientific literature regarding the relationship between energy and environmental taxes and renewable energy has been divided into two main topics. The first topic is that environmental taxes promote renewable energy consumption [14–17]. The second topic is that environmental regulations hinder renewable energy consumption [18–20]. The explanation is that the current environmental tax system is unusable and does not meet the EU’s 2030 and 2050 climate and energy commitment targets.

One of the possible solutions to improve the energy structure by pushing clean energy to decrease carbon emissions are environmental tax shocks [14]. In addition [15], studied the effects of environmental taxes, technologies and the environmental policy stringency index on renewable electricity generation on the basis of a sample of 29 developed countries during 1994–2018. They found that factors such as technologies, urbanization and the environmental policy stringency index have a favorable impact on renewable energy. Based on a sample of 18 Latin America and Caribbean countries, Wolde-Rufael and Mulat-Weldemeskel [21] explored the effectiveness of environmental tax and renewable energy in combating CO_2 emissions for the period 1994–2018. By applying novel panel methods of moments quantile regression with fixed effects, together with an augmented mean group, the dynamic ordinary least squares and Driscoll and Kraay estimators, they found interesting results. One of the findings are that there are heterogeneous effects of environmental taxes and renewable energy on CO_2 emissions. For example, a significant, negative effect was recorded in countries with higher emissions, but an insignificant effect in countries with lower emission. In addition, they found that environmental taxes and renewable energy are effective instruments in elevating environmental quality. The reason for that is that environmental taxes not only mitigate CO_2 emissions, but also elevate renewable energy [16]. used a spatial dynamic panel data model to investigate whether or not spillover effects played a role in renewable energy generation in EU countries during 1995–2016. They reached the following conclusions. First, an increase in renewable energy production in neighboring countries leads to an acceleration in the given country. Second, their results showed that determinants such as research and development expenses, gas and coal price volatility and environmental taxes have favorable effects on renewable energy production. Based on a sample of G7 countries from 1994 to 2014 [17], examined the marginal effects of an environmental tax on traditional energy consumption, natural resources rent and renewable energy consumption. Based on their results, they suggested that environmental taxes are effective in reducing emissions and confirmed that the marginal effects of environmental taxes on traditional energy consumption, natural resources rent and renewable energy consumption accelerate with the level of taxation. The results also suggested that stringent environmental tax laws enable firms to shift production to cleaner sources. By applying a computable general equilibrium model [22], found that environmental taxes not only reduce pollution, but are also positively associated with economic activity in the green industry [23]. examined the relationship between environmental regulations and GHG emissions in emerging economies. They found that environmental ordinances substantially decrease CO_2 emissions in emerging economies in favor of a cleaner environment and eventually lead to sustainable development goals. Similarly, by applying Continuously Updated Fully Modified (CUP-FM) and Continuously Updated Bias Corrected (CUP-BC) econometric techniques over the 1995–2018 period [24], also confirmed that environmental taxes have a positive impact on reducing CO_2 emissions based on a sample of E–7 economies, i.e., Canada, Japan, France, Italy, Germany, the UK and the USA [25]. found that environmental taxation appears to play a more important role in Europe than in other countries of the world. The reason lies in the greater reliance on and acceptance of taxes, and also in the fact that the public sector is generally larger and more ambitious in its energy-related and environmental goals. By applying a panel quantile regression [26], found based on a case of nine European economies (Belgium, the Czech Republic, France, Germany, Italy, the Netherlands, Poland, Spain and the UK) over 1994–2018 that environmental regulations, taxes, and energy policies are effective tools in supporting cleaner and greener EU economies. The nexus between renewable energy, environmental taxes, technologies and regulations was examined by Ref. [20] based on a sample of 29 OECD countries over the period 1996–2018. They pointed out two main conclusions. The first is that environmental taxes encourage the industry to reduce energy consumption and invest in green equipment. The second is that the OECD countries need to build a green financing system to elevate renewable energy. In another study and based on a same sample [27], examined the introduction of environmental taxes in minimizing energy consumption and intensity. To obtain meaningful results, the FMOLS, DOLS and quantile regression model were applied. The results show that environmental taxation supports research on green technology innovation, which decreases emissions. Their suggestion is that policy recommendations should be directed towards the adoption of environmentally friendly technologies for sustainable development and the reduction of energy consumption from fossil fuels. Regarding the specific category of environmental taxes [28], investigated the impact of energy taxes on household electricity consumption for EU member countries over the period 2005–2016. The results show that, in the long-run, energy taxes affect electricity consumption more efficiently through energy prices. Moreover, the efficiency of energy taxes can be enhanced by linking changes in energy prices and policy measures to consumption behavior.

From a different angle [18], investigated the role of environmental taxes and emissions trading schemes in European countries. They concluded that environmental taxes do not promote renewable energy in the short run, although the impact of economic instruments, i.e., environmental taxes, only becomes visible in the long run [19]. also demonstrated a positive nexus between the environmental tax and GHG emissions in their study of European countries, emphasizing that the environmental tax does not promote acceleration in renewable energy consumption [29]. argued that the introduction of energy taxes can be a pathway to sustainable transformation. Moreover, the specific ordinance of the energy tax requires a change in patterns of energy supply. However [30], showed that energy tax policy in EU countries is useless. Therefore, fiscal policy should be refined and combined with an emissions trading scheme to mitigate climate change [31]. studied the impact of environmental taxes on pollution and energy consumption based on a sample of European countries from 1995 to 2006 by applying two-stage generalized methods of moments approach. The results of the empirical analysis show that the implementation of environmental taxes has negative effects on carbon emissions reduction and bounded effects on the use of energy sources. This is also in line with the research by Ref. [32], where they also confirmed by means of their research that energy and environmental taxes are ineffective in reducing CO_2 emissions and promoting energy development.

Following the aforementioned arguments, the literature still lacks proper evidence for the linkage between energy and environmental taxes and renewable energy in the EU. Therefore, this paper focuses on that issue and its main hypothesis states that environmental and energy taxes have a negative impact on renewable energy consumption in the selected EU countries.

3. Model, data and methodology

This paper analyzes the impact of energy and environmental taxes on renewable energy deployment in the EU countries. Overall, in line with the recently published studies [20,33,34], the following models have been proposed:

Model I: $RENE_{it} = f\,(GDP_{it}, CO_{2it}, PRICE_{it}, ENVTAX_{it})$
Model II: $RENE_{it} = f\,(GDP_{it}, CO_{2it}, PRICE_{it}, EGYTAX_{it})$

where RENE is renewable energy consumption measured in quad BTU, and CO_2 stands for carbon dioxide emissions in million tons taken from the Energy Information Administration (https://www.eia.gov/); PRICE is the oil price per barrel taken from the BP statistics review (https://www.bp.com/); GDP is the gross domestic product in millions of euros, ENVTAX denotes environment-related taxes in millions of euros and EGYTAX are energy-related taxes in millions of euros as taken from EUROSTAT (https://ec.europa.eu/eurostat). The sample period is 1995–2019, and it should be noted that this study uses the largest time period for 25 European Union countries (The list of countries is reported in Table A1 in the Appendix). The descriptive statistics are reported in Table 1.

The descriptive statistics for the data used in this study are presented in Table 1. The data from the aforementioned table show that the observed variables vary widely across the 25 EU countries. This is evident from the wide range between the minimum and maximum values. The average logarithm of renewable energy consumption for the EU countries is −1.519, while the environmental tax is 8.128. The average logarithm of GDP is 11.849. The highest value of the standard deviation is for the environmental and energy tax, while the lowest is for the oil prices. The maximum value of renewable energy consumption is 1.617 and the minimum value is −5.394.

4. Results

Before presenting the long-run analysis several tests were applied. First, we apply cross-sectional dependence (CD) due to Ref. [35] to examine whether the analyzed variables are cross-sectionally independent. Table 2 presents that we have enough evidence to reject the null hypothesis of cross-section independence at 1% level of significance.

Second, unit root tests have been applied to test the presence of long-run characteristics of each variable. Specifically, the Im-Pesaran-Shin (IPS) panel unit root test [36] and the cross-sectionally augmented Dickey-Fuller (CADF) panel unit root test [37] were applied to investigate the stationarity of the variables. To avoid the problem of cross-section independence and slope homogeneity in the models, the second generation CADF test was applied. The results of the tests are presented in Table 3.

According to the results of the IPS and CADF panel unit root tests, all variables are stationary in the first difference at a 1% significance level. This means that the mean and variance of the variables used in both models vary over time. Hence, the Pedroni panel cointegration test [38] and the Westerlund panel cointegration test [39] were applied to determine whether or not variables move together in the long run. The first test records heterogeneity in covariates across countries, while the second test can be applied to models that suffer from slope heterogeneity. In addition, the test deals with cross-sectional dependence. The results of the Pedroni panel cointegration test are presented in Table 4. The empirical results based on both cointegration methods provide strong evidence for cointegration between the data sets of both models. Hence, it can be concluded that renewable energy consumption and the independent variables move together in the long run, implying that the variables analyzed have a stable long-run relationship.

In order to investigate the impact of environmental or energy taxes on renewable energy consumption with the inclusion of CO_2 emissions, GDP and oil prices as control variables, this paper applies the Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Square (DOLS) methods proposed by Refs. [40,41]. The pioneers of FMOLS were Philips and Hansen in 1990, who developed a method for optimal estimation of cointegrating regressions. FMOLS uses a nonparametric approach to correct for endogeneity and serial correlation problems. As our variables are measured in natural logarithms, the coefficients estimated from the long-run cointegration relationship can be viewed as long-run elasticities. While FMOLS permits for autocorrelation and endogeneity in the model due to the non-parametric estimation, DOLS adds past and future values of the first difference of the independent variables to address these issues. The FMOLS method is considered more appropriate for this analysis because it limits the number of lags and covers a relatively short time period. For robustness, the estimation results are also reported based on the DOLS.

As for the model diagnostic tests, all models satisfactorily fit reality. The values of R2 show that the panel models explain more than 96% of the variance in renewable energy consumption, while the F-statistics show that the models are correctly specified. The empirical results of the FMOLS and DOLS estimation methods are presented in Table 5. The FMOLS regression results show that GDP, CO_2 emissions, oil prices, environmental taxes and energy taxes are the main factors of renewable energy consumption in the 25 EU countries. From the results observed, it can be concluded that CO_2 emissions, environmental taxes and energy taxes have a negative impact on renewable energy consumption. In other words, by increasing environmental taxes or CO_2 emissions by 1%, renewable energy consumption is expected to decrease by 0.25% and 1.08%, respectively. However, real GDP and oil prices have a positive impact on renewable energy consumption, i.e., with a 1% increase in real GDP and oil prices, renewable energy consumption is expected to increase by 0.31% and 0.11%, respectively. Moreover [42], found that environmental taxes, renewable energy and energy efficiency are key determinants in reducing CO_2 emissions. The main result confirmed the significant inverse nexus between environmental or energy taxes and renewable energy consumption. In contrast, real GDP and oil prices had a positive impact on renewable energy consumption This is consistent with the research of [43,44], which found that GDP and institutional factors - the degree of market freedom and flexibility have the greatest influence on renewable energy consumption. Looking at the results from a critical perspective, further empirical analysis for the short and long

Table 1
Descriptive statistics.

	RENE	GDP	CO_2	PRICE	ENVTAX	EGYTAX
Mean	−1.519	11.849	4.228	3.817	8.182	7.904
Median	−1.566	12.004	4.146	3.993	8.307	7.965
Std. Dev.	1.455	1.528	1.322	0.656	1.551	1.511
Min	−5.394	8.002	1.594	2.543	3.243	2.785
Max	1.617	15.068	6.942	4.716	11.021	10.831

Note: The data presented are converted into their natural logarithm.

Table 2
Cross-sectional dependence test results.

	RENE	GDP	CO_2	PRICE	ENVTAX	EGYTAX
CD-test	34.24	82.44	37.92	86.60	77.88	76.27
P-value	0.00	0.00	0.00	0.00	0.00	0.00

Note: The null hypothesis of cross-section independence is tested referring to Ref. [35].

Table 3
Panel unit root test results.

	Levels		First-differences	
	IPS	CADF	IPS	CADF
RENE	−0.87	−1.19	−22.28***	−2.23***
GDP	−0.80	−1.82	−12.47***	−2.84***
CO_2	0.42	−1.87	−20.12***	−2.12**
ENVTAX	0.58	−1.98	−14.97***	−2.92***
EGYTAX	0.66	−1.77	−16.46***	−2.89***

Note: *** and ** represent 1% and 5% level of significances.

Table 4
Panel cointegration test results.

Pedroni cointegration			Westerlund cointegration		
	Model I	Model II		Model I	Model II
Modified Phillips-Perron	0.51	0.75			
Phillips-Perron	−9.34***	−8.51***	Variance ratio	−2.96***	−3.09***
Augmented Dickey-Fuller	−11.35***	−10.92***			

Note: *** represents 1% level of significance.

Table 5
Results of long-run estimations.

	FMOLS				DOLS			
	MODEL I		MODEL II		MODEL I		MODEL II	
	Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.
GDP	0.31***	0.009	0.24***	0.010	0.33***	0.090	0.17***	0.065
CO_2	−1.08***	0.016	−1.09***	0.016	−0.84***	0.116	−0.70***	0.099
PRICE	0.11***	0.016	0.11***	0.016	0.03	0.023	0.04**	0.017
ENVTAX	−0.25***	0.015	–	–	−0.17**	0.078	–	–
EGYTAX	–	–	−0.14***	0.019	–	–	−0.04	0.056
R^2	0.964		0.965		0.984		0.989	
Coefficient Diagnostic (Null Hypothesis: βi = 0)								
	Value	Prob.	Value	Prob.	Value	Prob.	Value	Prob.
F-stat	45.71***	0.00	39.24***	0.00	40.74***	0.00	56.48***	0.00
Chi^2-stat	182.8***	0.00	156.9***	0.00	162.9***	0.00	225.9***	0.00

Note: **, *** represent 5% and 1% level of significances.

term is inevitable to confirm the previous results.

Both the FMOLS and DOLS methods provide very similar results in terms of sign, magnitude and statistical significance. This also led to the same conclusions. The estimated coefficients are statistically significant at the 1% level and indicate a negative impact of environmental taxes on renewable energy. The estimated coefficient of oil prices and energy tax is not statistically significant under the DOLS approach, but is statistically significant at the 1% level under the FMOLS approach. Therefore, policies aimed at increasing energy or environmental taxes will reduce renewable energy consumption. These results suggest that increasing environmental taxes to transform EU countries into energy-efficient economies will require further policy adjustments. These results are consistent with those of [18] for European countries. They concluded that environmental taxes do not promote renewable energy in the short run, although the impact of fiscal instruments, i.e., environmental taxes, is only visible in the long run. In a study of the European countries [19], found that environmental tax does not promote the acceleration of renewable energy consumption [29]. concluded that taxation system, industrial regulations and reforms to achieve stable energy prices are inevitable for OECD countries. Moreover, effective environmental taxes need be spread over a longer period of time so that enterprises can adjust and maintain their competitiveness. By observing economic growth as one of the variables, it can be concluded that it is significant and shows a positive relationship in all econometric models. That means that economic growth has a meaningful impact on renewable energy consumption. Therefore, to prioritize clean energy sources in EU countries, effective and efficient policies need to be implemented, as well as renewable energy in the energy mix [45,46].

4.1. Robustness and sensitivity checks

As a first robustness and sensitivity check, Table 6 shows the empirical results using the share of renewables in the energy mix as the dependent variable, instead of renewable energy consumption in absolute terms (BTU) as in the previous section.

As a second robustness and sensitivity check, Table 7 shows the empirical results using environmental taxes and energy taxes as a share of GDP as key independent variables, instead of the absolute values (millions of euros) in the previous section. The results of the first and second robustness and sensitivity checks are very similar to the main results. The sign and significance of the tested variables are consistent with the main results, which means that CO_2 emissions, environmental taxes and energy taxes have a negative impact on renewable energy consumption. This provides evidence that higher energy or environmental taxes in the economy are more likely to have a negative impact on renewable energy consumption in the long run. This could be due to the fact that environmental taxes are poorly aligned with the negative side effects of energy consumption and have limited impact on efforts to reduce energy consumption, improve energy efficiency and encourage a shift towards less harmful forms of energy. Some of the most harmful fuels are taxed at particularly low rates or not at all, making them unduly attractive to end users. These harmful fuels are coal and petroleum products. Coal is the lowest and least frequently taxed fuel, where 85% of coal is used for heating and process purposes, and the average tax rate on coal is less than EUR 2 per ton of CO_2. On the other hand, petroleum products are taxed at an average of EUR 49 per ton of CO_2 [47]. There is still much scope to use taxation to improve the environment and mitigate climate change. Current tax systems need to be revised and modernized in order to meet current environmental, social and economic challenges.

Table 6
Results of long-run estimations using the share of renewable energy in total energy.

	FMOLS				DOLS			
	Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.
GDP	0.25***	0.009	0.15***	0.010	0.30***	0.083	0.12**	0.062
CO2	−1.68***	0.016	−1.68***	0.016	−1.44***	0.100	−1.28***	0.092
PRICE	0.09***	0.016	0.09***	0.016	0.03	0.022	0.03*	0.017
ENVTAX	−0.20***	0.015	–	–	−0.16**	0.069	–	–
EGYTAX	–	–	−0.06***	0.019	–	–	−0.02	0.053
R2	0.897		0.896		0.946		0.964	
Coefficient Diagnostic (Null Hypothesis: βi = 0)								
	Value	Prob.	Value	Prob.	Value	Prob.	Value	Prob.
F-stat	81.61***	0.00	70.91***	0.00	82.62***	0.00	98.62***	0.00
Chi^2-stat	326.4***	0.00	283.6***	0.00	330.4***	0.00	394.5***	0.00

Note: *, **, *** represent 10%, 5% and 1% level of significances.

Table 7
Results of long-run estimations using taxes as a share of GDP.

	FMOLS				DOLS			
	Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.
GDP	0.06***	0.009	0.05***	0.010	0.16***	0.044	0.13***	0.036
CO2	−1.08***	0.016	−1.10***	0.016	−0.83***	0.116	−0.71***	0.097
PRICE	0.11***	0.016	0.11***	0.016	0.03	0.022	0.04**	0.017
ENVTAX	−0.24***	0.015			−0.18**	0.077		
EGYTAX			−0.13***	0.017			−0.06	0.054
R^2	0.964		0.963		0.984		0.989	
Coefficient Diagnostic (Null Hypothesis: βi = 0)								
	Value	Prob.	Value	Prob.	Value	Prob.	Value	Prob.
F-stat	271.36		260.89		41.86716		59.54651	
Chi^2-stat	108.54		104.35		167.4686		238.1860	

Note: **, *** represent 5% and 1% level of significances.

Regarding the situation in the EU countries, the Energy Tax Directive (ETD) entered into force in 2003 and established structural rules and minimum excise tax rates for the taxation of energy products used as motor fuels, heating fuels and for the production of electricity. Nowadays, the directive does not reflect the EU's climate and energy policy framework. First, there is no connection in the ETD between the minimum tax rates for fuels and their energy content or environmental impact. Second, the real value of the minimum tax rates has eroded over time due to the introduction of numerous exemptions and reductions which favor the use of fossil fuels. Nowadays, the European Commission proposes a revision of the Energy Tax Directive (ETD) as part of the 'Fit for 55′ package [48]. The new rules aim to combat the harmful effects of energy tax competition and safeguard member states' green tax revenues. The plan is to eliminate outdated exemptions and incentives for fossil fuel use, such as aviation and maritime transport, by promoting clean technologies. The aim of the package is to help encourage investment in new and innovative green industries by clarifying the rules so that investors and innovators can more confidently plan their long-term investments in green technologies and renewable energy. In addition, it will facilitate the transition from fossil fuels to clean fuels and help the EU achieve its ambitious GHG emission reduction and energy savings targets [49]. It will also introduce the concept of green finance and green investment, which are a net recipient of shocks from renewable energy sources [50,51].

5. Conclusions and policy implications

In the literature there are deliberations regarding the nexus between energy and environmental taxes and renewable energy not only in the EU, but also abroad. Most of the arguments are based on theoretical arguments, while fewer are related to empirical evidence. Only a few authors [18,19,21,24,29] provide empirical evidence, but their results showed that environmental taxes are inevitable in achieving sustainable environment development. Therefore, this paper expands the horizon of these deliberations by aiming to analyze the impact of energy and environmental taxes on renewable energy consumption in EU countries over the period 1995–2019. In addition, this study also discusses the role of oil prices, CO_2 emissions and GDP in promoting clean energy sources. By applying the FMOLS and DOLS methods, GDP, CO_2 emissions, oil prices, environmental taxes and energy taxes were shown to affect renewable energy consumption in the 25 EU countries. Our empirical results show that energy taxes, environmental taxes and CO_2 emissions have a negative impact on renewable energy consumption, demonstrating the urgent need to reform the tax system so that EU countries can become more energy efficient.

In light of the above findings, this paper draws critical policy conclusions. Although EU countries have proposed a revision of the Energy Tax Directive as part of the "Fit for 55" package, the question of its purpose and objectives is still open. The general goal is to encourage investment in new and innovative green industries and to secure green tax revenues. To accelerate the transition to sustainable environmental development in EU countries, we recommend that policymakers focus on green growth. This can be achieved by adopting green technologies and renewable energy, accelerating green productivity, and strict environmental regulations. For example, by changing the traditional way of using old materials, the industry can focus on using new, modern, and more environmentally friendly materials, i.e., eco-innovation, to increase reliance on renewable energy sources. This will lead to a reduction in traditional energy consumption and an increase in renewable energy. As a result, this will promote green technologies and accelerate green productivity. Regarding the rigidity of environmental regulations, the environmental tax is considered an effective policy tool. Therefore, policymakers should introduce higher environmental taxes, especially on polluters, to make them pay for their actions. This will lead to a decrease in GHG and a change in consumer behavior. It will also create additional green revenue that can be reinvested in environmental cleanup programs and green growth. Green growth will thus create a green financial system and combat the harmful effects of energy tax competition. This will lead to decarbonization of energy. An important aspect is also the participation of citizens. Therefore, it is inevitable to involve citizens in the formulation and evaluation of energy and environmental development strategies and to improve the transparency of the energy system in each EU country. This will increase the environmental awareness of the urban population [52].

The limitations of this study are represented by the sample of a limited number of EU countries included in the analysis due to data availability and the variables analyzed. The deployment of renewable energy in the EU is influenced by a variety of factors, including energy and environmental taxes. Therefore, this analysis could represent further research, since most of the EU countries analyzed still rely on conventional energy sources. The direction for further research is to include more variables such as energy prices, research and development expenditures for environmental purposes, institutional quality factors and others. It would also be interesting to analyze each year and country separately.

Credit author statement

Eyup Dogan: writing, model, supervision; Sabina Hodzicmethodology, writing; Tanja Fatur Sikic: introduction, literature review.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

APPENDIX

Table A1
List of sample countries

Austria	Denmark	Greece	Lithuania	Portugal
Belgium	Spain	Croatia	Luxembourg	Romania
Bulgaria	Estonia	Hungary	Latvia	Slovakia
Czech Republic	Finland	Ireland	Netherlands	Slovenia
Germany	France	Italy	Poland	Sweden

Note: The countries are selected based on the data availability.

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