Chapter

The Environmental Influence of Tax Regimes in Selected European Union Economies

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Abstract

Eurostat and the European Environmental Agency have in 2019 reported there is still need to continue implementing zero-carbon practices in European Union (EU) Countries although there has been a noted decrease of 22% in emissions when compared to their 1990 levels. This paper employed a system-Generalised Method of Moments (GMM) framework to evaluate the environmental impacts of tax systems in selected 28 EU economies from 2010 to 2017. The results of the study proved that aggregate environmental tax is not effectively lowering greenhouse gas emissions as expected, although it improves environmental sustainability. Possibly the environment tax revenue collected in the European Union countries was not used to enhance energy efficiency; hence it could not lower greenhouse gas emissions. The other findings demonstrate that when environmental tax is disaggregated (energy tax and transport tax) these instruments have been more efficient in lessening emissions and also improves environmental sustainability (in the case of transport tax). The paper, therefore, highlights the importance of adopting green tax instruments which are more focused and harmonising directly with environmental goals for EU economies.

Keywords: greenhouse gas emissions, environmental sustainability, energy tax, transport tax, environmental tax, eco-innovation rating, production scores, green research and development, government expenditure, economic growth

1. Introduction

Conversations on emission and its effects on the economy and environment are increasing especially in developed countries. Among the key issues surrounding discussions on emission is the impact of taxation on carbon emission and environmental sustainability. There is unanimity among researchers on the effect of emissions on the environment. That is to say, emissions cause environmental degradation, diseases, reduces household welfare and are detrimental to economic growth and development [1–3]. In this light, it is evident that climate change has become a global problem [4]. This global problem has awakened the need for governments worldwide to invent techniques to minimise environmental issues and emissions. Some of the methods include subsidies, ecological laws, taxes, environmental policies and awareness programs [5]. Of particular importance are taxes which are an integral instrument in dealing with emission [6]. The significance of taxation on emission and environmental degradation has captured the attention of researchers and policymakers in developing policies and recommendations on minimising emission.

There is a noticeable increase in taxation on emissions and environmental sustainability in the European Union (EU). Taxation takes the form of energy tax, environment and transports tax especially, in Slovenia, Poland, France, Portugal, Finland, Latvia, Ireland and Denmark [7]. The main purpose of these taxes is to minimise emissions up to an acceptable level of 5 percent [8]. Furthermore, the government introduced environmental and emission taxes to reduce negative externalities caused by third parties in production and consumption since nobody takes responsibility for creating them [9]. The negative externalities include pollution, land degradation and the greenhouse effect that tends to cause diseases, low standards of living, low quality of products, reduction in income and energy consumption [10]. Since firms do not take any responsibility, the EU has taken the responsibility of reducing emissions to an acceptable standard [11]. Thus, fiscal authorities have imposed a certain amount of $50–100 per ton on production for any environmental misuse and emission [11]. Tax experts argue that the $50–100 per ton tax that is not shown in the final price of goods and services covers the social costs suffered by the third party [2]. Furthermore, environmental and emission taxes increase government revenue and contribute to economic growth significantly. A survey conducted by Sterner and Kohlin [12] found that environmental and emission tax contributes 8 percent of the government revenue and 3 percent of economic growth in the European Union region.

The introduction of environment and emission taxes has sparked heated debates among scholars. The main crust of these debates is whether taxation is an effective way of reducing environmental emissions. Noteworthy is the complementary school of thought which contends that tax on environmental emission addresses market failures to an acceptable standard and reduces health diseases [3, 8]. This means that taxation on emissions brings about efficiency and effectiveness in the production of goods and services since firms get to develop new regulations that foster efficiency and reduce the cost of production. Also, environmental tax improves the quality of the products produced in production processes [13]. On the other, the substitutive school of thought argues that taxes on emission are inclined to fiscal policies rather than environmental policies [14]. The substitutive school of thought recognises that environmental and emission taxes focus more on raising government revenue than reducing emissions as such taxes tend to be regressive as prices of goods and services change [15]. In this sense, the substitutive school of thought concludes that taxation does more harm than good because it causes a greater degree of the loss of welfare as compared to emission. Therefore, this study envisaged contributing to the current debate on tax on emissions and environmental sustainability.

Central to the problem is that environmental pressures are a global phenomenon. The European Union is not exempted from this problem. Environmental pressures have become an issue of concern as the emission threat has increased over the past years. Another factor that has become a cause for concern is the forecast by economists that emissions are likely to increase to 35 percent, and this poses a threat to environmental sustainability [16]. Of importance is that these environmental pressures pose a risk to people's health, welfare, and economy. Astuti and Maryono [17] note that emissions cause health diseases such as eye irritation, asthma, and pneumonia. Emissions and environmental pressures do not only undermine the environment and health faculties but affect the economic operations of a country as well. There is no doubt that these challenges should be addressed. The economic theory prescribes many methods of solving these challenges. Such methods include environmental tax, fuel tax, awareness programs, subsidies to mention but a few. Relevant to this study is environment taxation and tax emission, which are the main focus of this study. Hence, this study investigated the influence of emission on selected EU countries.

The purpose of the study is to contribute to the existing literature on environmental accounting significantly. Most of the studies have focused on the effects of tax on carbon emission [2, 6, 18, 19]. However; this study takes a different stance by examining the environmental influence of tax structures in selected EU economies by taking into account both short-run and long-run dynamics. The study focused on other variables that are immensely important to environmental issues and yet are barely used by other researchers. These variables include research and development, production scores, eco-innovation ratings and the different types of tax such as energy, transport, and environmental tax. The authors of this study conducted a thorough search of the relevant literature. They found no study that combined all the variables in one study to investigate the environmental influence of tax structures in selected EU economies. Hence, the current paper covers this research gap to find robust results that are important to policymakers. Furthermore, the results and the nature of the research provide a niche for future researchers focusing on few limitations of the study. The study also contributes to the body of existing knowledge on natural environmental studies.

Therefore, this paper is organised as follows. The literature review is summarised in the next section. The methodology and variables used in the study are discussed in Section 3. This also includes the source of the data and prior expectations. The empirical results and analysis are discussed in Section 4, while Section 5 consists of the summary, conclusion, recommendations, and limitations of the study.

1.1 Environmental tax in the European Union

The introduction of environment tax in the European Union can be traced back to 1990 [20]. Since then, it has received attention from various governments intending to minimise environmental degradation. The idea was to charge polluters a certain fee per unit of the damage they have caused to third parties. In line with this objective, the European Union introduced four types of environment tax, namely energy, transport, pollution and resources tax [12]. For the purposes of this study, researchers focused on energy tax and transport tax as they are widely used in the European Union. Eurostat [21] defined energy tax as a certain amount paid by the energy sector for causing negative externalities. Energy tax target polluters who make use of petrol, diesel, biofuels, electricity consumption and carbon fuels [21]. The energy tax is mainly used in Italy, Germany, Netherlands, France, Sweden and Finland as they use heavy power plants and consumes much electricity compared to other countries [22]. This also implies that these countries receive more tax revenue from electricity tax while Sweden and Denmark get more revenue from fuel tax. Second is the transport tax, which is an amount paid for making use of vehicles and vehicle ownership [23]. It includes the importation of motor vehicles, flight tickets, toll gates, car registrations and insurances [21]. This form of tax was introduced to raise revenue and minimise greenhouse gas emissions. The European Commission [24] reports that 25 percent of greenhouse gas emissions are caused by the transport sector of which road transport contributes 75 percent to these transport emissions followed by civil aviation and navigation respectively. This type of emission is common in Norway, Netherlands, Finland, Greece, Spain and Denmark.

Noteworthy is that energy tax is widely used in the region to reduce greenhouse gas emission. There has been an increase in the use of tax that leads to an increase in the energy tax revenue since 2000–2018. The increase in revenue has also led to the rise in the Gross Domestic Product. The contribution of environmental tax to GDP was experienced a decade later after the introduction of the environment tax in 1990. Notably is the 5 percent contribution from 2013 to 2019. Despite the use of environmental tax, the Eurostat [21] found contrasting results in the European Union. On one hand, it is a significant increase in greenhouse emission in countries such as Germany, France and Italy. On the other hand, it is a significant decrease in greenhouse emission in countries such as Lithuania, Latvia and Romania [25]. From the discussions, the environment tax influences greenhouse gas emission differently in the European Union individual countries depending on the environment policies used by each country towards eradicating the environment hazards. The question still remains: Does environmental tax reduces greenhouse emission and improves environmental sustainability since its implementation is influenced by price elasticity of energy and transport demand?

2. Literature review

This section is divided into two parts. The first part examines how tax and other variables influence carbon emissions in selected economies. The second part evaluates how tax frameworks affect environmental sustainability in countries studied.

2.1 Empirical literature on carbon emission

The influence of emission tax cannot be separated from past studies on taxation, economy and environmental economics. For instance, a survey carried out by Miller and Vella [19] investigated whether taxes are effective in dealing with pollution. The study examined if taxes on emission help to produce quality products. The study targeted 50 countries across all the regions and used panelised dynamic regression models. The results of the study revealed that taxes reduce carbon emission in all the countries. Also, the study showed that the quality of products is improved if the polluters are taxed. Similarly, Metcalf [6] achieved the same results that carbon tax reduces carbon emissions in Britain, Columbia and the United States of America. Metcalf [6] further observed that taxation on emission improves employment and economic growth. Worthy of note is that the preceding studies present a negative relationship between carbon tax and carbon emission. Thus, taxation on emission is the most effective way of reducing emissions to an acceptable level. The studies concur that taxes reduce environmental pollution despite their difference in geographical location.

In South Africa, carbon tax also has an inverse relationship with emission. This result was concluded by [2] who examined the effects of carbon tax on the economy. The study employed the dynamic Computable General Equilibrium modeling methodology and found an inverse relationship between carbon tax and emission. The study further showed that carbon tax is negatively related to economic growth. Thus, the more firms pay carbon tax the fewer goods and services they produce, thereby compromising economic growth. Klier and Linn [26] concur with these results as they reach the same conclusion after using the panel regression analysis in Sweden, France, and Germany. The authors' objective was to investigate the relationship between vehicle carbon taxation and carbon vehicle emission. This relationship was prevalent in France compared to other countries. Since firms were taxed for emission, a decrease in emissions from vehicles was experienced in all the countries. The common denominator between these two studies is that taxation has a negative effect on economic growth despite the use of different methodologies and geographical locations. A salient point to note on the carbon tax is that it discourages firms to be innovative and this leads to a decrease in investment and eventually a decrease in economic growth.

Lin and Li [18] using a panel regression analysis, examined the impact of carbon tax on carbon emission in selected European countries. The authors found three sets of results: a negative relationship between carbon tax and emission in Finland; a positive relationship between carbon tax and emission in Norway and no relationship was identified in Netherlands, Denmark, and Sweden. Since Norway is one of the heavy carbon polluters in Europe, taxing the firms reduced emission. The same result was achieved by Di Cosmo and Hyland [27] who concluded that carbon tax is an effective way of reducing emissions in Norway. On the other hand, in the Netherlands, Denmark and Sweden carbon tax did not influence carbon emission. This result is contrary to the findings of Lin and Li [18] who found an inverse relationship between carbon tax and emissions. The authors further propounded that fiscal authorities should increase tax on emitters for carbon tax to be effective. Moreover, an interesting result is the positive relationship between carbon tax and carbon emission found in Norway. This result is not common in the Organization for Economic Co-operation and Development (OECD) since all the governments joined hands to reduce emissions through the Piogiouvot method.

Anderson [28] inquired whether a carbon tax is the solution to greenhouse emissions. The author used 11 European Union countries as his case study. To achieve the aim of the study, the author employed a quasi-experiment and found that tax curtailed emissions by 11 percent. The study confirmed the economic theory that prescribes that carbon tax deals with negative externalities whilst also reducing emissions. A similar result was found in Norway by Bruvoll and Larsen [29]. The authors employed simulations and a diverse index from 1990 to 1999 and the study revealed an emission reduction of 2.3 percent. Revoredo-Giha et al. [30] examined the impact of carbon taxes on greenhouse emissions in the United Kingdom. The study showed that carbon tax reduces greenhouse emissions. Gonzalez [31] and Haites [32] concur with the above-mentioned studies by reiterating that carbon tax is the best instrument to reduce greenhouse emissions and the most effective approach in reducing emissions.

Concerning the relationship between economic growth and emission, Ameyaw and Yao [33] analysed the impact of economic growth on carbon emission in West African countries from 2007 to 2014 using panel regression. The results show an unidirectional cause from GDP to carbon emission. Thus, an economy that taxes emissions is likely to improve economic growth. The same result was also achieved by Asongu et al. [34] who investigated carbon emissions and economic growth and found a relationship running from economic growth to carbon emission to energy consumption. An interesting result was found by [35] who examined the effects of economic growth on emission in developing countries. The study used panel analysis and found a negative relationship between economic growth and emissions while [36] found no link. The study examined the link between energy consumption, emissions and economic growth in the Middle East and North Africa (MENA). The rationale behind this finding is that taxation discourages firms to produce more goods and services due to increased cost of production.

Other authors emphasised the fact that carbon tax on emission is regressive in nature and leads to loss of welfare [14, 15]. For instance, Devarajan et al. [15] found that taxes on carbon emission reduce household welfare by 40 percent, whilst also reducing carbon emission by 15 percent. In other words, carbon tax works better in reducing household welfare than in minimising emission, its main objective. The study further found that carbon tax is regressive as poor households spend more than 50 percent of their salaries on taxed goods and services. This result was also found by [14]. Marx and Slamang [37] and Sterner [38] examined the relationship between energy and carbon tax on emissions in European Union countries. The study concluded that transport taxes, energy and carbon taxes are regressive.

2.2 Empirical literature on environmental sustainability

Liobikiene et al. [39] investigated the role of energy taxes on climate change in the European Union. The main focus was to check if environmental tax influences environmental sustainability. The authors applied panel data methods and found that environmental tax influences environmental sustainability in a positive way. The same results were found by Nerudova et al. [40] who examined the tax system and environmental sustainability in the European Union and found a positive relationship between the two. Park and Yoon [41] studied the link between environment tax and sustainable development in China, Japan and Korea using a survey. The study revealed a positive relationship between the two in all these countries. It seems the above-mentioned studies point to a positive relationship between taxation and environmental sustainability. Thus, taxation on environmental pollution improves environmental sustainability. A study by Radulescu et al. [42] in Romania employed the Ordinary Least Square and Vector Error Correction Model. The authors found a negative relationship between environmental sustainability and environmental tax. The authors argued that fiscal authorities should use other methods other than taxation to achieve environmental sustainability.

Streimikiene et al. [43] added economic growth as a variable that was not examined by [39, 42] by investigating the role of green tax on sustainable energy development in Baltic countries. The study found a positive relationship between environmental tax, economic growth and environmental sustainability. The authors propounded that taxation ensures environmental sustainability that has a direct influence on economic growth. Kurniawan and Managi [44] and Moisesca [45] arrived at the same conclusion by examining the relationship between economic growth and sustainable development in Indonesia from 1990 to 2014. The study used the inclusive wealth framework and found that economic growth influences environmental sustainability in a positive way. From all the studies that examined the link between economic growth and environmental sustainability, a positive relationship was achieved therein.

Urbaniec [46] conducted a study on eco-innovation and environmental sustainability. The main objective was to assess the role played by eco-innovation on environmental sustainability. The study concluded that eco-innovation minimises environmental damage. Similar results were also concluded by [47] who carried out a study on the role of eco-innovation and environmental sustainability in Malaysia. The findings of both studies point to the fact that an increase in environmental compliance improves the environment. Another common denominator is that both studies used the same methodology: the theoretical structural model and found similar results. The eco-innovation is also positively linked to Research and Development, thus Powe [48] found that research and development have a positive impact on environmental sustainability. The authors argued that Research and Development yields results in big sectors, while in small sectors a link was not found. The same results were also found by [49] who examined the green economy and sustainable development worldwide from 2002 to 2010. The study found that research and development have a positive impact on environmental sustainability. However, Sauvé et al. [50] found a negative relationship between Research and Development and environmental sustainability. The authors arrived at this conclusion after employing an ordinary least square first difference.

Kim and Yoon [51] examined the relationship between environmental sustainability and production in manufacturing firms. The objective of the study was to check the impact of production on environmental sustainability. The results reveal that production has a positive influence on environmental sustainability. The same results were also found by [52] who examined environmental sustainability and production. The preceding results differ from those achieved in the study done by [53] who examined the relationship between sustainable environment and production using the trend and content analysis. The study found that production causes environmental hazards. The author concluded that production in developing countries over utilises resources with the objective of combating poverty. On the other hand, production in developed countries over utilises resources for export purposes.

Saud et al. [54] examined the link between energy use, government expenditure and financial development in Venezuela from 1971 to 2013. The study employed an autoregressive distributed lag (ARDL) model and found a positive link between energy use and environmental degradation. The study further revealed a negative relationship between land degradation and government expenditure. A study carried out by Uwazi [55] and You and Haung [56] examined the link between green growth and environmental sustainability in the OECD. The study looked at 30 provinces using panel data. The results show a positive relationship between government spending and green growth. A similar study was done by Oyebanji et al. [57] who conducted a study on green growth and environmental sustainability in Nigeria. The study considered energy depletion, forestry, carbon dioxide and employed the ARDL model. The study found a negative relationship between carbon emission, environmental depletion, and greenhouse energy. On the other hand, a positive relationship was found between green growth and deforestation.

From the empirical literature reviewed, there is no consensus on how taxes influence emission. Certain authors support a positive relationship between the variable, others see no link, while others support a negative relationship. Given such a scenario, the study, therefore, contributes to the existing literature by examining the influence of tax on emission.

3. Data and research methodology

This paper is based on associations among tax structures, environmental variables, income, production, transport, eco-innovation and green investments in a panel of 28 economies over a period of 7 years, that is, 2010 to 2017. The 7-year period was deemed sufficient due to data availability and sufficient cross-sections. These variables were chosen as they have a potential impact of reducing or increasing greenhouse gas emissions and environmental sustainability. The generalised below equations form the basis of the hypothesis.

$$\begin{aligned} Log\ GHG_{it} = {} & \alpha_1 + \alpha_2 Log\ GHG_{it-1} + \alpha_3 LogETT_{it} + \alpha_4 LogGDP_{it} + \alpha_5 LogPDN_{it} \\ & + \alpha_6 LogECO_{it} + \alpha_7 LogEC_{it} + \alpha_8 LogGRD_{it} + \alpha_9 LogGE_{it} \\ & + \varepsilon_{it} \ldots \ldots \ldots \ldots \ldots \ldots \end{aligned} \tag{1}$$

$$\begin{aligned} Log\ ANS_{it} = {} & \alpha_1 + \alpha_2 Log\ ANS_{it-1} + \alpha_3 LogETT_{it} + \alpha_4 LogGDP_{it} + \alpha_5 LogPDN_{it} \\ & + \alpha_6 LogECO_{it} + \alpha_7 LogEC_{it} + \alpha_8 LogGRD_{it} + \alpha_9 LogGE_{it} \\ & + \varepsilon_{it} \ldots \ldots \ldots \ldots \ldots \ldots \end{aligned} \tag{2}$$

And more specifically,

$$\begin{aligned} Log\ GHG_{it} = {} & \alpha_1 + \alpha_2 Log\ GHG_{it-1} + \alpha_3 LogENT_{it} + \alpha_4 LogTRT_{it} + \alpha_5 LogGDP_{it} \\ & + \alpha_6 LogPDN_{it} + \alpha_7 LogECO_{it} + \alpha_8 LogEC_{it} + \alpha_9 LogGRD_{it} + \alpha_{10} LogGE_{it} \\ & + \varepsilon_{it} \ldots \end{aligned} \tag{3}$$

And also,

$$Log\ ANS_{it} = \alpha_1 + \alpha_2 Log\ ANS_{it-1} + \alpha_3 LogENT_{it} + \alpha_4 LogTRT_{it} + \alpha_5 LogGDP_{it} + \alpha_6 LogPDN_{it} + \alpha_7 LogECO_{it} + \alpha_8 LogEC_{it} + \alpha_9 LogGRD_{it} + \alpha_{10} LogGE_{it} + \varepsilon_{it} \ldots \quad (4)$$

Where,

*Log*GHG shows greenhouse gas emissions. $Log\mathrm{GHG}_{it-1}$ is the lagged dependent variable of greenhouse gas emissions. *Log*ANS illustrates is an indicator of environmental sustainability.$Log\mathrm{ANS}_{it-1}$ is the lagged dependent variable of environmental sustainability. *Log*ECO indicates the Eco-innovation index with a point system eco-innovation indicator. *Log*PDN indicates production scores. *Log*GRD illustrates green research and development. *Log*GE demonstrates the government expenditure. *Log*ENT is Energy Tax. *Log*TRT is Transport Tax. *Log*EC is energy consumption. *Log*GDP represents income and/or economic growth. *Log*ETT is Environmental Tax. In this regard, the table below outlines the variables employed in this study and their sources.

An environmental tax is a certain amount that is imposed to environment polluters [21]. For the purposes of this study, environment tax includes the energy tax and transport tax and it is expected to reduce greenhouse gas emissions and increase environment sustainability depending with the price elasticity demand of energy and transport. The rationale is that environmental tax should create awareness to switch to energy efficiency and turn to other clean alternative fuels. Energy tax is the tax that is levied on the energy sector for polluting the environment [58]. Energy tax includes the consumption of petrol, diesel, petrol, diesel, biofuels, electricity consumption and carbon fuels [21]. Transport tax is a tax that pertains to the use of all vehicles in the European Union [23]. The aforementioned taxes are expected to reduce the green house emission at the same time promote environmental sustainability. Energy consumption is the energy used in both industries and at household level which is measured in tonnes of oil [59]. The study expects energy consumption to increase greenhouse gas emissions and reduce environmental sustainability.

Green Research and Development is defined as new innovations introduced to minimise emissions and climate change in the European Union [60]. A positive relationship between Green Research and Development and environment sustainability is expected while an inverse relationship on greenhouse gas emission is expected. The rationale is that new innovations provide better ways of energy use that minimises climate change. Likewise, eco-innovation includes all ideas from stakeholders to develop new products and processes that reduces environmental degradation [61]. Eco-innovation reduces the greenhouse emissions and increases the environmental sustainability.

Production is a scientific procedure of turning all the inputs into consumable goods and services of a certain good and service [62]. Since production makes use of energy, the variable is expected to positively contribute to greenhouse gas emission and reduces the environmental sustainability in the European Union. Gross Domestic Product entails the value of all goods and services produced in the European Union countries over a specified period [63]. The priori expectation is that GDP increases greenhouse emission and decreases environment sustainability in the short-run while betters environment sustainability in the long-run. Government spending is the money spent by the government in acquiring public goods and services [64]. Government expenditure is expected to increase greenhouse expenditure if less or no expenditure is done on reducing climate change. On the other hand, the greenhouse expenditure is likely to reduce if the government spent much on improving climate change.

From **Table 1**, the logarithm of greenhouse gas along with logarithm of adjusted net savings (excluding particulate emission damage) depicts the dependent variables. The remaining variables are all explanatory variables. All the variables were extracted from the Eurostat database with the exception of the logarithm of adjusted net savings (excluding particulate emission damage) which is the only variable gathered from the World Development Indicators (World Bank) database.

3.1 Estimation technique

The paper deployed the panel dynamic Generalised Method of Moments (GMM) as the main approach to address problems connected with, heteroskedasticity serial correlation and heterogeneity [65]. The GMM captures several common estimators that offers a valuable basis for comparison purposes [66]. It is considered as one of the best methods since it not biased, consistent compared to Fixed effects, Pooled Estimates and Ordinary Least Squares [67]. Furthermore, the model allows researchers to make use of many independent variables without facing the endogeneity problems. Thus, the model provides the robust coefficients through the automatic correction of biasness. Several researchers such as Leve and Kapingura [68], Meraya et al. [69] and Nayan et al. [70] have employed the GMM.

Variable	Definition	Unit	Source
*Log*ETT	Logarithm of Environmental Tax	Percentage of gross domestic product (GDP)	Eurostat
*Log*ENT	Logarithm of Energy Tax	Percentage of gross domestic product (GDP)	Eurostat
*Log*TRT	Logarithm of Transport Tax	Percentage of gross domestic product (GDP)	Eurostat
*Log*GHG	Logarithm of Greenhouse gas emissions	Greenhouse gas emissions per capita	Eurostat
*Log*EC	Logarithm of Energy consumption	Thousand tonnes of oil equivalent	Eurostat
*Log*GRD	Logarithm of Green Research & Development	Percentage of gross domestic product (GDP)	Eurostat
*Log*GDP	Logarithm of GDP	Current prices, million units of national currency	Eurostat
*Log*GE	Logarithm of Government Expenditure	Percentage of gross domestic product (GDP)	Eurostat
*Log*ECO	Logarithm of Eco-innovation Index	Yearly scores against the EU = 100 averaged score.	Eurostat
*Log*PDN	Logarithm of production	Yearly scores based on Index, 2015 = 100	Eurostat
*Log*ANS	Logarithm of adjusted net savings, excluding particulate emission damage	Current US$	World Development Indicators (World Bank)

Note: The Logarithm of Greenhouse gas emissions and Logarithm of adjusted net savings, excluding particulate emission damage indicates the dependent variable. The remaining variables are all explanatory variables.

Table 1.
Showing detailed description of variables.

For the purposes of this study, it is apparent that Eq. (1) is comprised of country time effects as well as country fixed effects which is inevitably generates the problem of unobserved country-specific heterogeneity. Thus, Arellano and Bond [71] highlights that GMM is able to transform such particular equations through first difference estimators. Research also shows that the GMM approach is largely suitable in surveys where the cross-section identifiers are greater in quantity (in this study, $N = 28$) against small time periods (in this article, $T = 7$ years) [72]. Overall, panel regression problems such as heterogeneity, heteroskedasticity along with serial correlation can be significantly addressed by using a panel GMM technique [73, 74].

4. Empirical analysis and results

This part of the survey outlines the findings of the study which includes the descriptive statistics, panel unit root test and the GMM results. The following section discusses the descriptive statistics.

4.1 Descriptive statistics

Table 2 illustrates a detailed view of the statistical characteristics of the variables used in this study. It is apparent that the mean of the considered variables is located between their own minimum and maximum values. As well, most of these factors are negatively skewed (63.6%) but only 36.4% demonstrates positive skewness. In this case, transport tax, energy consumption, green research and development, government expenditure, eco-innovation index, production, and environmental sustainability are negatively skewed. On the other hand, environmental tax, energy tax, greenhouse gas emissions, and economic growth are positively skewed. The positive values generated through kurtosis imply that all the variables have leptokurtic attributes.

Variable	Min.	Max.	Mean	Std. Dev.	Skewness	Kurtosis	Observation
*Log*ETT	0.196	0.617	0.405	0.102	0.114	2.254	224
*Log*ENT	0.033	0.521	0.286	0.103	0.246	2.575	224
*Log*TRT	−1.301	0.190	−0.393	0.353	−0.670	2.867	224
*Log*GHG	0.699	1.423	0.959	0.143	0.637	3.319	224
*Log*EC	2.589	5.315	4.206	0.620	−0.323	2.902	224
*Log*GRD	−0.420	0.572	0.128	0.256	−0.157	2.009	224
*Log*GDP	3.820	7.584	5.517	0.868	0.074	2.325	224
*Log*GE	1.420	1.814	1.654	0.066	−0.389	3.2358	224
*Log*ECO	1.301	2.173	1.915	0.1728	−0.709	3.046	224
*Log*PDN	1.203	2.124	1.926	1.926	−4.948	25.678	224
*Log*ANS	0	11.7289	8.969	3.535	−2.040	5.464	224

Source: Authors compilation.

Table 2.
Statistical summary of variables.

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4.2 Panel unit root test analysis

Table 3 shows that when the Augmented Dickey-Fuller test (ADF) tests; Levin, Lin, and Chu (LLC) and the Im-Pesaran-Shin (IPS) were employed the time series is not affected by the presence of unit roots. As such, through deploying a null hypothesis that a specific time series is non-stationary all the variables demonstrates that they are stationary at the first-order differenced series for all ADF, LLC and IPS tests (at 1% significant level) employing the first-generation panel unit-roots. Although variables such as transport tax, production, and environmental sustainability were not confirmed using the IPS test the other two remaining tests argument in favor of the general findings of the paper.

Using logarithm of greenhouse gas emissions as the dependent variable and total environmental tax as the main independent variable **Table 4** outlines the results of the research about the Pooled Ordinary Least Square (OLS) model, Fixed Effect (FE) and Random Effect (RE) models widely regarded as the static models. The details in **Table 4** demonstrates that Hausman test produces a chi-square value of 270.32 which is also significant at 5% ($p = 0.000 < 0.05$). This shows that we will reject the null hypothesis which illustrates that the RE model is suitable in favor of the alternative hypothesis which explains that the FE model is suitable. The dynamic nature of the FE model is further analysed using the two-step GMM model.

	At Level			At 1st Difference		
Variable	**ADF statistic**	**LLC Statistic**	**IPS Statistic**	**ADF statistic**	**LLC Statistic**	**IPS Statistic**
*Log*ETT	1.963 (0.025)**	−7.686 (0.000)***	0.886 (0.8122)	9.339 (0.000)***	−13.951 (0.000)***	−3.378 (0.000)***
*Log*ENT	2.467 (0.007)***	−8.548 (0.000)***	1.483 (0.931)	9.068 (0.000)***	−10.568 (0.000)***	−3.431 (0.000)***
*Log*TRT	2.861 (0.002)***	−8.234 (0.000)***	—	19.540 (0.000)***	−23.409 (0.000)***	—
*Log*GHG	8.940 (0.000)***	−8.525 (0.000)***	−1.817 (0.035)**	5.490 (0.000)***	−9.777 (0.000)***	−2.454 (0.007)***
*Log*EC	7.125 (0.000)***	−11.099 (0.000)***	−1.622 (0.052)*	9.722 (0.000)***	−19.600 (0.000)***	−2.532 (0.006)***
*Log*GRD	4.486 (0.000)***	−6.545 (0.000)***	−0.060 (0.476)	19.727 (0.000)***	−10.522 (0.000)***	−3.990 (0.000)***
*Log*GDP	−1.634 (0.949)	9.158 (1.000)	10.826 (1.000)	2.395 (0.008)***	−16.523 (0.000)***	−0.606 (0.272)
*Log*GE	7.899 (0.000)***	−3.947 (0.000)***	1.734 (0.9586)	10.764 (0.000)***	−15.177 (0.000)***	−3.398 (0.000)***
*Log*ECO	3.003 (0.001)***	−3.321 (0.004)***	−1.948 (0.026)**	23.576 (0.000)***	−13.886 (0.001)***	−4.826 (0.000)***
*Log*PDN	−2.484 (0.994)	5.508 (1.0000)	—	10.630 (0.000)***	−9.284 (0.000)***	—
*Log*ANS	9.972 (0.0000)***	−2.517 (0.006)***	—	18.614 (0.000)***	−20.013 (0.000)***	—

*Notes: ***;**;* mean significant at 1%, 5%, 10% level of significance respectively. Numbers in brackets are* p-*values.*

Table 3.
Showing the panel unit root test results.

	Pooled Model		Random Effect Model		Fixed Effect Model	
	Coefficient	Standard Error	Coefficient	Standard Error	Coefficient	Standard Error
*Log*ETT	0.018 (0.851)	0.093	−0.032 (0.599)	0.062	−0.094 (0.078)*	0.053
*Log*EC	0.028 (0.241)	0.024	0.417 (0.000)***	0.060	0.563 (0.000)***	0.086
*Log*GRD	0.298 (0.000)***	0.056	−0.028 0.442	0.037	−0.076 (0.017)**	0.032
*Log*GDP	−0.065 (0.000)***	0.016	−0.336 (0.000)***	0.041	−0.707 (0.000)***	0.054
*Log*GE	−0.367 (0.041)**	0.178	−0.046 0.489	0.066	−0.224 (0.000)***	0.060
*Log*ECO	−0.031 (0.667)	0.074	0.026 0.399	0.030	−0.025 (0.339)	0.026
*Log*PDN	−0.062 (0.011)**	0.024	0.194 (0.001)***	0.060	0.678 (0.000)***	0.078
Constant	1.942 (0.0000)***	0.292	0.729 (0.005)***	0.260	1.654 (0.000)***	0.449
R^2	0.239		0.012		0.003	
Wald (χ^2)			86.07			
F statistic	9.70				34.14	
Breusch-Pagan test (χ^2)			654.5 (0.000)***			
Hausman test (χ^2)					270.3 (0.000)***	
No. of observations	224		224		224	

*Notes: ***; **; * mean significant at 1%, 5% and 10% significance level, respectively. Numbers in brackets are* p-*values.*

Table 4.
Estimates of static panel data for total environmental tax: Case of Greenhouse Emissions.

The results found in **Table 4** are also generally congruent with outcomes found in **Table 5**. For example, the Hausman test generates a chi-square estimate of 15.24 which is also significant at 5% (p = 0.0330 < 0.05) supports the FE model which permits the study to use the two-step GMM analysis procedure.

The findings generated in **Tables 4** and **5** are also generally confirmed with results in **Table 6** (although in this case energy tax and transport tax are the main independent variables). For instance, the Hausman test shows a chi-square estimate of 195.27 which is also significant at 5% (p = 0.000 < 0.05) favoring the FE model. As such, the two-step GMM analytical process will be applied.

In **Table 7**, the Hausman test generates a chi-square estimate of 18.41 which is also significant at 5% (p = 0.0184 < 0.05) thereby supporting the FE model.

Table 8 presents the outcomes acquired by running the two-step GMM analytical method within the short-run context with regards to total environmental tax as the main independent variable. We begin first by evaluating greenhouse gas emissions as the dependent variable. To begin, the lagged factor $Log\text{GHG}_{it-1}$ of greenhouse gas emissions indicates a positive and significant relationship with greenhouse gas emissions. Hence, a 1% increase in lagged greenhouse gas emissions

	Pooled Model		Random Effect Model		Fixed Effect Model	
	Coefficient	**Standard Error**	**Coefficient**	**Standard Error**	**Coefficient**	**Standard Error**
*Log*ETT	3.719 (0.076)*	2.088 (0.230)	3.199	2.666	1.963 (0.516)	3.017
*Log*EC	1.889 (0.000)***	0.531 (0.385)	1.230	1.414	−11.462 (0.021)**	4.917
*Log*GRD	4.266 (0.001)***	1.240 (0.881)	−0.227	1.517	−3.132 (0.087)*	1.818
*Log*GDP	0.893 (0.013)**	0.357 (0.127)	1.478	0.968	−1.589 (0.606)	3.077
*Log*GE	−13.285 (0.001)***	3.977 (0.018)**	−6.706	2.824	−6.407 (0.061)***	3.401
*Log*ECO	0.200 (0.899)	1.653 (0.072)*	2.400	1.330	0.981 (0.507)	1.477
*Log*PDN	−0.582 (0.278)	0.535 (0.948)	0.091	1.398	10.747 (0.016)**	4.403
Constant	16.742 (0.011)**	6.513 (0.942)	0.710	7.025	53.571 (0.038)**	25.632
R^2	0.382		0.324		0.301	
Wald (χ^2)			26.43			
F statistic	19.07				3.69	
Breusch-Pagan test (χ^2)			489.70 (0.000)***			
Hausman test (χ^2)					15.24 (0.033)**	
No. of observations	224		224		224	

*Notes: ***; **; * mean significant at 1%, 5% and 10% significance level, respectively. Numbers in brackets are* p-values.

Table 5.
Estimates of static panel data for total environmental tax: Case of Environmental Sustainability.

triggers a 0.218% increase in greenhouse gas emissions. This diagnosis implies that when past greenhouse gas emissions in the EU economies rise then they will also stimulate current emission levels. This is confirmed by continued increase in emissions globally [60, 75] which require to be lowered.

Secondly, the total environmental tax shows a positive and highly significant association with greenhouse gas emissions. In this context, a single rise in total environmental tax leads to a 0.22 increase in greenhouse gas emissions. However, this study finding conflicts with [76] who noticed significantly small and even negative carbon leakage after unilateral environmental tax reforms were integrated in Europe between the studied periods 1995 to 2005. Third, a 1% increase in energy consumption also results in a significant 0.73% rise in emissions thereby agreeing with [77] analysis on 116 countries over the period 1990 to 2014. Fourth, a percentage rise in green research and development in the short-run is also leading to a 0.36% increase in greenhouse gas emissions. However, this finding contradicts Fernández, López and Blanco's [78] survey on 15 European Union countries, the United States and China between 1990 and 2013 and spotlights that green research and development adds positively to a decline in emissions in developed countries.

	Pooled Model		Random Effect Model		Fixed Effect Model	
	Coefficient	**Standard Error**	**Coefficient**	**Standard Error**	**Coefficient**	**Standard Error**
*Log*ENT	0.109 (0.215)	0.087	−0.056 (0.293)	0.054	−0.067 (0.148)	0.046
*Log*TRT	−0.100 (0.001)***	0.029	0.032 (0.419)	0.039	−0.015 (0.685)	0.036
*Log*EC	0.015 (0.498)	0.023	0.411 (0.000)***	0.060	0.564 (0.000)***	0.087
*Log*GRD	0.245 (0.000)***	0.056	−0.029 (0.433)	0.037	−0.075 (0.022)***	0.032
*Log*GDP	−0.060 (0.000)***	0.016	−0.334 (0.000)***	0.040	−0.703 (0.000)***	0.054
*Log*GE	−0.060 (0.752)	0.190	−0.045 (0.501)	0.066	−0.226 (0.000)***	0.060
*Log*ECO	0.058 (0.447)	0.076	0.022 (0.467)	0.031	−0.025 (0.347)	0.026
*Log*PDN	−0.092 (0.000)***	0.025	0.191 (0.001)***	0.059	0.672 (0.000)***	0.078
Constant	1.290 (0.000)***	0.337	0.768 (0.003)***	0.262	1.618 (0.000)***	0.451
R^2	0.284		0.010		0.003	
Wald (χ^2)			87.09			
F statistic	10.68				29.53	
Breusch-Pagan test (χ^2)			659.64 (0.000)***			
Hausman test (χ^2)					195.27 (0.000)***	
No. of observations	224				224	

*Notes: ***; **; * mean significant at 1%, 5% and 10% significance level, respectively. Numbers in brackets are* p-*values.*

Table 6.
Estimates of static panel data for total energy tax and transport tax: Case of Greenhouse-gas Emissions.

However, other remaining variables indicates negative and significant links to greenhouse gas emissions. For example, a percentage increase in economic growth leads to a 0.40% significant decrease in emissions. Nonetheless, this study outcomes disagrees with Salahuddin et al. [79] research on Kuwait for the period 1980–2013 by applying the autoregressive distributed lag (ARDL) bounds testing approach and adds that economic growth motivates emissions in both short-run and long-run. In another context, a 1% rise in government expenditure significantly lowers greenhouse gas emissions by 0.815%. However, [80] studied the Venezuelan context over the period from 1971 to 2013 and contributes that government expenditure has a positive effect on environmental degradation-emissions. In addition, the eco-innovation rating is also responsible for decreasing emissions significantly by 0.0039% in these studied EU countries in the short-run. Using the GMM technique on China's 30 provinces during 2000–2013, [81] also contributes that environmental innovation resources along with green knowledge innovation are essential components for emissions reduction. The results of this study also demonstrates that a

	Pooled Model		Random Effect Model		Fixed Effect Model	
	Coefficient	**Standard Error**	**Coefficient**	**Standard Error**	**Coefficient**	**Standard Error**
*Log*ENT	4.516 (0.025)**	1.999	0.839 (0.717)	2.318	−1.207 (0.639)	2.571
*Log*TRT	0.382 (0.564)	0.662	2.106 (0.113)	1.327	5.084 (0.012)**	2.008
*Log*EC	1.787 (0.001)***	0.522	1.182 (0.412)	1.44	−12.918 (0.009)***	4.896
*Log*GRD	4.484 (0.001)***	1.286	−0.362 (0.813)	1.525	−3.436 (0.059)**	1.805
*Log*GDP	0.902 (0.012)**	0.3572	1.397 (0.159)	0.992	−0.837 (0.784)	3.047
*Log*GE	−13.352 (0.002)***	4.334	−6.780 (0.016)**	2.827	−6.056 (0.073)*	3.357
*Log*ECO	0.422 (0.809)	1.742	2.122 (0.116)	1.352	0.578 (0.696)	1.475
*Log*PDN	−0.737 (0.197)	0.569	0.370 (0.786)	1.438	9.717 (0.027)**	4.355
Constant	17.462 (0.024)**	7.699	3.327 (0.647)	7.264	60.900 (0.017)**	25.302
R^2	0.3883		0.274		0.304	
Wald (χ^2)			27.19			
F statistic	17.06				4.06	
Breusch-Pagan test (χ^2)			482.89 (0.000)***			
Hausman test (χ^2)					18.41 (0.0184)**	
No. of observations	224				224	

*Notes: ***; **; * mean significant at 1%, 5% and 10% significance level, respectively. Numbers in brackets are* p*-values.*

Table 7.
Estimates of static panel data for total energy tax and transport tax: Case of Sustainability.

1% increase in production will also likely reduce emissions by a significant 0.40%. However, Ganda [82] survey on the BRICS (Brazil, Russia, India, China, and South Africa) using panel data from 1992 to 2014 express that production practice, through industrial initiative adds to emissions.

The second part of this section will examine the short-run results by examining environmental sustainability as the dependent variable. In this case, a 1% rise in past adjusted net savings, excluding particulate emission damage, which is the proxy for environmental sustainability ($Log\text{ANS}_{it-1}$) will significantly improve current environmental sustainability levels in the scrutinised EU economies by 0.235%. Secondly, a percentage increase in total environmental tax leads to a 2.88% increase in environmental sustainability. Kosonen [83] suggests that environmental taxes are major instruments that governments can deploy in order to achieve sustainability although their regressive effects require extensive consideration. Thirdly, a 1% increase in energy consumption significantly rises environmental sustainability by 5.56%. This outcome is elaborated by [84] study on OECD

	*Log*GHG		*Log*ANS	
	Coefficient	**Standard Error**	**Coefficient**	**Standard Error**
$Log\ GHG_{it-1}$	0.218 (0.004)***	0.075		
$Log\ ANS_{it-1}$			0.235 (0.000)***	0.009
*Log*ETT	0.222 (0.006)***	0.0803589	2.877 (0.000)***	0.681
*Log*EC	0.731 (0.000)***	0.1221115	5.556 (0.000)***	1.159
*Log*GRD	0.362 (0.000)***	0.084	−0.753 (0.053)*	0.389
*Log*GDP	−0.403 (0.000)***	0.083	−1.324 (0.094)*	0.790
*Log*GE	−0.815 (0.000)***	0.184	−10.793 (0.000)***	0.877
*Log*ECO	−0.004 (0.091)*	0.038	−1.542 (0.000)***	0.109
*Log*PDN	−0.396 (0.000)***	0.131	2.910 (0.000)***	0.681
Constant	1.862 (0.000)***	0.377	5.028 (0.000)***	2.380
Wald (χ^2)	88.56 (0.000)		11340.75 (0.000)	
Arellano-Bond test for AR (1) in first differences	z = −0.97 Pr > z = 0.003		z = −1.15 Pr > z = 0.025	
Arellano-Bond test for AR (2) in first differences	z = −0.52 Pr > z = 0.600		z = 0.29 Pr > z = 0.769	
Hansen test of overidentifying. Restrictions	Chi-square = 30.79 Prob > chi2 = 0.683		Chi-square = 21.06 Prob > chi2 = 1.000	
Sargan test of overidentifying. Restrictions	Chi-square = 16.49 Prob > chi2 = 0.284		Chi-square = 106.77 Prob > chi2 = 0.2	
No. of observations	196		196	

*Notes: ***; **; * mean significant at 1%, 5% and 10% significance level, respectively. Numbers in brackets are* p-values.

Table 8.
Findings of GMM short-run results as the dynamic regression approaches: In case of total environmental tax.

economies from 1980 to 2011 using the STIRPAT model and highlights that renewable energy consumption promotes sustainability by lowering emissions while non-renewable energy use increase emissions thereby destroying the natural environment.

Fourth, when short-run green research and development increased by 1% then environmental sustainability will significantly decrease by 0.75%. This finding conflicts with [85] study on US electric generators who adds that short-run decisions to integrate green technologies also provide significant emission reduction opportunities even before new technologies have been fully integrated on a broadened scale.

Furthermore, income is also found to be lowering environmental sustainability in the short-run for the studied EU countries. In this context, a percentage increase in economic development significantly decreases sustainability by 1.32%. Nevertheless, Ganda [86] study on OECD economies also highlights that disagrees with these outcomes as income is ascertained to increase environmental sustainability by 17.8% in the short-run. Another variable, government expenditure is also ascertained to significantly lower environmental sustainability by 10.79% when it increases by a single percent. Then, a 1% rise in eco-innovation is also accountable to a significant decrease estimated at 1.54% of environmental sustainability. However, a 1% increase in production will significantly heighten environmental sustainability by 2.91%. As such, Severo, de Guimarães, Dorion and Nodari [87] having explored the Brazilian Metal-Mechanic industry posits that cleaner production positively influences environmental sustainability.

Table 9 also depicts the results obtained by implementing a two-step GMM analysis process. The presentation disaggregates total environmental tax by identifying energy tax and transport tax as the main independent factors in this analysis. As previously done in the previous section, we commence by initially assessing greenhouse gas emissions as the dependent variable. In this context, it is evident that the lagged variable factor $Log\text{GHG}_{it-1}$ of greenhouse gas emissions indicates a positive and significant link with greenhouse gas emissions. More precisely, a percentage increase in lagged greenhouse gas emissions stimulates a 0.29% rise in greenhouse gas emissions. These results concur with earlier results determined in this paper when total environmental tax was analysed as an aggregate green tax proxy.

In addition, energy tax demonstrates a positive and significant connection with greenhouse gas emissions. As such, a 1% rise in energy tax is sufficient to increase emissions by 0.10%. However, Solaymani [88] study on Malaysia found out that energy tax can reduce emissions although carbon tax was found to be a more effective tax instrument for emissions reduction programs. Furthermore, the paper outcomes show that transport tax shows a negative and highly significant association with greenhouse gas emissions. In this context, a single rise in transport tax leads to a 0.13% decrease in greenhouse gas emissions. González and Hosoda [89] also conducted a study in Japan between 2004 and 2013 using the Bayesian structural time series model and they highlight that the integration of fuel tax has unequivocally minimised aircraft emissions.

As well, the research illustrates that a 1% increase in energy consumption also results in a significant 0.47% rise in emissions thereby agreeing with findings presented in **Table 8**. Conversely, the results in **Table 9** further indicates that a percentage rise in green research and development generates a 0.15% decrease in greenhouse gas emissions thereby supporting [79] study on 15 European Union countries. Furthermore, economic growth has a negative and significant association with emissions. As such, a 1% increase in income stimulates a 0.28% reduction in emissions. However, Magazzino [90] study on Italy over the period 1970 to 2006 demonstrates a bidirectional causality link between economic growth and emissions.

The other outstanding variables indicate positive and significant links to greenhouse gas emissions. For instance, a percentage increase in government expenditure leads to a 0.176% significant rise in emissions. Contradicting with these findings [91] study on a panelised data of 94 countries between 1970 and 2008 illustrates that government expenditure exercise a significant direct influence in reducing the amount of emissions. As well, the eco-innovation rating is also responsible for rising emissions significantly by 0.11%. However, Costantini et al. [92] exploration of European industries confirm that both indirect and direct impacts of eco-innovations assist lessening environmental degradation although the strength varied throughout the industry value chain. The outcomes of the research also confirm

	*Log*GHG		*Log*ANS	
	Coefficient	**Standard Error**	**Coefficient**	**Standard Error**
$Log\ GHG_{it-1}$	0.286 (0.000)***	0.062		
$Log\ ANS_{it-1}$			0.163 (0.000)* **	0.019
*Log*ENT	0.100 (0.066)*	0.055	−4.369 (0.011)**	1.719
*Log*TRT	−0.130 (0.001)***	0.038	5.740 (0.000)***	1.397
*Log*EC	0.466 (0.000)***	0.059	0.539 (0.644)	1.166
*Log*GRD	−0.149 (0.001)***	0.043	1.750 (0.099)*	1.062
*Log*GDP	−0.280 (0.000)***	0.050	1.304 (0.056)*	0.684
*Log*GE	0.176 (0.008)***	0.066	−12.552 (0.000)***	3.015
*Log*ECO	0.113 (0.000)***	0.019	0.341 (0.008)***	0.128
*Log*PDN	0.155 (0.012)***	0.062	−5.987 (0.001)***	1.848
Constant	−0.615 (0.010)***	0.244	33.271 (0.000)***	8.032
Wald (χ^2)	411.85 (0.000)		3202.15 (0.000)	
Arellano-Bond test for AR (1) in first differences	z = −2.09 Pr > z = 0.036		z = −1.10 Pr > z = 0.022	
Arellano-Bond test for AR (2) in first differences	z = 0.32 Pr > z = 0.752		z = 0.60 Pr > z = 0.547	
Hansen test of overidentifying. Restrictions	Chi-square = 19.82 Prob > chi2 = 0.898		Chi-square = 20.10 Prob > chi2 = 0.890	
Sargan test of overidentifying. Restrictions	Chi-square = 43.9 Prob > chi2 = 0.38		Chi-square = 38.51 Prob > chi2 = 0.111	
No. of observations	196			

*Notes: ***; **; * mean significant at 1%, 5% and 10% significance level, respectively. Numbers in brackets are* p*-values.*

Table 9.
Findings of GMM short-run results as the dynamic regression approaches: In case of energy tax and transport tax.

that as production in the short-run increases by 1% emissions also heightens by 0.15%. Likewise, Phalan et al.'s [93] survey on the Brazilian beef industry expresses that production is highly unlikely to help lower emissions, and is possibly likely to exacerbate deforestation.

The remaining segment of this section will evaluate the GMM findings through scrutinising environmental sustainability as the dependent variable. Thus, from **Table 9**, if lagged environmental sustainability ($Log\mathrm{ANS}_{it-1}$) increases by 1% then a

0.16% improvement in current environmental sustainability levels in the studied EU countries is apparent thereby supporting outcomes validated in **Table 8**. Secondly, a percentage increase in total energy tax leads to a 4.37% decrease in environmental sustainability. Likewise, Choi et al.'s [94] survey on the United States gas taxes and fuel subsidy policy explains that in situations where part of gasoline tax revenue is prioritised towards subsidising biofuel production then better resource consumption and mitigated emissions will be evidenced. However, this paper outcomes indicate that a 1% rise in transport tax increase environmental sustainability by 5.74%.

The paper results also demonstrate that a 1% increase in energy consumption significantly rises environmental sustainability by 0.54%. Furthermore, it can be ascertained that if green research and development increased by 1% then environmental sustainability will significantly increase by 1.75%. Moreover, a percentage rise in income motivates a 1.30% rise in environmental sustainability. Hatfield-Dodds et al. [95] study on Australia also contributes that it is quite difficult to decouple economic growth and environmental outcomes and mobilisation of technologies and engagement of environmental incentives are essential for advancement towards sustainable prosperity. The research outcomes also show that a 1% increase in government expenditure is also ascertained to significantly lower environmental sustainability by 12.6%. In addition, a 1% rise in eco-innovation is also accountable to a significant increase estimated at 0.34% of environmental sustainability. Nevertheless, a 1% increase in production will significantly lessen environmental sustainability by 5.99%.

Table 8 which was presented earlier in this section outline the regression findings in the short-run scenario in case where environmental tax was identified as the main independent variable. **Table 10** above extends the discussion by examining the association involving environmental tax as the primary independent factor to both emissions and environmental sustainability but on a long-run setting. In detail, it is evident that environmental tax form a positive relationship with both greenhouse gas emissions and environmental sustainability (although it is significant in this context). Likewise, energy consumption shows a significantly positive link with

	***Log*GHG**		***Log*ANS**	
	Coefficient	**Standard Error**	**Coefficient**	**Standard Error**
*Log*ETT	0.004 (0.970)	0.102	2.642 (0.000)***	0.674
*Log*EC	0.513 (0.000)***	0.145	5.320 (0.000)***	1.157
*Log*GRD	0.144 (0.241)	0.123	−0.988 (0.012)**	0.394
*Log*GDP	−0.622 (0.000)***	0.110	−1.560 (0.049)**	0.792
*Log*GE	−1.034 (0.000)***	0.209	−11.028 (0.000)***	0.881
*Log*ECO	−0.222 (0.025)**	0.099	−1.778 (0.000)***	0.108
*Log*PDN	−0.614 (0.000)***	0.164	2.675 (0.000)***	0.685

*Notes: ***; **; * mean significant at 1%, 5% and 10% significance level, respectively. Numbers in brackets are* p*-values.*

Table 10.
Findings of GMM long-run results as the dynamic regression approach: in case of total environmental tax.

	*Log*GHG		*Log*ANS	
	Coefficient	**Standard Error**	**Coefficient**	**Standard Error**
*Log*ENT	−0.185 (0.021)**	0.080	−4.532 (0.008)***	1.713
*Log*TRT	−0.416 (0.000)***	0.074	5.577 (0.000)***	1.400
*Log*EC	0.180 (0.058)*	0.095	0.376 (0.745)	1.157
*Log*GRD	−0.435 (0.000)***	0.078	1.587 (0.136)*	1.064
*Log*GDP	−0.566 (0.000)***	0.058	1.142 (0.099)*	0.692
*Log*GE	−0.110 (0.292)*	0.104	−12.714 (0.000)***	3.005
*Log*ECO	−0.173 (0.005)***	0.061	0.178 (0.156)	0.126
*Log*PDN	−0.131 (0.193)*	0.101	−6.150 (0.000)***	1.842

*Notes: ***; **; * mean significant at 1%, 5% and 10% significance level, respectively. Numbers in brackets are* p*-values.*

Table 11.
Findings of GMM long-run results as the dynamic regression approach: In case of energy tax and transport tax.

both emissions and environmental sustainability. Green research and development produce a positive link with emissions but its connection with environmental sustainability is significantly negative. The results further prove that economic growth, government expenditure, and eco-innovation show significant negative relationships to both emissions and environmental sustainability in the long-term. Lastly, production generates a significantly negative link with emissions but its association with environmental sustainability is significantly positive.

Table 9 of this part of the study produced short-run associations by disintegrating total environmental tax through isolating energy tax and transport tax as the main independent variables. **Table 11** expand this analysis by identifying the association of these explanatory variables against both emissions and environmental sustainability within a long-run basis. In brief, energy tax, government expenditure and production produces a significantly negative connection with both emissions and environmental sustainability. Other findings confirm that transport tax, green research and development, economic growth and eco-innovation demonstrate negative and positive associations with both emissions and environmental sustainability. The relationship involving energy use to both emissions and environmental sustainability is positive in both cases.

5. Discussion and implications

This section presents a detailed analysis of the study also highlights the implications of the research.

Table 12 provide useful insights about the context involving the association between total environmental tax and both greenhouse gas emissions along with environmental sustainability. Total environmental tax appears to be increasing emissions both on the short-and long-run scenario although it is found to be also

	Environmental tax				Energy tax and Transport tax			
	***Log*GHG**		***Log*ANS**		***Log*GHG**		***Log*ANS**	
	Short-Run	**Long-Run**	**Short-Run**	**Long-Run**	**Short-Run**	**Long-Run**	**Short-Run**	**Long-Run**
*Log*ETT	+	+	+	+				
*Log*EC	+	+	+	+	+	+	+	+
*Log*GRD	+	+	—	—	—	—	+	+
*Log*GDP	—	—	—	—	—	—	+	+
*Log*GE	—	—	—	—	+	—	—	—
*Log*ECO	—	—	—	—	+	—	+	+
*Log*PDN	—	—	+	—	+	—	—	—
*Log*ENT					+	—	—	—
*Log*TRT					—	—	+	+

Table 12.
Summary of GMM short-and long-run results.

simultaneously increasing environmental sustainability. This implies that while overall natural environmental effect as a result of imposing environmental tax improves there is also a need for EU economies to introduce specific green taxes which directly focus on particular environmental indicators so that emission reduction is effectually achieved. Moreover, there is a need to transform or remove particular environmental taxes which are not effectively achieving zero-emission targets. As well, taxes can be modified by adding regulatory instruments so that they are aligned with natural environmental objectives and goals. It is also apparent that energy consumption has been increasing the level of emissions and environmental sustainability. In this case, EU economics should continue expanding the integration of renewable energy and oppose further consumption of fossil fuels. There is evidence of renewable energy use in EU economies [13, 60] in pursuit of lower emissions which can possibly explain the improved environmental sustainability context. However, there is also a need to upgrade energy systems of green energy technologies so that they do not add to heightening emissions.

Green research and development is found to be highly effective when environmental taxes are emphasising of particular environmental measures instead of adopting a holistic environmental tax policy. For instance, when environmental tax was disaggregated the tax tools used managed to motivate green research and development to lower emissions and simultaneously raise environmental sustainability. Economic growth is quite effective in lowering the level of greenhouse gases whether environmental tax is aggregated and/or disaggregated. Of note is that economic growth effectively improve environmental sustainability in the short and long-run when EU economies use specific environmental taxes when adopting a comprehensive environmental tax instrument.

On the one hand, government expenditure is very efficient in lowering emissions in the short and long-run but is also not able to promote environmental sustainability during these periods in case where aggregate environmental tax is employed. On the other hand, the situation is also predominantly noticeable when environmental tax has been disaggregated (energy tax and transport tax) except that it increases emissions in the short-run. This indication shows that government expenditure in EU economies needs to focus on an inclusive approach which supports all issues related to sustainability instead of putting much emphasis on emissions alone. In this case, government expenditure should also include environmental standards and regulations and measures which heighten environmental sustainability.

It is also observable that eco-innovation is capable of lowering emissions whether environmental tax is aggregated or disintegrated. However, in the case where environmental tax is not aggregated, that is, specific eco-innovation improves environmental sustainability but it worsens environmental sustainability in case of total environmental tax. This shows the importance of introducing specific eco-innovation regulatory standards that fits different parts of the production and ultimate distribution of manufactured goods and services.

Although production in EU economies manage to lower emissions in cases where environmental is aggregated and/or not is has not been able to improve environmental sustainability. In this case, while production has managed emissions reduction targets the impacts of this procedure on other natural environmental components require to be upgraded.

Lastly, it is apparent that energy tax has been lessening environmental sustainability but transport tax has been effective in creating required environmental sustainability scenarios. Both these taxes are also effective in the long-run in lowering emissions although energy tax is found to ineffective in lowering emissions in the short-run. It is evident that the transport tax appears to be a more effective instrument to meet environmental goals when compared to energy tax in EU economies. In this case, there is a need to revise energy policy and regulatory instruments that deal with energy in these countries so that such tools are harmonising with sustainability goals and objectives.

6. Conclusion

The first findings presented regression results when the aggregate environmental tax was employed. These outcomes show that total environmental tax, energy consumption, green research and development significantly heightened emissions in the short-run scenario. The results further demonstrate that in the short-term economic growth, government expenditure, eco-innovation rating and production scores significantly lowered emissions. The results also confirm that total environmental tax, energy consumption and production significantly increase environmental sustainability in the short-run. Conversely, green research and development, economic growth, government expenditure, and eco-innovation significantly lower environmental sustainability in the short-run. The long-run results demonstrate that environmental tax and energy consumption develop a positive relationship with both greenhouse gas emissions and environmental sustainability respectively. In addition, green research and development generates a positive connection with emissions although its link with environmental sustainability is significantly negative. Economic growth, government expenditure, and eco-innovation illustrates a significant negative relationships to both emissions and environmental sustainability in the long-term. In the long-run, production produces a significantly negative association with emissions but a significantly positive relationship with environmental sustainability.

The second part of the results section outlined regression when disaggregated environmental tax (energy tax and transport tax) was deployed. Thus, in the short-term, energy tax, energy consumption, government expenditure, eco-innovation rating, and production scores spur a significant rise in emissions. However, transport tax, green research and development, and income influence lessens emissions in the short-run. Furthermore, energy tax and production significantly reduce environmental sustainability in the short-term. Nonetheless, transport tax, energy consumption, green research and development, income and eco-innovation significantly increase environmental sustainability in the short-run. The long-run findings proves that energy tax, government expenditure and production produces a significantly negative relationship with both emissions and environmental sustainability. As well, transport tax, green research and development, economic growth along with eco-innovation produce negative and positive associations with both emissions and environmental sustainability. Lastly, energy use shows a significantly positive link to both emissions and environmental sustainability.

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