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Research Article

Environmental Performance and Carbon Emissions: Revisiting the Role of Environmental Taxes and Policy Stringency for OECD Countries

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Abstract

Effectively combating climate change is a critical objective in the twenty-first century, with rising global temperatures, extreme weather events, and environmental degradation having severe social and economic consequences, necessitating urgent policy actions. The current study examines the impact of environmental taxes and environmental policy stringency on CO_2 emissions in OECD countries, utilizing a balanced panel dataset of 32 OECD countries from 2000 to 2022. Additionally, this study incorporates key control variables, including renewable energy consumption, economic growth, financial development, urbanization, and human capital, to provide a comprehensive analysis. The empirical results reveal that 1% increase in environmental taxes leads to a 0.119% reduction in CO_2 emissions, while a 1% increase in environmental policy stringency results in a 0.040% decrease in CO_2 emissions. Renewable energy significantly reduces emissions, whereas urbanization contributes positively to CO_2 emissions. Using system GMM for robustness tests shows that environmental taxes and strict environmental policies can effectively improve the quality of the environment in OECD countries. Moreover, we categorized 32 OECD countries into two groups to address potential heterogeneity: low-emitting countries and high-emitting countries. Our empirical findings of these groups are consistent with the overall results. Finally, our empirical results support the EKC hypothesis by confirming an inverted U-shaped relationship between economic growth and CO_2 emissions across all models. Thus, we concluded that environmental taxes and strict environmental policies have a significant impact on CO_2 emissions among OECD countries.

Keywords

CO_2 Emissions, Environmental Taxes, Environmental Policy Stringency, Renewable Energy

1. Introduction

1.1. Background

Environmental degradation is considered a challenging problem that has attracted attention from researchers throughout the world because it is a likely threat to sustainable development [1]. Rising temperatures and carbon dioxide (CO_2) emissions have a detrimental effect on the planet's

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ecosystem and human life. Extreme weather events are caused by CO_2 emissions and growing atmospheric pollution levels [2]. Extreme weather events are becoming more frequent and intense, indicating that climate change is an existential concern that poses serious hazards to people, society, and the economy. The study by [3] estimated that the cost of economic losses from weather-related disasters was USD 470 billion in 2017, and these figures are anticipated to increase significantly soon. The most terrifying aspect of the climate crisis is that doing nothing will affect everything. The Egypt Climate Pact, the outcome of COP27, was the result of two weeks of demanding discussion with over 200 countries, months of hard effort, and two years of ongoing participation. The panel decided to take several critical actions, including acknowledging the urgency of keeping average temperature growth less than 2 ℃ and aiming to maintain it below 1.5 ℃, stepping up efforts to maintain carbon dioxide emissions at a rate of 45%, which will lead to net zero emissions by 2050, substituting green resources and renewable energy sources for fossil fuels, and providing funding for the rapidly changing climate.

Extreme weather conditions caused by climate change will affect energy supply and demand. Most severe weather is directly related to power outages and distribution, as extreme phenomena can disrupt the power supply. In this case, Climate change will lead to higher energy consumption. In Figure 1, the graph illustrates the total energy supply in the OECD, highlighting that renewable energy has grown significantly in recent years. However, most of the energy supply still comes from coal, oil, and natural gas, which are harmful to the environment.

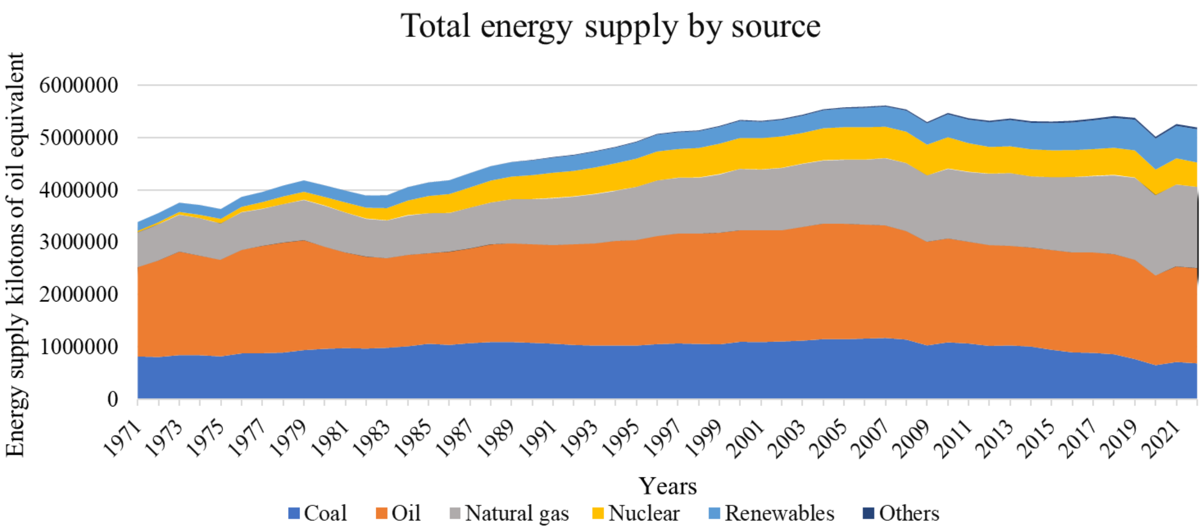

Figure 1. *Total energy supply in kilotons of oil equivalent.*

As [4] points out that mitigating climate change will gain more popularity if it also tackles several other significant societal objectives, like improved public health, clean air, and increased availability of electricity through dispersed renewable energy technologies. In other words, effective environmental regulations and measures to decrease CO_2 emissions are required to mitigate the harmful effects of environmental challenges. In addition to playing an essential role in the global economic system, OECD countries significantly contribute to environmental degradation; OECD nations contributed 45.70% of global GDP in 2021. According to the British Petroleum (BP) and World Bank, primary energy use and CO_2 emissions in OECD countries accounted for 38.6% and 31.2% of global totals, respectively, with fossil fuels accounting for 77.40% of their energy supply. The energy sector, which accounts for over 27% of GHG emissions across all countries in the OECD, on average, has the biggest emitter. Transportation, at 23%, agriculture, at 10%, and industry, at 12%, are the next most significant emitters shown in Figure 2. Countries are drafting plans to reduce greenhouse gas emissions, considering the catastrophic climate change brought on by increased economic activity and rising energy consumption due to industrialization.

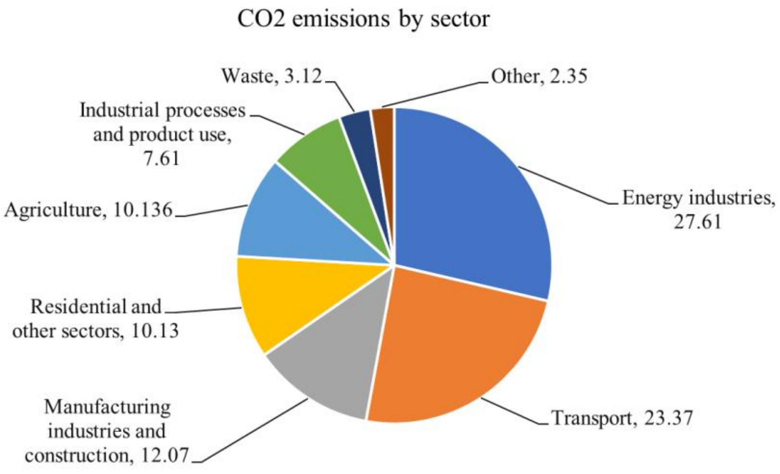

Figure 2. *Emissions by sector in OECD countries.*

1.2. Environmental Taxes

To reduce environmental concerns and increase energy efficiency, climate policies are driven mainly by environmental regulations. Regulations, education campaigns, innovation policies, and environmental subsidies are just a few of the many green policy options available to governments to address climate change and related environmental issues [5]. According to [6], an environmental tax, often called an environmentally related tax, is a compulsory and non-refundable payment given to the government. It is imposed on specific tax bases with major environmental significance. These taxes are typically administered by fiscal authorities and serve to both increase tax revenue and allocate it toward other entities or environmental initiatives. Environmental taxes are often known as Pigovian taxes, which are imposed at a rate equivalent to the marginal damage cost to rectify the inefficiencies. Essentially, the Pigovian tax is responsible for determining a tax rate that adequately offsets the cost of environmental damage.

Most OECD nations have implemented environmental taxes differently over the last decade. Many countries have also adopted complete green tax reforms, while others are now considering adopting environmental taxes [7]. Environmental taxes help to raise money in addition to their unique role in preserving and enhancing the environment. In addition to financing upcoming projects related to sustainable energy, profits are divided in several ways. For instance, according to revenue statistics from the OECD, environmental taxes contribute an average of 6.7% of all tax collections and 2% of GDP in OECD countries. It is important to note that the amount of revenue governments receive from environmental taxes varies significantly between nations; in the United States, they range from 0.7% to 1.9% of GDP, while in Slovenia, they are 4.5% of GDP [8]. Further, [9] reports that throughout the last 21 years, income from environmentally linked taxes has consistently decreased despite ongoing efforts to improve the tax base (shown in Figure 3). In 2017, environmental taxes accounted for 2.3% of GDP, lower than the 2.4% growth in 2000 and 2010.

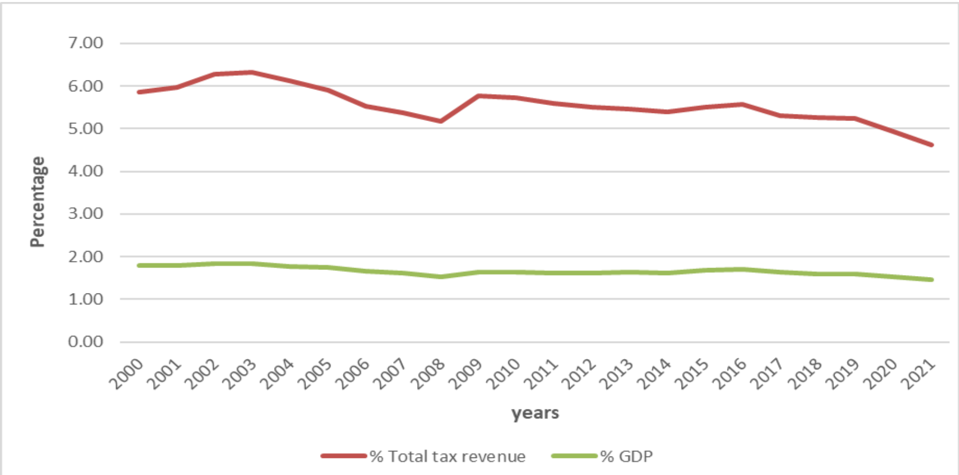

Figure 3. *Percentage of GDP and total tax revenue.*

1.3. Environmental Policy Stringency

As per [10], the Environmental Policy Stringency Index is a globally equivalent and country-specific indicator of the stringency of environmental regulations. Stringency is defined as the extent to which environmental policies impose an explicit or implicit cost on polluting or environmentally harmful activity. The vital role of the EPS is demonstrated by its three primary components, which may each have a distinct effect on how organizations behave about the environment: market-based policies that aim to tax harmful behaviors, non-market-based policies that emphasize green behavior standards, and technological support.

Recognizing the severity of environmental degradation, countries worldwide have implemented stringent policy measures, such as environmental taxes, emissions standards, and trading schemes, to address these environmental challenges. [11] developed a strictness measure that utilizes the Environmental Policy Stringency Index to differentiate between market and non-market-based instruments.

The study by [10] stated that the major goal of environmental regulations is to restrict polluting emissions while maintaining growth targets. When environmental regulations become more rigorous, they usually involve measures to reduce CO_2 emissions, such as establishing reduction targets, implementing a carbon pricing system, expanding renewable energy, and promoting energy efficiency. These regulations encourage businesses to use environmentally friendly technologies and practices, leading to a reduction in CO_2 emissions.

The research by [12] acknowledges that environmental policy stringency has attracted the interest of scholars and has been utilized to examine the relationship between economic growth and climate change or to evaluate the effectiveness of environmental policies in decreasing greenhouse gases. Nevertheless, current literature places significant emphasis on the absence of a dependable metric for gauging the stringency of environmental policies, which leads to an unequal response to environmental issues across nations, as discussed by [13]. Hence, the OECD policy stringency measure is a dependable indicator for conducting cross-country assessments.

Figure 4 shows the theoretical framework behind developing the Environmental Policy Stringency Index.

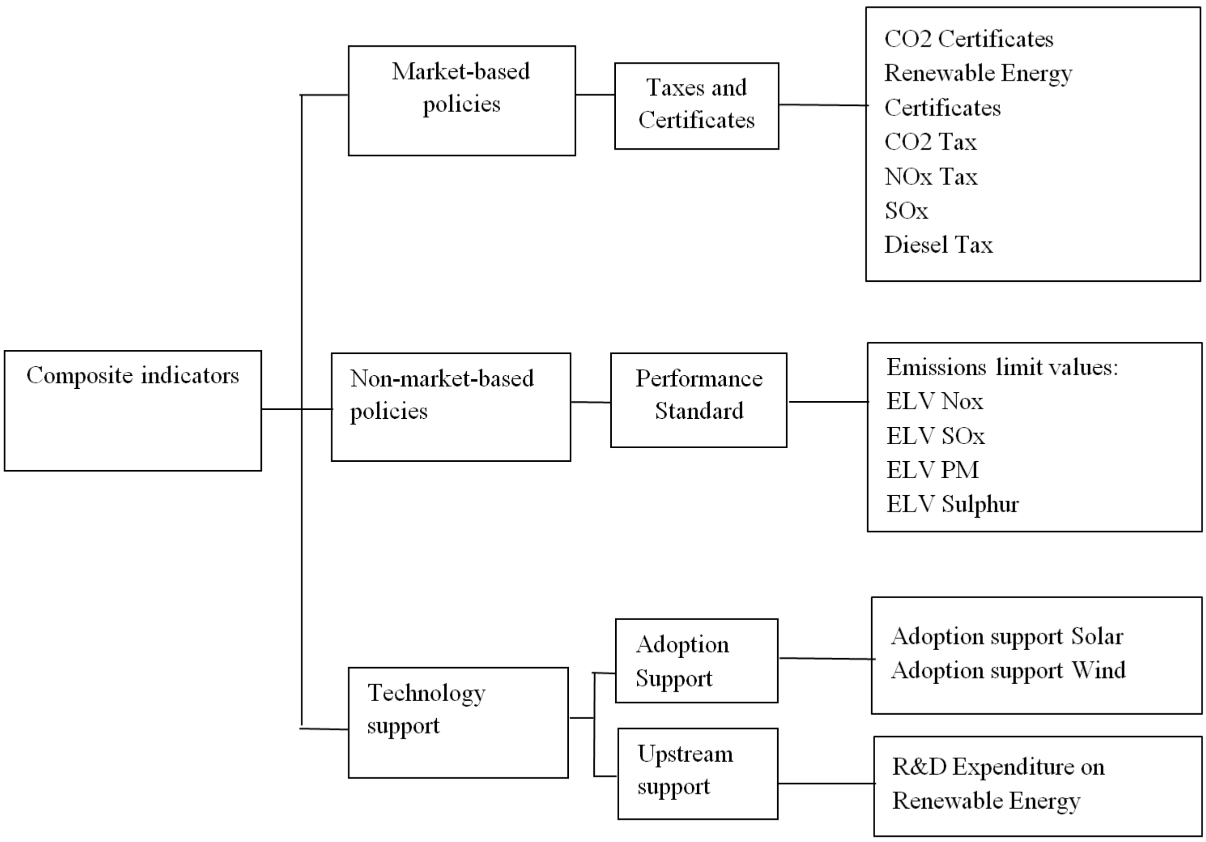

Figure 4. *Environmental policy stringency structure.*

The current study makes numerous unique contributions to the existing literature. Firstly, by departing from previous research that has mostly focused on environmental taxes, the current study adds to the literature by empirically examining the combined effects of environmental taxes and environmental policy stringency on CO_2 emissions across 32

OECD countries from 2000 to 2022, highlighting the joint role of fiscal and regulatory tools. Secondly, it is among the first to incorporate the updated version of the environmental policy stringency index, launched in 2022, which includes a technology support dimension in addition to traditional market-based and non-market-based policies, thereby providing a more comprehensive measure of environmental regulation than previous studies. Third, the study incorporates a broad range of control variables, including renewable energy, economic growth, urbanization, financial development, and human capital, to provide a multidimensional view of the determinants of CO_2 emissions in advanced economies. Fourth, the study employed both static models (fixed effect) and dynamic panel system GMM estimation techniques to address potential econometric issues like endogeneity, unobserved heterogeneity, and serial correlations, thus ensuring the robustness and reliability of the findings. Fifth, the study conducts heterogeneous analysis by distinguishing between low-emitting and high-emitting OECD countries, providing policy-relevant insights into the differential effects of environmental policies across different emission profiles. Finally, the study empirically validates the Environmental Kuznets Curve (EKC) hypothesis in OECD countries, broadening its relevance to countries with advanced and regulatory frameworks and strict environmental regulations.

2. Literature Review

2.1. Literature on Environmental Taxes and CO_2 Emissions

The environmental taxation claims that placing taxes on environmental issues will stimulate the development of ecologically friendly solutions to reduce the consumption of fossil fuels and other harmful resources [14].

Notably, [15] investigated the impacts of various carbon pricing strategies on both the environment and the economy from 1994 to 2015. The panel smooth transition regression approach was employed in the study, and empirical evidence showed that when globalization levels increased, environmental taxes led to a decrease in CO_2 emissions. A study by [16] investigated the impact of environmental taxes and environmental policy stringency on enhancing environmental quality. The study utilized a causal test to analyze the panel data of the E7 nations from 1994 to 2015. The findings of the study show that environmental taxes significantly and negatively affect CO_2 emissions.

In addition, [17] examine the effect of environmental taxes on the CO_2 emissions of the G7 countries from 1994 to 2014. The relationship between economic complexity and natural resources, which contribute to CO_2 emissions, is also explained. The analysis suggests that environmental taxes control CO_2 emissions and energy usage. Furthermore, the findings demonstrate that environmental taxes can effectively build a carbon-free economy. If a well-designed environmental tax system is implemented, businesses will immediately shift to unaffected production methods. Furthermore, [18] revealed that the application of environmental taxes, such as the total environmental tax, pollution tax, and energy tax, resulted in a decrease in CO_2 emissions in OECD nations.

Further, a study by [19] examined the impact of environmental taxes and stringent environmental policies on CO_2 emissions within a 20-country panel from 1995 to 2012. Panel cointegration tests revealed a statistically significant adverse relation between CO_2 emissions and environmental taxes. The author claimed that reducing CO_2 emissions correlated with strict environmental policies. Additionally, [20] investigated the impact of eco-innovation, renewable energy, and environmental taxation on environmental degradation in China. They emphasize that environmental fees help to reduce environmental degradation; furthermore, eco-innovation and renewable energy help promote environmental sustainability in China. Guo et al. (2014)[21] used the computable general equilibrium model (CGE) to investigate the impact of carbon tax on the Chinese economy and environmental degradation. The findings show that implementing environmental taxes reduces the CO_2 emissions caused by fossil fuel consumption. Bashir et al. (2020)[22] explore the effect of environmental taxes on carbon emissions in OECD nations from 1995 to 2015, alongside other key variables such as renewable energy and financial development. In this study, GMM and quantile regression models were used. The empirical outcomes of these analyses confirm the hypothesis that environmental taxes adversely affect environmental degradation. Another study by [23] explored the effect of environmental taxes and economic growth on the increasing ecological footprint of 29 OECD countries. The study utilized the autoregressive distributed lag (ARDL) methodology to attain its objectives. The study employed DOLS, FMOLS, and fixed effects to verify the robustness of the ARDL estimator. The findings indicated that environment-related taxes and renewable energy consumption negatively affect the ecological footprint in OECD countries. As stated above, the study established the following hypothesis.

H1. Environmental taxes affect the CO_2 emissions in OECD economies.

2.2. Literature on Environmental Policy Stringency and CO_2 Emissions

The particular section of literature focuses on the relationship between environmental regulations and environmental degradation. Severe environmental regulations and policies are being pushed to reduce the worsening environmental quality; as a result, reducing CO_2 emissions requires severe environmental regulations. The main objective of this indicator is to increase the cost of environmental pollution services to shift producer and consumer behavior toward environmentally friendly items.

The study by [24] examined the potential of government regulations on the mining industry's efficiency in China. The findings revealed variations in the effects of laws based on the type of property. According to the authors, a deviation from the profit maximization objective, a lack of a monitoring mechanism, and an inadequate reward all hinder eco-efficient performance. They suggested command-and-control tools, suitable target-based rules for state-owned corporations, and market-oriented regulatory tools for private businesses, such as tax benefits and subsidies. Moreover, [25] examined the influence of stringent environmental regulations on CO_2 emissions in 32 countries from 1990 to 2015 using a quantile fixed-effect panel data technique. According to the study, stricter environmental policies reduce emissions and have a greater effect in countries with smaller carbon emissions.

Furthermore, [26] employed linear and non-linear panel ARDL models to examine the influence of environmental policy stringency on CO_2 emissions in the top five carbon-emitting countries (China, India, Russia, the United States, and Japan) between 1990 and 2019. The findings of both models show that increasing environmental policy stringency reduces CO_2 emissions over time. Comparably, [27] have shown that reforming the coal tax policy helps encourage emissions reductions and other environmental advantages, but the results vary depending on the tax rates applied. A sensible decision to lower CO_2 emissions in China may be to impose a 5% tax on coal resources, which may discourage excessive resource use, increase efficiency, and minimize environmental harm. In addition, [28] examined the effects of tax and subsidy policies on reducing CO_2 and air pollutant emissions in China's transport sector from 2008 to 2050 by using the CIMS model. The findings suggest that the tools most likely to reduce CO_2 emissions intensity are energy and fuel taxes, while vehicle subsidies show limited impact. The author also demonstrated that carbon prices could be a useful policy instrument to mitigate environmental pollution.

Further, the study by [29] claims that EPS can mitigate the harmful impacts of CO_2 emissions by promoting environmentally friendly technologies and discouraging carbon-intensive and ecologically inefficient ones. As a result, environmental regulations, tariffs, and EPS can shift production and consumption patterns toward environmentally friendly practices and less carbon-intensive goods. According to a study by [30], a strategic combination of market and non-market environmental policies proves to be more effective in promoting sustainable innovation among firms. Market-based environmental policies promote innovation, while non-market-based policies yield rapid outcomes but impede sustainable technological innovation when applied independently. Based on the above literature, we formulated the given hypothesis.

H2. Environmental policy stringency negatively impacts CO_2 emissions in OECD countries.

2.3. Other Control Variables

In recent years, using renewable energy to combat climate change and lower emissions of greenhouse gases, carbon emissions (CO_2) have been a topic of much discussion. The study by [31] used the NARDL to analyze the relationship between the use of natural gas, green energy, and CO_2 pollution in the United States from 1997 to 2017. The results revealed a long-term negative relationship between natural gas, green energy use, and CO_2 emissions. Additionally, [32] used the CS-ARDL model to analyze data from 45 exporting countries. Their findings revealed that higher energy productivity, GDP, renewable energy, total resident and non-resident patents, and the economic complexity index were associated with a reduction in the ecological footprint.

Further, [33] employed the ARDL model to analyze MINT countries from 1980 to 2018 and discovered a positive correlation between economic growth and CO_2 emissions. The study by [34] used the ARDL model to study the relationship between financial development, GDP growth, and carbon emissions. According to the evidence, economic growth and energy use significantly increase CO_2 emissions. However, financial development and trade openness help mitigate CO_2 emissions. The study by [35] examines the relationship between financial development and environmental deterioration. They concluded that financial development can lower carbon emissions and benefit environmental disclosure in transitional economies. Additionally, [36] examined the impact of financial development on carbon emissions in 19 emerging nations. According to the empirical findings, financial development has a detrimental long-term effect on carbon emissions, suggesting that it may be able to reduce environmental degradation.

In addition, [37] explored the relationship between urbanization and energy use and how it affects environmental quality. The findings show significantly positive connections between urbanization and environmental damage brought on by energy use. Recently, [38] investigated whether urbanization, renewable energy, and economic growth could contribute to being environmentally friendly in several Asian countries. Long-term estimates revealed that energy use and urbanization lead to higher CO_2 emissions, while economic growth contributes to their reduction. Based on these findings, the authors strongly recommended the implementation of smart urban systems across the sampled countries. Further, [39] examined the influence of human capital on carbon emissions in 30 Chinese regions. Overall, the results suggested that primary, institutional, trained, and knowledgeable human capital would contribute to reducing carbon emissions in various regions. Similarly [40] examined the impact of human capital, exports, energy, and economic development consumption on CO_2 emissions in newly industrialized countries. The findings revealed that economic development and human capital contributed positively to reducing CO_2 emissions.

3. Data and Methodology

The current study utilizes secondary data to examine the role of environmental taxes and environmental policy stringency on CO_2 emissions. The empirical datasets from 2000 to 2022 for 32 OECD countries are examined. The countries were designated based on the availability of data. The model variables are CO_2 emission, environmental tax, environmental policy stringency, Renewable energy consumption, gross domestic product, human capital, financial development, and urbanization. The data on CO_2 emissions are measured in kilo tons, while data on environmental tax is measured as a percentage of total taxes. Environmental policy stringency is measured as an index. Renewable energy consumption is measured as the percentage usage of total energy. The data for financial development is measured as domestic credit to the private sector (percentage of GDP), the gross domestic product is measured as GDP (current USD), and urbanization is measured as urban population. The human capital index is measured as an index (based on years of schooling).

Table 1. *Variables description.*

Variables	Description	Source	Measurement
CO_2	Carbon emissions	WDI	Kilo Tons
ETAX	Environmental taxes	OECD (2023)	% of total tax revenue
EPS	Environmental policy stringency	OECD (2023)	Index
RE	Renewable energy	OECD (2023)	% of total final energy consumption
GDP	Gross domestic product	WDI	GDP per capita (Constant 2015 $)
UPOP	Urbanization	WDI	Urban Population
FD	Financial development	WDI	Domestic credit to private sector (% of GDP)
HC	Human capital	Penn World Table	Index (based on years of schooling)

The present study builds upon recent research conducted by [41] and [22] to examine the impact of environmental taxes and environmental policy stringency on CO_2 emissions in OECD countries.

$$CO_{2it}=\beta_0+\beta_1 ETAX_{it}+\beta_2 EPS_{it}+\beta_3 REC_{it}+\beta_4 GDP_{it}+\beta_5 FD_{it}+\beta_6 UPOP_{it}+\beta_7 HC_{it}+\varepsilon_{it} \quad (1)$$

To address the heteroscedasticity problem and reduce the impact of outliers, the current study applies natural logarithms. This transformation reduces the variability and smooths the data. Additionally, it makes the coefficients easier to interpret. Furthermore, Eq. (1) can be arranged logarithmically as given;

$$lnCO_{2it}=\beta_0+\beta_1 lnETAX_{it}+\beta_2 lnEPS_{it}+\beta_3 lnREC_{it}+\beta_4 lnGDP_{it}+\beta_5 lnFD_{it}+\beta_6 lnUPOP_{it}+\beta_7 lnHC_{it}+\varepsilon_{it} \quad (2)$$

Where CO_2 represents carbon emission, ETAX is environmental tax, EPS is Environmental policy stringency, REC is renewable energy consumption, GDP is Gross domestic product, FD is financial development, UPOP is urbanization, and HC is a human capital index, where i represents countries under consideration and t represents time, while ε represents the error term.

Firstly, the study will employ two types of approaches: the fixed effects and random effects models. The fixed effect model accounts for unobserved country-specific characteristics that could bias the results. Since OECD nations have different environmental policies and economic conditions, the fixed effect model eliminates time-invariant heterogeneity, resulting in more accurate estimates.

Simultaneously, the random effects model implies that the corresponding impacts of the cross-sections and period effect vectors are generally uncorrelated. The current study employed the [42] test to determine the most suitable model. The Hausman test compares coefficient estimates from fixed and random effects models. Since the fixed effect and random effect are weak in managing correlation and heterogeneity across variables, the study additionally employed the generalized method of moments (GMM).

Since managing the serial correlation, heterogeneity, and heteroskedasticity problem, the generalized method of moments (GMM) is also used to check the robustness of the results. The GMM-based strategies have an advantage over panel data approaches in estimating a dynamic panel model [43]. For example, the usage of instrumental variables in the GMM process ensures consistent estimation, even with measurement errors [44], endogenous right-hand side variables [45], serial correlation [46], and heteroscedasticity [47], There are two kinds of GMM estimators: the difference GMM and system GMM estimators. The difference GMM approach removes the time-invariant factor as well as the unobserved cross-sectional individual effect. When the regression series shows high persistence, the difference GMM estimator has a serious bias issue [48]. Such persistence produces weak instruments, meaning that the association between the instruments and the variable to be captured remains limited in strength. Furthermore, the Sargan test in one-step GMM doesn't account for heteroscedasticity, leading to potential bias in coefficient estimates [44]. To overcome this problem, this study employs the two-step system GMM estimator for the dynamic panel data model, developed by [48, 49]. The current study uses variables' lagged differences and constants. Since the lagged dependent variable causes an endogeneity concern, other estimators such as Mean Group and Pool Mean Group could be inaccurate. The GMM estimator is reliable and efficient when N (countries) is larger than T (time).

Additionally, the Hansen test is used to assess the validity of the instrumental variables in GMM models. The Hansen test is a Chi-square test that determines whether the residuals are associated with the instrumental variables. When we fail to reject the null hypothesis of the Hansen test, we can assume that the instruments are valid and there is no evidence of instrument misspecification.

The traditional EKC model is used in assessing the impact of economic growth on the environment. Following [50] It was adopted in this study and written as;

$$lnCO_{2it}=\beta_0+\beta_1 lnETAX_{it}+\beta_2 ENP_{it}+\beta_3 lnREC_{it}+\beta_4 lnGDP_{it}+\beta_5 GDP^2_{it}+\beta_6 lnFD_{it}+\beta_7 lnUPOP_{it}+\beta_8 lnHC_{it}+\varepsilon_{it} \quad (3)$$

Where $lnGDP^2$ denotes the square of GDP, in the quest to examine the potential presence of an inverted U-shaped relationship between economic growth and environmental quality within OECD economies.

4. Empirical Findings

It is normal to assess the descriptive statistics of numerical variables before doing regression analysis. Descriptive statistics seek to provide general information about the applicable variables, such as the number of observations, mean, standard deviation, or minimum and maximum values of a specific variable. Furthermore, any occurrence of an outlier variable is easier to identify. Table 2 provides a summary of the descriptive statistics for all variables in this study. The descriptive statistics given in the study show that all variables are performing normally, and there are no outliers in the data series.

Table 2. *Descriptive statistics.*

Variable	Observations	Mean	Std. Dev.	Minimum	Maximum
$LnCO_2$	704	11.727	1.42	8.868	15.569
LnETAX	704	1.86	0.387	0.315	2.832
LnEPS	704	1.254	0.474	0	2.89
LnRE	704	1.081	0.397	0.261	1.795
LnGDP	704	10.278	0.709	8.04	11.8
LnFD	704	4.155	1.247	1.681	5.377
LnUPOP	704	7.084	0.632	5.565	8.44
LnHC	704	1.061	0.357	0.421	1.348

The Variance Inflation Factor (VIF) test is used to assess multicollinearity. Table 3 demonstrates no evidence of multicollinearity since the VIF scores of the independent variables are all less than 7.

Table 3. *Multicollinearity test results.*

Model	VIF	1/VIF
LnETAX	1.33	0.75
LnEPS	1.51	0.66

Model	VIF	1/VIF
LnREC	1.19	0.61
LnGDP	1.63	0.83
LnFD	1.23	0.81
LnUPOP	1.30	0.76
LnHC	1.20	0.83
Mean VIF	1.34	

According to the Hausman test, the fixed effects model was selected for the OECD countries, as presented in Table 4. Further, the countries were divided into two groups to deal with the heterogeneity concerns in the panel. For all three panel groups, the Chi-square is significant at the 5% level; thus, we conclude that the fixed effect model best fits the analysis. The results indicate that ETAX significantly and negatively impacts carbon dioxide emissions across all models. Specifically, a 1% increase in ETAX reduces CO_2 emissions by 0.119% in all OECD countries. However, the effect is slightly weaker in high-emitting countries. The environmental policy stringency index (EPS) is found to have a significant and negative impact on CO_2 emissions. The results of the fixed effect model show that a 1% increase in EPS reduces CO_2 emissions by 0.040% in all OECD countries. Notably, the impact is stronger in higher-emitting countries compared to low-emitting countries. The results suggest that stricter environmental policies serve as an effective tool for lowering CO_2 emissions in OECD countries. Regarding the impact of renewable energy consumption (REC), the findings indicate that REC has a negative and significant influence on CO_2 emissions. Specifically, a 1% increase in renewable energy consumption reduces CO_2 emissions by 0.562%, 0.702%, and 0.398% across all models. Interestingly, renewable energy is more effective in reducing emissions among low-emitting countries.

Further, GDP exhibits a statistically significant and positive effect on CO_2 emissions across all models, indicating that economic growth contributes to increased emissions in OECD countries. The impact of financial development on CO_2 emissions in OECD countries is positive and significant in models 1 and 2. The impact of urbanization on CO_2 emissions is positive and significant in models 1 and 2, but insignificant for the high-emitting countries. The human capital index has a significant role in increasing carbon emissions, and results show that a 1% increase in human capital increases CO_2 emissions by 0.105%, 0.118%, and 0.95% across all models. The R^2 of all models showed values of 0.520%, 0.511%, and 0.705%. This implies that the independent variables explained variations of 52%, 51.1%, and 70.5% on the dependent variable.

Table 4. *Estimates of the Fixed Effect.*

(Dependent Variable: CO_2 Emissions)			
Variables	**(Model 1) All (32 countries)**	**(Model 2) Low-emitting countries**	**(Model 3) High-emitting countries**
LnETAX	-0.119***	-0.120*	-0.085***
	(0.015)	(0.047)	(0.010)
lnEPS	-0.040*	-0.005	-0.034***
	(0.005)	(0.008)	(0.006)
LnREC	-0.562***	-0.702***	-0.398***
	(0.025)	(0.039)	(0.026)
LnGDP	0.109***	0.070***	0.214***
	(0.016)	(0.021)	(0.027)
LnFD	0.014*	0.013*	0.004

(Dependent Variable: CO_2 Emissions)			
Variables	**(Model 1) All (32 countries)**	**(Model 2) Low-emitting countries**	**(Model 3) High-emitting countries**
	(0.004)	(0.005)	(0.005)
LnUPOP	0.834***	0.802**	0.110
	(0.166)	(0.251)	(0.213)
LnHC	0.105***	0.118***	0.095***
	(0.013)	(0.019)	(0.015)
Time FE	Yes	Yes	Yes
Observations	704	484	213
R-squared	0.520	0.511	0.705
Hausman (chi2)	33.34***	13.79*	25.008***

Note: ***p<0.01, **p<0.05, and *p<0.1 denote significance levels.

Further, to check the Robustness of the results, the study employed Generalized Methods of Moments (GMM). This method was initially developed by [48] and is based on the Arellano-Bond approach. A two-step System Generalized Method of Moments (System-GMM) estimation technique is utilized. Considering the statistical significance of the lagged dependent variable (CO_{2t-1}), it is recommended that the suitability of the dynamic specification be assessed in Table 5. System GMM was utilized, and the coefficients obtained were statistically significant across all models. This suggests that the CO_2 emissions in the year depend on the CO_2 emissions in the previous year.

Table 1. *Estimates of System GMM.*

(Dependent variable: CO_2 emissions)			
Variables	**(Model 1) All (32 countries)**	**(Model 2) Low-emitting countries**	**(Model 3) High-emitting countries**
$LnCO_2$. L1	0.559**	0.806***	0.684***
	(0.203)	(0.174)	(0.119)
LnETAX	-0.141*	-0.235**	-0.057**
	(0.075)	(0.078)	(0.017)
lnEPS	-0.052***	-0.043***	-0.079**
	(0.010)	(0.005)	(0.021)
LnREC	-0.271*	-0.176*	-0.122*
	(0.132)	(0.104)	(0.057)
LnGDP	0.026	0.032*	0.154*
	(0.052)	(0.054)	(0.082)
LnFD	-0.021	0.026	-0.028
	(0.028)	(0.023)	(0.020)
LnUPOP	0.896*	0.372	0.538*
	(0.438)	(0.073)	(0.271)
LnHC	0.108***	0.073*	0.124**

(Dependent variable: CO_2 emissions)			
Variables	**(Model 1) All (32 countries)**	**(Model 2) Low-emitting countries**	**(Model 3) High-emitting countries**
	(0.031)	(0.029)	(0.038)
Observations	704	484	213
AR (1)	0.013	0.010	0.041
AR (2)	0.194	0.219	0.833
Hansen test	0.621	0.696	0.342

Note: ***p<0.01, **p<0.05, and *p<0.1 denote significance levels.

The results presented in Table 5 show that most of the coefficients are statistically significant. The selected economies show a statistically significant impact of ETAX on CO_2 emissions across all models. Based on the evidence, it can be concluded that ETAX has some utility as a policy instrument for reducing CO_2 emissions in OECD economies. Furthermore, ETAX generates revenue that may finance additional environmental activities, such as developing new sustainable technologies. ETAX is an important policy tool for lowering CO_2 emissions and encouraging economic expansion and sustainable development in OECD countries. The empirical findings are consistent with existing research that highlights the effectiveness of environmental tax policy as an instrument. The findings mentioned above support the results reported by [51-53] jointly arguing that environmental taxes can potentially boost economic performance while also effectively addressing environmental degradation, including carbon emissions. Additionally, [54] Investigated a panel dataset of Nordic and European economies to examine the impact of introducing environment-related taxes on carbon emissions in the region. Using a propensity score approach, the researchers claimed that ETAX has a negative effect on CO_2 emission levels, particularly in developed economies.

Environmental policy stringency has a statistically significant and negative relation to CO_2 emissions across all models, as a 1% increase in the ENP will lead to a 0.052%, 0.043%, and 0.079% decline in CO_2 emissions. This underscores the effectiveness of stringent environmental policies in curbing carbon emissions, as each incremental increase in environmental stringency policy (EPS) is associated with a proportional decline in CO_2 emissions across OECD countries.

The findings demonstrate connections to previous studies, such as the study conducted by [16]. Additionally, [55] discussed that the adaptation of strict environmental policies has forced businesses to utilize alternative and clean energy sources in their manufacturing and management operations in compliance with serious environmental regulations, which leads to reduced carbon emissions. In addition, another related study by [56] argued that the strictness of environmental policies strongly encourages sustainable development and the adoption of renewable and environmentally friendly energy sources. It is achieved by reducing the negative effects of economic growth, such as the destruction of the environment.

The results suggest that financial incentives and subsidies are provided by environmental regulations to encourage the implementation of greener practices and technologies. These incentives can encourage businesses to invest in energy-efficient technologies, cleaner industrial processes, and renewable energy sources. Governments can directly limit the quantity of CO_2 emissions allowed by implementing these policies [57]. By strengthening these environmental initiatives, the need for fossil fuels and other activities with high emissions diminishes, leading to reduced levels of CO_2 emissions. By promoting environmentally friendly alternatives, such as renewable energy and energy-efficient technologies, environmental regulations reduce reliance on fossil fuels and high-emission activities. This shift leads to lower CO_2 emissions, supports sustainable development, and helps countries meet their climate targets through cleaner production.

Similar findings were also noted by [58], who pointed out that Stringent environmental policies often give priority to research and development initiatives in green technologies. The results highlighted the advancement of low-carbon solutions, such as energy storage and renewable energy, and emphasized that as these technologies become more widely available and cost-effective, they will increasingly substitute carbon-intensive energy sources, thereby contributing to the reduction of CO_2 emissions.

Among the control variables, REC shows a negative connection with CO_2 emission across all models, likely due to a shift towards renewable energy sources. Greater adoption of renewable energy leads to reduced reliance on fossil fuels, major contributors to CO_2 emissions. In high-emitting countries, the impact of renewable energy is possibly weaker due to high dependency on fossil fuels. According to the study by [59] Renewable energy plays an important role in reducing CO_2 emissions. These results are supported by [60, 61]. Renewable energy technology is the primary method for reducing CO_2 emissions, as it makes use of clean and more environmentally beneficial forms of energy that meet the demands of the present and the future. GDP has a positive but insignificant relationship with CO_2 emission in model 1, while it shows a significant relationship in models 2 and 3. A 1% increase in GDP will lead to a 0.032% and 0.154% increase in CO_2 emissions because economic growth is intimately related to energy consumption and industrial output, contributing significantly to CO_2 emissions. As economies grow, energy consumption and industrial activities often rise, leading to increased CO_2 emissions.

The rapid growth of cities poses a significant challenge to achieving sustainable development. The results show a significant and positive effect of urbanization on CO_2 emissions, as a 1% increase in urbanization leads to a rise of 0.896% and 0.538% in CO_2 emissions across models 1 and 3, but shows an insignificant relationship in model 2. A recent study by [62] discovered a strong and statistically significant correlation between urbanization and the environment, while financial development shows a negative and insignificant impact on CO_2 emissions.

Human capital has a significant and positive relationship with CO_2 emissions. Human capital is causing a 0.108%, 0.073%, and 0.124% increase in CO_2 emissions across all models. Increasing human capital often leads to higher economic activity, which in turn results in more energy consumption and industrial output, consequently increasing CO_2 emissions, technological advancements leading to efficiency gains and adoption of energy-intensive technologies, contributing to CO_2 emissions, increasing demand for carbon-intensive goods and services, and higher transportation-related emissions.

The study further investigated the EKC hypothesis in the OECD countries. The negative coefficient of the squared GDP indicates the existence of an inverted U-shaped association between income and environmental pollution. As shown in Table 6, the outcome supports the assumptions behind the Environmental Kuznets Curve (EKC). This suggests that pollution levels in the selected economies increased at the start of economic growth, but declined when economic growth reached a certain point. At this point, the government becomes more concerned about the environment. There has been a shift toward renewable energy consumption, accompanied by the implementation of strict environmental policies by governments and policymakers aimed at discouraging high-polluting industries from continuing environmentally harmful practices.

Table 6. *Environmental Kuznets Curve (EKC).*

(Dependent variable: CO_2 emissions)			
Variables	**(Model 1) All (32 countries)**	**(Model 2) Low-emitting countries**	**(Model 3) High-emitting countries**
LnGDP	0.950***	1.004***	3.910***
	(0.171)	(0.215)	(0.510)
$LnGDP^2$	-0.043***	-0.048***	-0.177*
	(0.008)	(0.011)	(0.024)
Control variables	Yes	Yes	Yes
R^2	0.538	0.530	0.767
Curve	Inverted U-shaped	Inverted U-shaped	Inverted U-shaped

Note: ***p<0.01, **p<0.05, and *p<0.1 denote significance levels.

5. Conclusion

The main purpose of the current study was to examine the impact of environmental taxes and environmental policy stringency on CO_2 emissions in the context of OECD economies from 2000 to 2022. To that purpose, this study examines existing literature, assesses empirical facts, and collects panel datasets to perform in-depth analysis and discussion through empirical research. Along with environmental taxes and environmental policy stringency, several factors and indicators substantially influence the CO_2 emissions of such OECD economies. The current study considered the role of renewable energy, economic growth, financial development, urbanization, and human capital. Since OECD countries are taking various initiatives and measures to reduce CO_2 emissions. At the same time, to find the answers to the given questions, empirical analysis, fixed effect, and random effect were mainly used, where, through the Hausman test, it is ensured that the fixed effect model is more appropriate for the panel data. Further, system GMM was used to check the robustness of the results.

The empirical results show that environmental taxes have a significant negative impact on carbon dioxide emissions.

Specifically, the fixed effect results indicate that a 1% increase in ETAX is associated with approximately a 0.119% decrease in CO_2 emissions, indicating that ETAX plays a vital role in preventing environmental degradation in OECD economies. These taxes contribute to achieving sustainable development goals by accelerating the shift from fossil fuels to clean, renewable energy. Based on the findings, incorporating environmental taxes into comprehensive environmental policies can not only promote environmental stability but also encourage industrial sectors to adopt proactive measures to minimize the harmful effects of fossil fuel consumption. The findings of the study show that environmental policy stringency negatively affects CO_2 emissions; a 1% increase in the EPS leads to a 0.040% reduction in CO_2 emissions. Thus, strict environmental policies can serve as an effective determinant of CO_2 emissions and can help OECD countries achieve the goal of reducing CO_2 emissions. Environmental policy stringency is crucial for achieving sustainability by reducing CO_2 emissions and promoting cleaner practices. Stricter policies force industries to adopt green technologies and improve energy efficiency, driving significant progress in combating climate change. Environmental policy stringency also fosters innovation, as firms develop sustainable solutions to meet regulatory demands. The effectiveness of environmental regulations is key to meeting environmental commitments under various climate agreements (Paris Climate Agreement and Kyoto Protocol). Finally, the empirical findings showed the presence of the EKC hypothesis in all three panels, demonstrating an inverted U-shaped relationship between economic growth and CO_2 emissions. Initially, economic growth leads to a significant increase in CO_2 emissions; however, after reaching a certain income threshold, the relationship reverses, and further economic growth contributes to a reduction in emissions.

Based on the above discussion and empirical results, this study argues that environmental taxes and environmental policy stringency can be used as a policy tool to effectively reduce carbon emissions. Industrial economies such as the OECD countries not only need to flexibly apply environmental policies but also need to cooperate with COP27 and be in line with the United Nations Sustainable Development Goals (SDGs) to curb environmental degradation. Some developing countries still do not fully utilize environmental policies, as this may affect short-term economic growth. In some other economies, environmental reforms still face great political resistance due to reluctance to introduce environmental reforms, higher dependence on fossil fuels, and a lack of policy initiatives to integrate clean energy into the energy mix. However, this research provides rich policy recommendations based on empirical results. This will provide a reference for policymakers in developed and developing economies, enabling them to take a comprehensive approach to environmental policies to protect the environment and encourage the use of renewable energy.

Abbreviations

CO2	Carbon Dioxide
OECD	Organization for Economic Co-operation and Development
GHG	Greenhouse Gas
GDP	Gross Domestic Product
EPS	Environmental Policy Stringency
R&D	Research and Development
DRS	Deposit and Refund Scheme
ETAX	Environmental Taxes
FMOLS	Fully Modified Ordinary Least Square
DOLS	Dynamic Ordinary Least Square
GMM	Generalized Method of Moments
EKC	Environmental Kuznets Curve

Data Availability Statement

Data will be available on request.

Conflicts of Interest

The authors state that they have no financial interests or personal relationships that could have potentially influenced the work presented in this paper.

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