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TÁC ĐỘNG CỦA THUẾ MÔI TRƯỜNG VÀ CHÍNH SÁCH NGHIÊM NGẶT VỀ MÔI TRƯỜNG ĐẾN LƯỢNG PHÁT THẢI CO_2: NGHIÊN CỨU TẠI 31 QUỐC GIA OECD GIAI ĐOẠN 2010-2020

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Tóm tắt

Các vấn đề môi trường ngày càng gia tăng đòi hỏi các nhà hoạch định chính sách thực hiện biện pháp quản lý môi trường nhằm đạt mục tiêu giảm thiểu biến đổi khí hậu. Trong số đó, thuế môi trường và các chính sách nghiêm ngặt về môi trường đã trở thành những công cụ thiết yếu. Tuy nhiên, nghiên cứu về tính hiệu quả thực tế của các phương pháp này hiện còn đang hạn chế. Sử dụng dữ liệu bảng của 31 quốc gia OECD trong giai đoạn 2010 – 2020, nghiên cứu định lượng này sẽ đánh giá vai trò của thuế môi trường và các chính sách nghiêm ngặt về môi trường trong việc giảm lượng phát thải CO_2. Kết luận rút ra cho thấy trong khi lượng phát thải CO_2 có mối quan hệ nghịch với thuế môi trường, thì việc thực hiện các chính sách nghiêm ngặt về môi trường lại có tác động tích cực đến lượng phát thải CO_2. Những phát hiện này gợi ý các cơ quan có thẩm quyền nên sử dụng thuế môi trường như một công cụ bảo vệ môi trường, bên cạnh đó, cần xem xét các yếu tố bên ngoài khi thực hiện các chính sách nghiêm ngặt về môi trường.

Từ khóa: *thuế môi trường, chính sách nghiêm ngặt về môi trường, lượng phát thải CO_2, quốc gia OECD*

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THE IMPACT OF ENVIRONMENTAL TAXES AND ENVIRONMENTAL STRINGENCY POLICIES ON CO_2 EMISSIONS: A STUDY OF 31 OECD COUNTRIES FROM 2010 TO 2020

Abstract

Increased environmental issues have required policymakers to implement environmental regulatory measures to achieve the climate change mitigation target. Among different methods, environmental taxes and environmental stringency policy have become critical instruments to tackle environmental degradation. However, research on the effectiveness of these methods is limited. Using panel data from 31 OECD countries from 2010 to 2020, this quantitative study assesses the role of environmental taxes and environmental stringency policy in reducing CO_2 emissions. The findings reveal that CO_2 emissions are negatively related to environmental taxes while environmental stringency policies have a positive impact on CO_2 emissions. The findings suggest that governments should utilize environmental taxes as a tool to protect the environment. Meanwhile, external factors need to be considered when implementing environmental stringency policies.

Keywords: *environmental taxes, environmental stringency policies, CO_2 emissions, OECD countries*

1. Introduction

Climate change and global warming have emerged as major global challenges, with CO_2 emissions from human activities being the main driver. According to the IPCC (2018), as emissions continue to rise, we are facing "painful environmental problems" sooner than expected. Despite urgent warnings, the climate crisis persists, as the global community hesitates to fully commit to necessary actions for deleting its effects (UN 2020, p.50). To achieve fast economic growth, energy consumption has increased, causing harmful effects of increasing atmospheric carbon dioxide emissions, which creates climate change and global warming. The energy sector accounts for more than two-thirds of total greenhouse gas emissions and more than 80% of CO_2 emissions (International Energy Agency, IEA 2019). CO_2 emission is considered the driving force of global warming and climate change. International Energy Agency, IEA (2020) informed that global energy-related CO_2 emissions have risen from 20,521 million tonnes in 1990 to around 32,840 million tonnes in 2017.

The increase in CO_2 emissions has significant impacts on economic growth, environmental sustainability, and human well-being. Moreover, the negative effects of environmental issues have motivated policymakers to implement effective environmental regulatory measures to achieve the CO_2 emissions reduction target, as regulated in the Kyoto Protocol (Abdullah and Morley, 2014). Consequently, governments worldwide have introduced various policy instruments to mitigate CO_2 emissions, among which environmental taxes and environmental stringency policies are some of the best alternative tools with additional benefits for governments. Pollution and environmental degradation, mostly originating from carbon emissions, is another issue of sustainability. In this respect, a surplus that the government needs to sustain their debt budget can be balanced through taxation that reduces emissions and thus environmental quality can be improved (Halkos and Papageorgiou, 2018). On the other hand, higher taxes and charges for pollution may be helpful in utilizing resources and encouraging economic growth (Shi et al., 2019). Therefore, environmental taxes and environmental stringency policies can be considered a fundamental tool to regulate markets, and externalities originating from polluting activities can be reduced by transferring the costs to their producers (Wang et al., 2019a).

This study aims to examine the effectiveness of environmental taxes and environmental stringency policies on CO_2 emissions. By analyzing the relationship of environmental taxes and environmental stringency policies on CO_2 emissions, this research suggests insights into the role of regulatory interventions in reducing CO_2 emissions. Finally, this study contributes to the broader discussion on sustainable development by evaluating the role of policy instruments in achieving a low-carbon future.

2. Literature review

2.1. The relationship between environmental taxes and CO_2 emissions

Pigou (1920) pioneered by highlighting the role of environmental taxes as an externality to solve environmental issues. In addition to offering financial resources to the state, environmental taxes are said to influence producers and consumers' behaviors, encouraging them to reduce their harm to the environment (Borozan, 2019; Shahzad, 2020). Environmental taxes increase the cost of fossil fuels for both producers and consumers, resulting in a change in the structure of production and consumption towards an environmentally friendly way (Mardones and Baeza 2018; Shahzad 2020). A carbon tax could also facilitate the adoption of low-carbon technologies and alternative fuels while supporting efforts to reduce carbon emissions (OECD 2010). Furthermore, revenues from the implementations of environmental tax might offer financial support to update obsolete infrastructure that produces more pollution and implement modern technologies that ensure energy efficiency (Ulucak et al., 2020).

While the relationship between environmental taxes and environmental degradation has been widely discussed, the conclusion is inconsistent. The environmental taxation theory posits that levying environmental charges and taxation would help to protect the environment (Vatn, 2015). Such tax can foster the transition to clean technologies which improve energy efficiency to minimize energy consumption - one of the major contributors to CO_2 emissions (Calderón et al., 2016). Environmental taxes were found to negatively affect CO_2 emissions (Haites, 2018; Miller and Vela, 2013). Likewise, while investigating data from 15 European countries, Aydin and Edsen (2018) found that environmental taxes not only reduce carbon emissions but also promote technological innovation. According to Hashmi and Alam (2019), a 1% increase in environmental tax revenue per capita reduces CO_2 emissions by 0.033% in OECD countries. This is in line with Wolde-Rufael (2021) who found that environmental taxes contribute to reducing CO_2.

However, there also exist opposite opinions. Gerlagh and Lise (2005) and Lin and Li (2011) found no evidence to prove the effectiveness of environmental taxes in reducing CO_2 emissions. Similarly, Loganathan et al. (2014) investigating Malaysia and Radulescu et al. (2017) examining Romania reached the same conclusion. In the context of EU countries, Liobikienė et al. (2019) found that taxes did not influence Greenhouse gas emissions. Meanwhile, in China, Zhang (2016) found that the impact of environmental regulations were negligible.

Based on the above discussion, we propose the following hypothesis:

H1: Environmental taxes negatively affect CO_2 emissions.

2.2. The relationship of environmental stringency policies on CO_2 emissions

Environmental stringency policies have emerged as an indispensable measure that helps regulate and mitigate human footprints on the environment, whether socially (Levinson and Taylor, 2008), economically (de Angelis, Di Giacomo and Vannoni, 2019) or technologically (Ahmed, 2020). Stringency, according to Galeotti, Salini and Verdolini (2020), is generally understood as internalizing the social cost of pollution, or at reducing the price wedge between clean and dirty technologies. In other words, they systematically increase the cost of polluting activities, therefore encouraging enterprises and individuals to embrace eco-friendly practices (Neves, Marques and Patrício, 2020). The long-existing debate surrounding the effectiveness of these policies in reducing CO_2 emissions, as well as their correlation has been supported from different viewpoints, by various research.

Specifically, the Porter Hypothesis suggests that well-designed environmental policies can result in technological innovation, which in turn improves both environmental and economic performance (Porter and Linde, 1995). This claim has been supported by other studies such as Dechezleprêtre and Sato (2017) and Sun et al. (2020), indicating that stringency policies motivate firms towards cleaner technologies, reducing emissions. Also, strict regulations are proven to minimize the reliance on dirty technologies through promoting other energy-efficient alternatives (Ambec et al., 2024; Cohen and Tubb, 2018).

On a national level, there has been research that claims the negative correlation between environmental stringency policy and the amount of CO_2 emissions. In the Netherlands, van Leeuwen and Mohnen (2016) has confirmed that strict environmental regulations help promote green innovations using new technologies, which after that narrow down CO_2 emissions. Likewise, in China, the growth of green industries is positively fostered by these policies (Wang and Shen, 2016). Meanwhile in other developed countries that integrate better-implemented policy practices, namely the U.S. (Shapiro and Walker, 2018) and the UK (Cole, Elliott and Shimamoto, 2005), air pollution including CO_2 emissions has been improved, with the pollution intensity generated from numerous industries being much more strictly regulated.

While there is strong empirical proof for the negative relations between environmental stringency policies and CO_2 emissions, opposing viewpoints still arise. Specifically, Wolde-Rufael and Weldemeskel (2020) claims that the cost burden from such policies may disincentivize companies from making eco-friendly investments. Also, they argue that the relationship between the 2 variables here follows an inverted U-shape, as is consistent with the Environmental Kuznets Curve (EKC) hypothesis proposed by Wolverton et al. (2017). This means that initially strict environmental stringency policy does not produce improvements to the environment, but only after a certain level or a threshold point could such policies enhance environmental quality. Furthermore, according to the Pollution Haven Hypothesis (Levinson and Taylor, 2008), firms in developed economies may move their production to countries with weak, loosened environmental policies, which offsets global emissions cuts. Meanwhile, the developing countries themselves may lower their environmental standards for better FDI attractions (Kim and Rhee, 2019).

Based on the above discussion, we propose the following hypothesis:

H_2: Environmental stringency policies negatively affect CO_2 emissions.

3. Methodology

3.1. Data description

The research team collected data of Environmental policy stringency, Environmental tax, CO_2 emissions, GDP per capita, and Population of OECD countries from 2010 to 2020. Data on taxes and environmental policy stringency index are gathered from the database of the Organization for Economic Co-operation and Development (OECD), while data on real GDP per capita and Population come from World Bank.

The data is a panel dataset of 341 observations from 31 OECD nations. In line with the literature review, we specify a model for assessing the variables that affect CO_2 emissions. Thus, Environmental policy stringency, Environmental tax, CO_2 emissions, GDP per capita, and Population were investigated.

The authors utilized the CO_2 emissions as the sole dependent variable within our model, using previous research of Wolde-Rufael and Mulat-Weldemeskel (2021). The research team decided to include two independent variables in the model: Environmental policy stringency and Environmental taxes.

Moreover, the study also used two control variables named GDP per capita and Population, for the reasons as follows. We selected GDP per capita to measure a country's level of economic development, which can affect CO_2 emissions. According to the Environmental Kuznets Curve (EKC), CO_2 emissions tend to increase due to higher industrial activity and energy consumption. However, when an economy reaches a certain income level, many countries tend to invest in cleaner technology and stricter environmental policies, which reduces emissions (Wolde-Rufael and Mulat-Weldemeskel, 2021). Thus, GDP per capita is used as a control variable to separate the effects of economic growth from the effects of environmental policies and environmental taxes on CO_2 emissions.

In terms of the selection of population as a control variable, it plays an important role in determining total CO_2 emissions, as larger populations typically mean higher energy consumption and increased demand for manufacturing, transportation, and resource use. According to studies by Botta, E., and Koźluk, T. (2014) and OECD (2016), countries with larger populations may have higher CO_2 emissions, even if they have strict environmental policies. Thus, the population variable is included in the model to control this factor, helping to ensure that the impact of environmental policies and environmental taxes on CO_2 is not confounded by population size.

Table 1. Variables description

	Variable	Symbol	Unit
Explained variable	CO_2 emissions	co2	tonnes/capita
Explanatory variables	Environmental taxes	tax	million USD
	Environmental stringency policies	esp	0-6 scale
Control variables	Economic growth - GDP per capita	gdp	USD
	Population	popu	persons

Source: The authors compiled

The descriptions for all the variables are presented in Table 1. The Environmental policy stringency index (EPS) ranges from 0, indicating no stringency, to 6, representing the highest level of stringency. According to the OECD (2016) stringency is defined as the "…implicit or explicit cost of environmentally harmful behavior" (p.5). The indicator focuses on such as energy and transport and their effects on air and climate policies (Botta, E., and Koźluk, T., 2014; European environmental agency, EEA 2005; OECD 2016). According to the OECD, an environmental tax is defined as a tax whose base is "a physical unit, for example, a litre of petrol or a passenger flight that has a proven negative impact on the environment" (OECD 2018b).

3.2. Regression model

The authors applied a regression model utilizing panel data to test the direct impact of environmental taxes and environmental stringency policies on CO_2 emissions. The two main regression models considered with panel data are the Fixed Effects Model (FEM) and the Random Effects Model (REM). Thus, the authors formulated the models:

$$Y_{it} = \beta_{1i} + \beta_2 X_{2it} + \beta_3 X_{3it} + \beta_4 X_{4it} + \ldots + u_{it} \text{ (FEM)}$$

$$Y_{it} = \beta_{1i} + \beta_2 X_{2it} + \beta_3 X_{3it} + \beta_4 X_{4it} + \ldots + \varepsilon_i + u_{it} \text{ (REM)}$$

where $i = 1,2,\ldots,N;\ t = 1,2,\ldots,T$

ε_i represents the random error with a mean of zero and variance σ^2

The Fixed Effects Model (FEM) considers that differences between entities, such as policies or economic structures in different countries are captured through separate intercepts, rather than being included in the error term. This method accounts for unobserved differences by assigning each entity its own intercept while assuming a common effect of the independent variables. In contrast, the Random Effects Model (REM) treats variations across entities as random and not related to the explanatory variables. These differences are included in the error term, which is assumed to follow a normal distribution with a mean of zero and some variance.

The authors conduct a Hausman test in order to determine the appropriate model between FEM and REM and to assess whether the REM assumption that individual-specific effects are not related to the explanatory variables. The hypotheses tested are:

• Null Hypothesis (H0): The REM is appropriate, implying that individual-specific effects are random and uncorrelated with the regressors.

• Alternative Hypothesis (H1): The FEM is preferred, suggesting that individual-specific effects are associated with the explanatory variables.

The results have been determined that if the p-value is less than 0.05, the null hypothesis is rejected, indicating that FEM is the superior model, however, if the p-value is greater than 0.05, the null hypothesis cannot be rejected, meaning that REM is preferred.

In addition, the authors have conducted diagnostic tests to detect possible problems in the model after selecting the most suitable regression model, such as multicollinearity, heteroscedasticity, and autocorrelation. In other words, this is an econometric estimation technique designed to address heteroscedasticity and autocorrelation violations in regression models. If any errors are detected, they are corrected using the Generalized Least Squares (GLS) method. This is an econometric method that helps to fix problems related to heteroscedasticity and autocorrelation in regression models. By allowing a more flexible error structure, GLS provides more accurate and reliable parameter estimates when these issues arise. Additionally, by minimizing the generalized residual sum of squares, GLS becomes the preferred choice when the conditions of the Gauss-Markov theorem are not met. However, while GLS is commonly used in REM modeling, it is rarely applied to FEM due to the basic differences in the assumptions of the two models.

Multicollinearity happens when two or more independent variables in a regression model are strongly related. Thus, this makes it hard to see how each variable affects the dependent variable (Shrestha, 2020). To test this issue of multicollinearity, the authors utilizes VIF (Variance Inflation Factor). If Mean VIF is greater than 10, there exists a multicollinearity error in the model, meaning that corrective actions such as variable selection, transformation, or regularization need to be taken.

Heteroskedasticity happens when the variance of the residuals is not the same across different measured values. To deal with this situation, the authors had decided to use Breusch-Pagan test and run our regression model again by regressing the squared residuals from the first regression model and running another regression with the predictor variables. Then, it checks if the new coefficients are significant (Breusch and Pagan, 1979).

Residuals in panel data that are correlated across different time periods are called serial correlation or autocorrelation. In other words, this violates the assumption that the errors must be independent (Wooldridge, 2010). The Wooldridge test checks for first-order autocorrelation in the errors of the panel data model. It does this by using the residuals from a first-differenced regression of the dependent variable on its lagged values (Wooldridge, 2010).

Cross-sectional dependence happens when errors are linked between different entities, which in this study refer to countries, due to unobserved common factors (Pesaran, Schuermann and Weiner, 2004). To detect this dependence, the Pesaran CD test was used by analyzing the correlation pattern of the residuals.

3.3. Conceptual framework

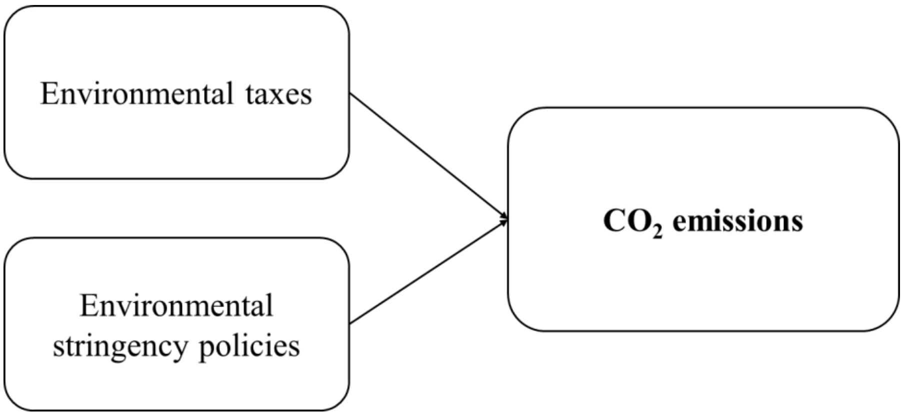

Figure 1. Conceptual framework

Source: The authors compiled

3.4. Setting up the model

The authors use the Hausman test to test suitable regression model. After conducting the test, the authors had a p-value of 0.9063 (Prob > chi2 = 0.9063), which is greater than 0.05. This means that the favored regression model should be the REM, which treats unobserved entity-specific effects as random and uncorrelated with the explanatory variables. Therefore, the model of the present study is developed as shown below:

$$co_{2it} = \beta_1 + \beta_2 tax_{it} + \beta_3 esp_{it} + \beta_4 gdp_{it} + \beta_5 popu_{it} + \ldots + \varepsilon_i + u_{it}$$

where co_{2it} is CO2 emissions of country i at year i, tax_{it} is environmental taxes of country i at year t, esp_{it} is environmental stringency policies of country i at the year t, gdp_{it} is economic growth of country i at the year t, and $popu_{it}$ is population of country i at the year t.

β_1, β_2, β_3, β_4, β_5 are the parameters to be estimated.

ε_i represents the random error with a mean of zero and variance σ^2

u_{it} is the error term.

4. Empirical results

4.1. Descriptive Statistics

Table 2: Descriptive statistics

Variable	Obs	Mean	Std. dev.	Min	Max
co2	341	7.151232	3.1126	2.81	20.98
tax	341	22663.17	31200.1	301.2503	155106.2
esp	341	2.902248	0.9483932	0.5556	4.8889
gdp	341	43414.39	18144.26	16087.38	121973.6
popu	341	3.75e+07	6.24e+07	318044	3.32e+08

Source: Authors' calculation using STATA17

From the description table above, a summary is as follows:

The table provides descriptive statistics for 5 variables, using a total of 341 observations from 31 nations in the dataset during the 2010 - 2020 period.

The standard deviation of CO_2 emissions in the sample equals 3.1126 tonnes, showing a quite far distribution from the mean value at 7.1512 tonnes. This can be understood as that there is a significant diversity in the level of CO_2 emissions among countries. Also, the minimum and maximum values at 2.81 and 20.98 tonnes, respectively, indicates a notable gap between the nations having the highest and lowest emissions.

It can be clearly seen that results regarding environmental tax revenues (tax) show spark difference indicates clear difference across nations, with a mean of 22663.17, but a standard deviation of 1.5670. Besides, the substantial range between 301.2503 million USD and 155106.2 million USD can be interpreted as that some countries apply fossil fuel subsidies, or tax exemption for industries reliant on fossil fuels, while others impose substantial levies. Likewise, the ESP variable has an average value of 2.9022, with a standard deviation of 0.9484, suggesting moderate variations in the degree of strictness to which different countries implement their environmental policies.

Meanwhile, the two control variables, namely GDP per capita and population size all show notable disparities in economic and demographic level among the sampled nations. Specifically, the variable GDP per capita receives a mean of 43414.39 USD and a high standard deviation of 18144.26 USD, while figures for population size across countries range from 0.318 to 332 million people.

4.2. Regression analysis results

4.2.1. Testing for Multicollinearity

The result for the test for Multicollinearity is shown in Table 3, with a mean VIF of 3.08, which is smaller than 10, the overall model does not meet the multicollinearity problem. This ensures the reliability of coefficient estimates (Wooldridge, Wadud and Lye, 2016). Thereby, the model can proceed without any corrective actions and any worrying about inflated standard errors or biased estimates, since all variables stay well below the VIF threshold, negating.

Table 3. Results of multicollinearity test

Variable	**VIF**	**1/VIF**
tax	4.98	0.200625
popu	4.68	0.213597
esp	1.48	0.675325
gdp	1.16	0.863663
Mean VIF	3.08	

Source: Authors' calculation using STATA17

4.2.2. Testing for Heteroskedasticity

Using the Breusch and Pagan Lagrangian Multiplier (LM) test, the authors aim to test for heteroskedasticity. The results shown in Table 4 confirm the significance of heteroskedasticity (p-value: Prob > chibar2 = 0.000 < 0.05), which makes the null hypothesis strongly rejected. In other words, the current model has the problem of heteroskedasticity that needs further corrective actions.

Table 4. The results of the Breusch and Pagan Lagrangian Multiplier (LM) test

Breusch and Pagan Lagrangian multiplier test for random effects		
co2[id,t] = Xb + u[id] + e[id,t]		
Estimated results:		
	Var	**SD = sqrt(Var)**
co2	9.68828	3.1126
e	.5812632	.7624062
u	5.536978	2.353078
Test: Var(u) = 0		
chibar2(01) = 865.04		
Prob > chibar2 = 0.0000		

Source: Authors' calculation using STATA17

4.2.3. Testing for Autocorrelation

The autocorrelation test was conducted using the Wooldridge test. The results in Table 5 detect the presence of first-order serial correlation, with the F-statistic equals 157.362, p-value = 0.0000. This also means the null hypothesis of having no autocorrelation. Hence, the error terms are correlated over time and need corrective actions in the upcoming steps.

Table 5. The results of the Wooldridge test for autocorrelation in panel data

Wooldridge test for autocorrelation in panel data
H0: no first-order autocorrelation
F(1, 30) = 157.362
Prob > F = 0.0000

Source: Authors' calculation using STATA17

4.2.4. Testing for sectional independence

Since the p-value of the Pesaran's test equals 0.430, which is greater than 0.05, the null hypothesis of weak cross-sectional independence was not rejected. Likewise, there exists no evidence of shared shocks or spillover effects among groups (Pesaran, Schuermann and Weiner, 2004).

Table 6. The results for The Pesaran CD test for cross-sectional dependence

Pesaran's test of cross-sectional independence =	15.053, Pr = 0.0000
Average absolute value of the off-diagonal elements =	0.430

Source: Authors' calculation using STATA17

4.2.5. Fix model having Heteroskedasticity and Serial autocorrelation using GLS method

To solve those aforementioned issues of heteroskedasticity and serial correlation, the authors employ the Generalized Least Squares (GLS) method. Because the GLS method adjusts the estimation process to account for heteroskedastic and autocorrelated errors, it is particularly stated to be well-suited for panel data whenever these two violations occur (Baltagi, 2008). By transforming the data to remove these problems, the GLS method generates unbiased and efficient coefficient estimates.

The Wald chi-squared statistic, χ^2 is 4818.94 with a p-value of 0.000, which is below 1% significance level ($\alpha = 0.01$). In other words, the regression coefficients do not equal 0 simultaneously, meaning that the overall model is statistically significant at 1% significance level. Thanks to the significance, the independent variables collectively explain a substantial portion of the variation in CO_2 emissions.

Table 7. Results of GLS estimation

co2	**Coefficient**	**Std. Error**	**z**	**p-value**	**95% Conf. Int**
tax	-0.0000115	5.42e-06	-2.13	0.033	[-0.0000221, -9.00e-07]
esp	0.0697076	0.0353733	1.97	0.049	[0.0003772, 0.139038]
gdp	0.0000816	2.08e-06	39.24	0.000	[0.0000776, 0.0000857]
popu	2.12e-08	7.47e-09	2.84	0.004	[6.58e-09, 3.59e-08]
_cons	2.8451	0.0804045	35.38	0.000	[2.68751, 3.00269]

Source: Authors' calculation using STATA17

As the variable tax has the p-value = 0.033 < 0.1 and coefficient of -0.0000115, the environmental tax has a negative impact on CO_2 emissions. Specifically, at the significance level of 5%, if the environmental tax increases by 1 million USD, CO_2 emissions will decrease by 0.0000115 tonnes, holding other factors fixed. This goes according to hypothesis H1. ***Therefore, H1 is supported.***

As p-value = 0.049 < 0.1, there is a statistically significant relationship between environmental stringency policy and CO_2 emissions. Also, the positive coefficient (0.0697076) suggests that at the 5% significance level, environmental stringency policy positively affects

CO_2 emissions. Specifically, an increase of 1 unit in environmental stringency policy will lead to a decrease of 0.0697076 tonnes in CO_2 emissions, holding other factors fixed. This finding is not compatible with hypothesis H2. ***Therefore, H2 is not supported.***

Additionally, the coefficient for GDP per capita is 0.0000816 (with p-value being $0.000 < 0.01$), meaning that this variable has a statistically significant positive effect on CO_2 emissions at a 1% significance level. Likewise, population size, with a coefficient of 2.12e-08 and p-value of 0.004 (smaller than 0.01), shows a similar positive relationship with the emissions of CO_2.

5. Discussion

5.1. Theoretical contributions

Several theoretical contributions are indicated in the literature and empirical results of the research.

First, this study provides an overview of recent literature regarding the impact of environmental taxes and environmental stringency policies on CO_2 emissions in 31 OECD countries from 2010 to 2020. Specifically, the research once again confirms the mitigating impact of environmental taxes on CO_2 emissions in these countries, as also stated in research by Hashmi and Alam (2019) and Wolde-Rufael (2021). Indeed, this impact aligns with environmental taxation theory, as environmental taxation is really the means of dealing with the increasing CO_2 emissions, especially in OECD countries where technological development excess can create rebound effects, thereby increasing CO_2 emissions. In fact, environmental taxes can encourage the adoption of green technologies which minimize the impact of fossil fuel energy consumption, resulting in a decrease in CO_2 emissions.

Second, the research shows the positive impact of environmental stringency policies on CO_2 emissions in 31 selected OECD countries. This finding contradicts the hypothesis proposed, especially the Porter Hypothesis, which suggests that carefully designed environmental policies can result in innovation, which helps hinder environmental impacts (Porter and Linde, 1995). However, the finding is still proven in numerous studies reviewed, that strict environmental policies could increase the level of pollution because firms might hesitate to invest in or transform to green technology (Wolde-Rufael and Weldemeskel, 2020; Wang and Wei, 2020). Moreover, since most of the OECD countries are developed countries, the high environmental stringency index and positive impact of environmental stringency policies on CO_2 emissions could become a fundamental factor for carbon leakage, where industries, predictively, try to relocate to countries with weaker environmental regulations as concluded in the pollution haven hypothesis. These theoretical contributions raise an issue in these OECD countries, thus, require further practical solutions to address the problem.

5.2. Practical contributions

Alongside theoretical contributions, this study also brings relevant practical implications for governments and businesses.

First, environmental taxes are generally considered one of the most effective methods to reduce environmental pollution. By proposing the regression model to investigate the correlation between environmental taxes and CO_2 emissions, the empirical findings have verified the negative impact of environmental taxes on CO_2 emissions. In line with Borozan (2019); Shahzad (2020) statement of resource financing and pollution mitigating role of environmental taxes, this study has provided empirical evidence to help governments clearly realize the significance of environmental taxes on the journey to reduce pollution, particularly CO_2 emissions. To tackle environmental issues, the governments should impose heavier tax rates on carbon-intensive industries to encourage businesses to adopt cleaner technologies. The implementation of progressive tax structures which means that industries with higher emissions bear greater financial responsibility should be taken into account. Moreover, the revenues generated through environmental regulations should be reinvested into developing green infrastructure, renewable energy projects and research.

Second, maintaining a balance between high levels of economic growth and sustainable development should be the ultimate goal of economies. Environmental stringency policies should be implemented, as well as simultaneously promoting renewable energy development should be put forward as the long-term goals for nations. Especially for countries with lenient environmental policies, developing more strict environmental regulations is of utmost importance to prevent being the pollution haven of other countries.

In terms of businesses, the results indicate the necessity of adapting to environmental stringency regulations by investing in green technologies and low-carbon production processes. Companies that proactively transition to sustainable practices would not only avoid unnecessary environmental costs but also gain a competitive advantage in the market. In addition, businesses could also seek help from consultant companies to prepare sustainability reports, ensuring transparency and compliance with regulations set by the government. By doing this, the risks related to regulatory procedures can be minimized.

5.3. Limitations and further suggestions

First, the data includes only 31 selected OECD countries because some lack detailed data on environmental stringency policies and CO2 emissions. This limits the research's general perspectives, particularly to non-OECD countries and developing countries, since most of the nations considered are developed. Hence, future research is expected to expand the dataset to other countries, such as non-OECD countries or other specific regions such as Asia or Sub-Saharan Africa for a broader knowledge of these different scopes.

Second, the time of the study covers 11 years, which is quite a short period that can not be sufficient enough to capture long-term policy effects. Therefore, future research is supposed to extend the duration of the data, especially post-2020 trends for more updated contributions.

Third, the study uses the panel regression model, which is suitable for identifying the correlation between environmental stringency policies and CO_2 emissions, as well as the correlation between environmental taxes and CO_2 emissions. However, this model does not fully study the causal relationship between the 2 explanatory variables and CO_2 emissions. Future research, as a result, is suggested to use other regression models, such as the Instrumental variable regression, or Difference-in-Differences (DiD) model to learn more about causal relationships.

6. Conclusion

Research on the impact of environmental taxes and environmental stringency policies on CO2 emissions is gaining more importance, especially in the current context of industrialization and environmental issues. Based on the research objectives and methodology, the study has arrived at certain conclusions as follows:

Firstly, the research confirms higher environmental taxes significantly reduce CO_2 emissions, supporting their importance in discouraging carbon-intensive activities and promoting green practices. In contrast, a positive relationship between environmental stringency policies and CO_2 emissions means there still exists inefficiency, implementation gaps, or carbon leakage as side effects. These findings indicate the need for more well-designed policies that balance regulations and incentives for cleaner production.

However, limitations still exists in the literature. This study is limited to OECD countries, with a 11-year period, making it not applicable to other developing countries, and not able to fully capture long-term policy effects. Additionally, the panel regression model helps point out correlation but not causality. These limitations can be taken as research gaps for future research to consider for better coverage and analysis.

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