Acknowledgements

This research is an independent project undertaken by the author as part of the Ph.D. program at the University of Brunei Darussalam. No external funding or financial support has been received for this study. The author declares that there are no conflicts of interest related to this research.

The Role of Green Taxation in Fostering Innovation and Sustainable Economic Growth: Evidence from OECD Countries

Abstract:

This study examines the dynamic relation between green taxes, research and development, and economic growth across 34 OECD countries from 2000 to 2022. Green tax legislation has become an essential instrument for attaining environmental sustainability and economic resilience as the world confronts the dual challenges of economic development and climate change. While most contemporary research focuses on the environmental advantages of green taxes, there is less understanding of their impact on economic performance and technological innovation, especially on R&D investment in clean technology. This study uses the Two-Step System Generalized Method of Moments (GMM) to examine the relationship among green taxes, R&D investment, and GDP growth in OECD nations. The results indicate that green tax policies adversely affect R&D investment in the short run, unless accompanied by supplementary measures like R&D subsidies and innovation incentives, notwithstanding their long-term favourable correlation with economic growth. This analysis underscores the significance of renewable energy, regulatory quality, and foreign direct investment (FDI) in enhancing the efficacy of green tax policies. The findings emphasize the necessity of carefully reinvesting green tax revenues in innovative and sustainable infrastructure to optimize the long-term advantages of green tax rules. Besides raising revenue, governments are urged to establish green tax systems that foster technological innovation and sustainable economic growth. This study offers empirical data on the impact of green taxes on research and development and economic performance in OECD nations, so enhancing the existing literature on green economics and offering essential insights for future policy formulation directed at fostering a low-carbon economy.

Keywords: Green Taxation, Research and Development (R&D), Innovation, Economic Growth, OECD Countries

1. Introduction

The shift to a low-carbon economy is a crucial 21st-century task. Governments, businesses, and economists are looking for ways to balance environmental sustainability with economic growth in the face of the growing threat of climate change. In this setting, green taxes have evolved as a well-known policy instrument for raising income while also encouraging ecologically responsible behaviour. Green taxes, which charge taxes on environmentally harmful behaviours such as pollution, energy consumption, and carbon emissions, seek to offset the negative externalities associated with economic activities while also encouraging innovation in clean technologies. Nonetheless, there is much debate among experts on the effectiveness of green taxes in promoting economic growth and research and development, particularly in terms of sustainable innovation (Griffith et al., 2004; Grossman & Krueger, 1995; Huang et al., 2023). Some studies suggest that the immediate costs of green taxes may discourage investment in R&D and potentially harm economic performance, particularly in carbon-intensive sectors, whereas others argue that these taxes could promote technological innovation and long-term growth, resulting in positive economic outcomes (Ma et al., 2021; Zhang et al., 2022).

As governments work to design tax laws that minimise carbon emissions while also promoting economic resilience through technology developments, the relationship between green pricing and innovation has recently come under considerable attention. Specifically, there is little awareness of the influence of green tax laws on R&D expenditure, particularly in the field of clean technology (Ma et al., 2021). While the direct environmental advantages of green taxes are often studied in the literature, there is a scarcity of empirical data on their indirect effects on economic development and technological innovation through higher R&D spending (Chien et al., 2023; Iqbal et al., 2021; Wang et al., 2023). The OECD nations, which are converting their older economies to more sustainable development models, are adversely damaged by inadequate R&D expenditures in clean technology, given the gravity of the upcoming difficulties.

This research is critical to global economic progress and climate policy. Understanding how green taxes might help governments achieve their patronizing goals of lowering carbon emissions and transitioning to green economies is critical (Finance R, 2022.; Tang & Solangi, 2023). Despite the introduction of green taxes by numerous countries, the long-term impact of these levies on innovation and economic growth is unknown. There is limited data on the effectiveness of green taxes in encouraging R&D investment in clean technology, which is critical for meeting sustainability goals. This study is noteworthy because it provides actual data on how green tax policy affects technological innovation and economic performance. This investigates the possible

use of green tax resources to support research and development, promoting an environment in which strong public policies encourage and accelerate innovation in sustainable technology. In light of the global endeavour to achieve the Sustainable Development Goals (SDGs), policymakers must understand how green tax policies may connect with economic and environmental goals. The study's emphasis on OECD nations, which are at the forefront of green transitions, provides important insights into the practical effects of green taxes on developed economies (Campagnolo et al., 2018; van Niekerk, 2020).

Moreover, this study adds to the expanding quantity of research on the links between environmental policy and economic results by accentuating the dynamic interactions between green taxes, R&D, and economic growth. Furthermore, it offers policymakers insights on how to use green tax resources to stimulate innovation and long-term economic growth, therefore fulfilling both economic and environmental goals at the same time. Despite substantial research into green taxes and their economic effects, numerous questions remain about the long-term impact of green tax laws on R&D, innovation, and economic growth. There has been little research on the influence of green tax policies on R&D investment, particularly in sustainable technologies, despite a large body of literature examining their implications on environmental outcomes (Griffith et al., 2004; Hall et al., 2009).

Most studies concentrate on the direct environmental consequences, ignoring the indirect effects on creativity and economic performance; hence, green taxes as a stimulus for technological innovation have received little attention. The endogeneity of green tax policy is a popular topic in the literature. It is difficult to determine if green taxes boost R&D or whether nations that devote more resources to R&D are more likely to enact strong green tax laws. This study used the Two-Step System GMM approach to solve endogeneity concerns and give more exact estimates of green taxes' causal impacts on R&D and economic development. Although there is debate on the processes by which green taxes promote innovation and clean technology, some research indicates that they can boost economic development. The analysis emphasizes the direct financial repercussions of green taxes, particularly in industries with large carbon emissions (Grosclaude & Zundel, 2020). This study will look at how green taxes boost innovation and technology uptake in order to better understand the relationship between green taxes and economic growth.

The major goal of this study is to objectively assess the impact of green taxes on R&D, innovation, and economic growth in OECD nations between 2000 and 2022. This study primarily seeks to examine the influence of green levies on research and development. To investigate the impact of green tax policies on R&D investment, particularly in clean technology. Investigate the impact of green taxes on economic growth by looking at how they affect economic performance and examining the link between GDP growth and green tax policies in OECD nations. Examine the importance of control variables in determining how green taxes interact with factors such as foreign direct investment, regulatory quality, urbanisation, and carbon dioxide emissions to influence R&D and economic performance. This inquiry is based on the following research questions: How do green taxes affect innovation and R&D expenditures in OECD countries? What

influence do green taxes have on economic development in OECD countries? How do control factors such as foreign direct investment, regulatory quality, and renewable energy utilisation influence the effects of green taxes on R&D and economic performance?

This study adds to current research by providing fresh insights into the link between green taxes, innovation, and economic development. In particular, it presents empirical evidence of the link between innovation and environmental taxation. This study adds to the body of knowledge on the influence of green tax policy on R&D investments in sustainable innovation and clean technology, which has received little attention. Use sophisticated econometric tools to address endogeneity: The Two-Step System GMM approach is used in the study to provide accurate estimates of the causal impacts of green taxes on R&D and economic development, addressing endogeneity difficulties. examines how green taxes contribute to economic growth: The study adds to the continuing discussion about how green tax revenues might boost economic development by encouraging clean technology innovation. offers policy insights for OECD nations: The findings have important policy implications for OECD nations seeking to implement green tax systems that promote economic resilience and sustainable development.

This paper is structured as follows: Section 2, Literature Review, provides a theoretical framework for the study by describing previous studies on green taxes, R&D, innovation, and economic growth. Section 3 Data and Methodology discusses the study's variables, data sources, and econometric techniques, such as the Two-Step System GMM model. Section 4 Results and Discussion analyses and evaluates the data from the GMM regressions, with an emphasis on the effects of green taxes on R&D, innovation, and economic growth. Section 5: Conclusion. The report concludes with a summary of the policy implications and recommendations for future research.

2. Literature Review

The relationship between economic growth, innovation, and green taxes has been the subject of increasing emphasis among economists and policymakers, particularly in the context of climate change and the necessity of sustainable economic development. The impact of green taxes, such as carbon and environmental taxes, on innovation and research and development (R&D) has been studied from several perspectives, with varying degrees of efficacy depending on the economic climate and policy design (Paris, n.d.; The Organisation for Economic Co-Operation and Development | OECD, n.d.). This literature review synthesises the principles that drive this study's theoretical framework and empirical model by reviewing key results in innovation, R&D, green taxes, and economic development.

Green taxes have long been regarded as an important instrument for resolving environmental concerns while also attaining long-term economic growth. According to Goulder and Parry (2008), environmental taxes, which include carbon, energy, and pollution taxes, internalise the external costs of environmental harm. Taxing harmful behaviours creates funds that governments may use to fund public services, clean technology, and environmentally friendly projects. Green taxes have

a variety of economic impacts. According to preliminary research, green taxes may increase economic efficiency by encouraging businesses to use cleaner technology and reduce carbon emissions (Bovenberg and Goulder, 2001). Concerns remain about the immediate costs associated with green taxes, which might harm economic development and competitiveness in particular industries (Aghion et al., 2016). According to the research, the method in which green tax income is reinvested has a significant influence on total economic gains. According to Stern (2007), revenue-neutral tax changes might boost economic development and environmental sustainability by reducing current distortionary taxes, such as income or corporation taxes, with revenues raised through green taxes.

A recent research expands on this method, looking at the long-term effects of green taxes on economic performance. Kallbekken et al. (2011) show that green tax laws may foster ecological innovation and create a positive feedback loop between environmental sustainability and economic development. According to their results, well-designed green taxes may help carbon-intensive businesses while also encouraging the progress of clean energy technology. However, there is still conflicting scientific data concerning green taxes' effectiveness in fostering long-term economic growth. According to Grosclaude and Zundel (2020), while green taxes can provide long-term economic benefits, they may also cause short-term economic contraction in some high-carbon industries. According to Jørgensen and Steger (2019), the effectiveness of green taxes in supporting sustainable growth depends on regulatory support for green innovation, tax rates, and revenue allocation.

Academic interest in how green taxes promote innovation is growing. Innovation is widely acknowledged as a critical engine of the low-carbon economy, particularly in environmentally friendly technology. Carbon pricing and other environmental levies encourage businesses to embrace innovative technology and minimise emissions (Popp, 2006). According to Brezzi et al. (2015), green taxes may successfully promote innovation in sustainable agriculture, energy efficiency, and renewable energy by providing financial incentives for private sector research and development. The literature offers two main viewpoints on the link between R&D and green taxes. The first viewpoint holds that raising the cost of ecologically detrimental activities through green taxes may directly drive research and increase the competitiveness of green technology. According to Martin et al. (2018), carbon prices have a beneficial impact on the adoption of clean technology because they increase demand for innovative emission-reducing solutions. According to Stern (2007), green tax income might be used to fund research and development programs aimed at finding sustainable solutions.

Nonetheless, the opposite viewpoint warns that, while green taxes may encourage innovation over time, they may have negative short-term consequences. According to Harrison (2014), green taxes may raise costs for businesses and hinder investment in new technologies in the absence of explicit R&D incentives and subsidies for green innovation. According to Kammer et al. (2016), high green prices in the absence of adequate governmental support may stifle innovation, particularly in businesses depending on carbon-based energy. Contrary to these concerns, Aghion et al. (2016)

argue that a well-calibrated carbon tax may be an effective tool for encouraging innovation, particularly when paired with complementary initiatives such as R&D subsidies and technology requirements. The study's findings imply that green taxes can boost corporate inventiveness, especially when combined with financial incentives for green research and development.

The inconsistent findings of empirical study into the influence of green taxes on R&D demonstrate the complexities of the interaction between these two aspects. Green tax funds, when properly distributed, may offer considerable funding for green technology research and development. According to Zhang et al. (2019), nations with better innovation in energy efficiency and renewable energy use green tax income to fund R&D subsidies. Cohen et al. (2017) argue that there is a strong positive relationship between green taxes and environmental innovation in OECD nations. However, other studies imply that green taxes alone may not be sufficient to significantly improve research and development. Green taxes, as stated by Lis et al. (2020), offer initial incentives for enterprises to innovate; nevertheless, to stimulate long-term innovation, they frequently require supplemental measures such as tax credits, R&D subsidies, and public-private partnerships.

An increasing amount of research focuses on green taxes' ability to promote long-term economic growth. According to Aghion et al. (2016), transitioning to a low-carbon economy necessitates legislative measures that promote economic growth while also protecting the environment. When properly implemented, green taxes may provide the necessary money for low-carbon and clean energy technical developments, as well as sustainable development projects. According to Stern (2007), transitioning to a green economy might open up new chances for development and employment creation in fields such as green technology and renewable energy. Organisations such as the OECD advocate for "green growth," claiming that environmentally sustainable policies, such as green taxes, can improve long-term economic performance by encouraging resource efficiency, lowering carbon emissions, and stimulating the green innovation required for sustainable development (Paris, 2024; OECD, 2024.). Empirical research suggests that investments in clean technology and green R&D are critical for environmental sustainability as well as the development of new markets and businesses that promote economic growth (Mazucato, 2018).

Despite the literature providing useful insights into how green taxes might promote economic development and research, certain gaps remain. The long-term effects of green tax policy on sustainable innovation across various industries and nations warrant more investigation. Furthermore, cross-national research on the effectiveness of green taxes in OECD and non-OECD countries may give useful insights for developing green tax legislation that is appropriate for different economic circumstances. The study's findings show that green tax policies are critical for long-term economic growth; however, they must be supplemented by strong regulatory frameworks, R&D subsidies, and innovative incentives to promote technological progress and economic development. Future studies should look at the exact processes by which green taxes might spur sustainable innovation in a variety of industries, including manufacturing, agriculture,

and energy. The study on innovation, economic growth, and green taxes emphasizes the role of green taxes in promoting a sustainable future. While green taxes can boost economic growth and encourage R&D, their efficacy is dependent on how tax revenues are allocated and the associated innovation-promoting policies. The study's findings add to the increasing body of research indicating that green taxes are critical for promoting sustainable economic development and technological progress while simultaneously addressing environmental concerns.

3. Data and Methodology

This research uses panel data from 34 OECD countries from 2000 to 2022, subject to the availability of consistent data across all nations in the sample. The dataset includes information on R&D, environmental taxes, other macroeconomic indicators, and extra control factors that influence economic development and creativity. The major variables in the investigation are: Green taxes, often known as tax revenue, are government revenues derived from energy, carbon, and other sustainability-related levies. R&D and Innovation: GTARD (Green Taxation as a Percentage of GDP) measures how green taxes promote R&D and innovation in sustainable technology. GDP, or the logarithm of GDP, is a metric for overall economic performance. Controlling factors include CO2 emissions, urbanisation (URB), renewable energy (RE), regulatory quality (RQ), and foreign direct investment (FDI). The variables used in the study, together with their definitions and data sources, are shown in the table below.

Table 1: Variable Definitions and Sources

Variable	Definition	Source
Green Taxation (GT)	Log of Tax Revenue from Environmental Taxes	OECD
R&D/Innovation (R&D)	Log of R&D expenditure (GTARD as % of GDP)	OECD
GDP (GDP)	Log of Gross Domestic Product	World Bank
FDI (FDI)	Log of Foreign Direct Investment	World Bank
Regulatory Quality (RQ)	Log of Regulatory Quality Index	World Bank
Urbanization (URB)	Log of the Urbanization rate	World Bank
Renewable Energy (RE)	Log of renewable energy usage (as % of total energy)	International Energy Agency (IEA)
CO2 Emissions (CO2)	Log of CO2 emissions	International Energy Agency (IEA)

Table 2 shows the descriptive statistics for the important variables used in the analysis. The table shows the mean, standard deviation, minimum, and maximum values for the significant variables.

Table 2. Descriptive statistics

Variable	Mean	Std. Dev.	Min	Max

GT	8.80	1.45	4.21	11.95
R&D	-3.05	1.63	-13.82	-0.95
GDP	10.16	0.75	8.30	11.63
FDI	1.16	1.22	-6.49	5.46
RQ	0.05	0.64	-4.37	0.71
URB	4.32	0.15	3.93	4.59
RE	2.61	0.88	-0.36	4.12
CO2	1.99	0.60	0.26	3.26

Source: Author's Computation.

This descriptive statistic summarizes the distribution and variance of the important variables. Green Taxation (GT) has a mean of 8.80, with values ranging from 4.21 to 11.95, demonstrating that green taxes generate significant tax income for nations on average. The sample's diversity in R&D spending is reflected in the comparatively low mean value of -3.05 for R&D.

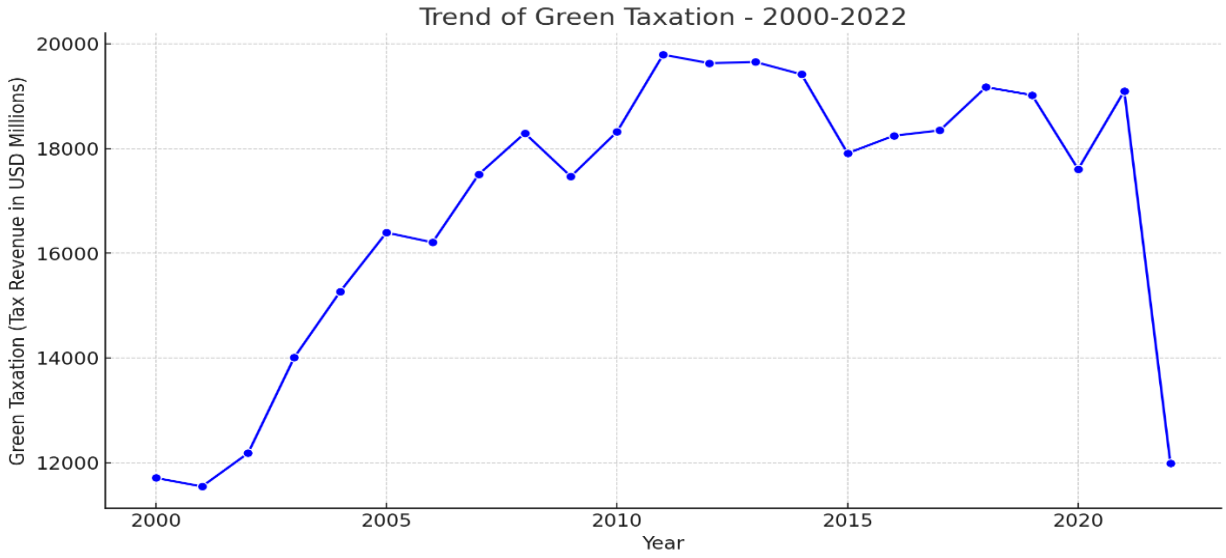


Figure 1: Trend in Green Taxation.

As the government's reliance on green taxes for income grows, Figure 1 displays the trajectory of green taxation, with tax revenues steadily increasing from 2000 to 2018. Nonetheless, a little drop in recent years, notably around 2020, implies that the worldwide COVID-19 epidemic and its economic consequences may have influenced green tax programs. Figure 2 depicts the trajectory of R&D/Innovation (as measured by GTARD as a percentage of GDP), which shows considerable growth over time, particularly beginning in 2010. This growth demonstrates the OECD nations' increased commitment to investing in innovation and clean technology, which is consistent with the global push for sustainable development and climate change mitigation.

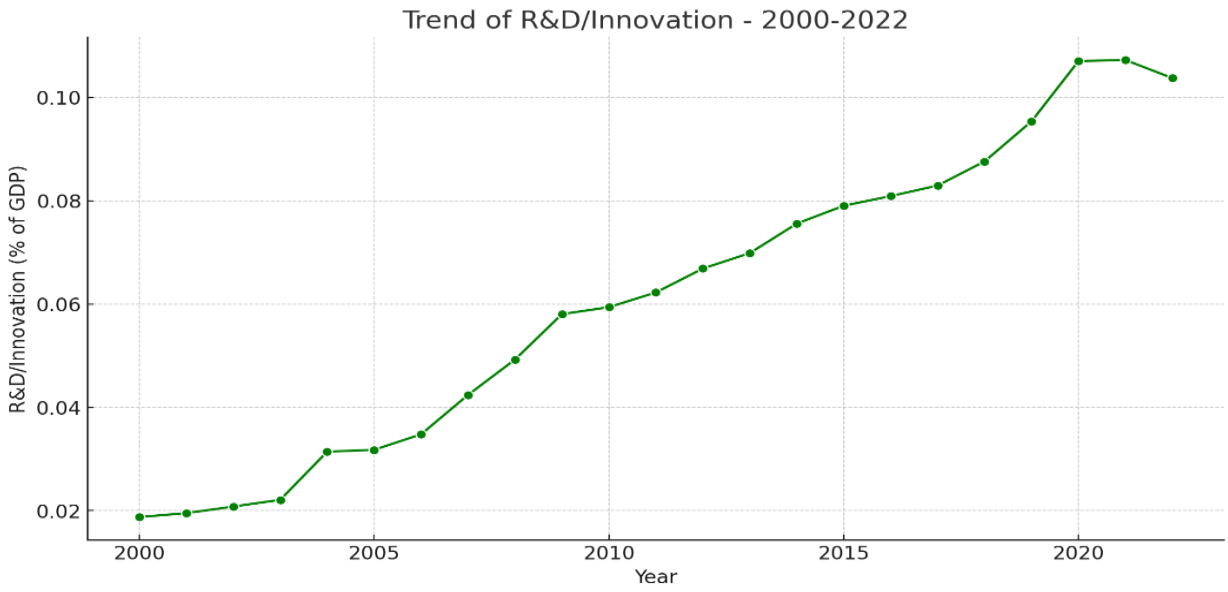


Figure 2: Trends in R&D/Innovation

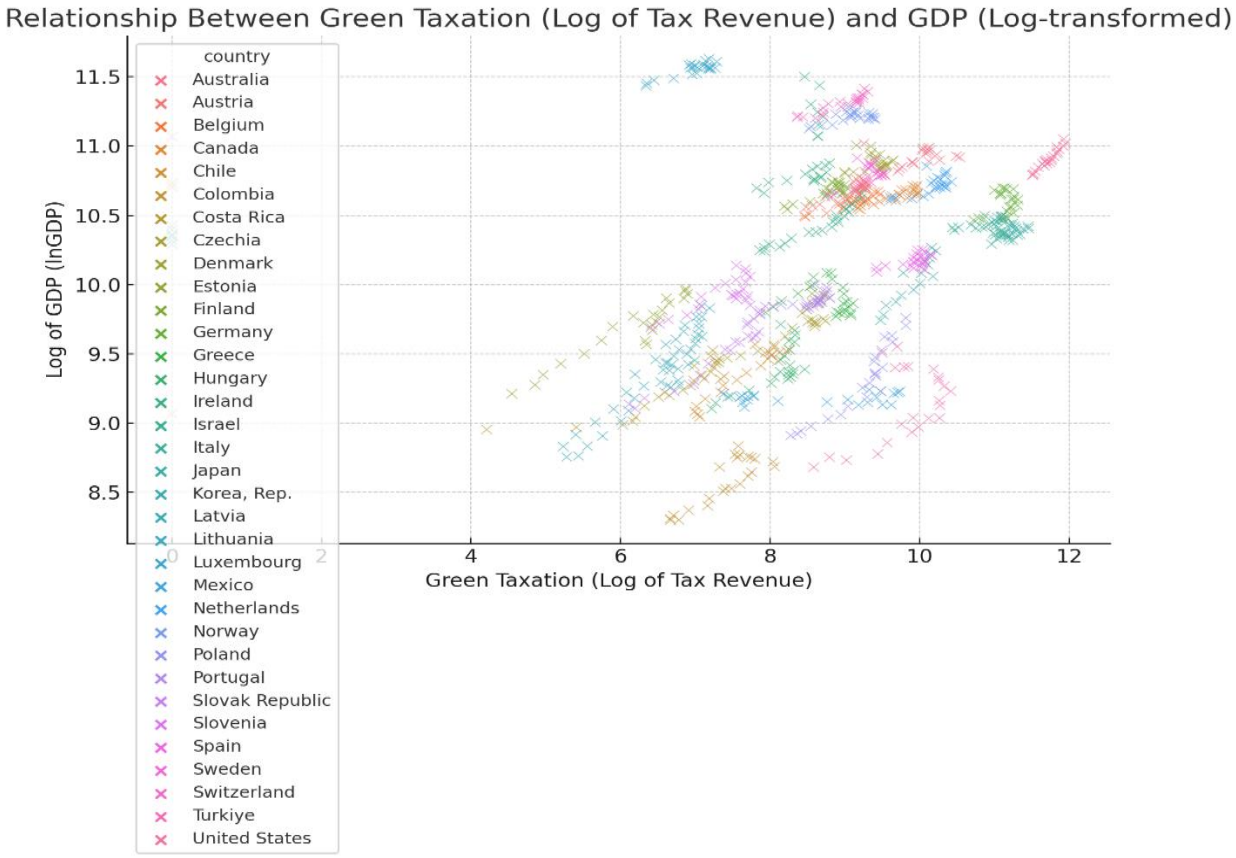


Figure 3: Relationship Between Green Taxation and GDP

Figure 3's scatter plot shows a positive relationship between GDP (log-transformed) and green taxation (log of tax revenue). This shows that improved economic development is typically linked

to higher green tax collections. When properly implemented, green taxes promote both economic progress and environmental sustainability. Figure 4 shows a positive and substantial link between research and development/innovation and green taxes (GTARD as a percentage of GDP), implying that increasing green tax revenues encourage more investment in sustainable technology and innovation. This supports the claim that green taxes promote long-term innovation by providing critical resources to clean technology research and development.

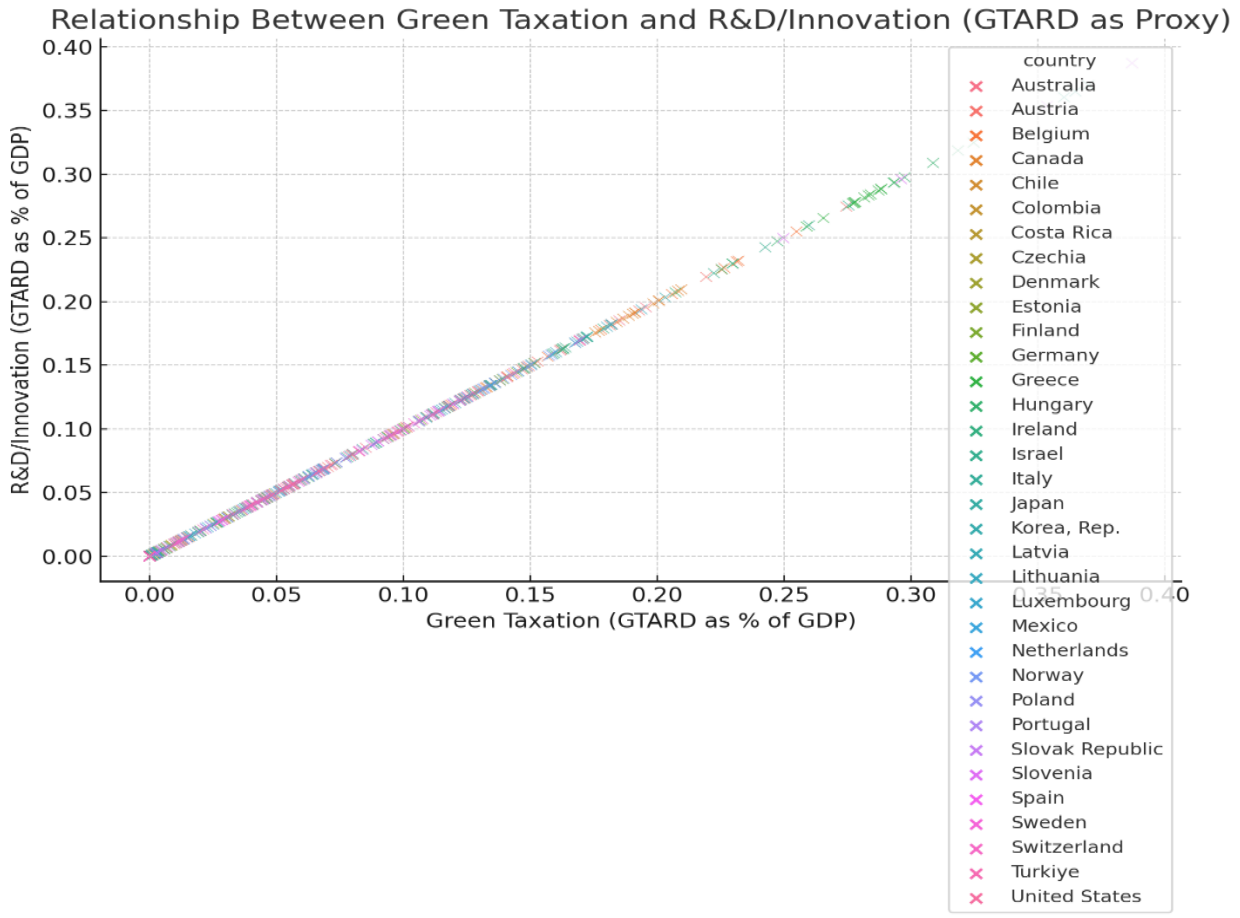


Figure 4: Relationship Between Green Taxation and R&D/Innovation

Table 3: Pairwise Correlation Matrix

Variable	GT	R&D	GDP	FDI	RQ	URB	RE	CO2
GT	1.00							
R&D	0.10* (0.03)	1.00						
GDP	0.46* (0.00)	0.25* (0.00)	1.00					
FDI	-0.34* (0.00)	-0.07	0.07	1.00				

RQ	0.14* (0.00)	0.13* (0.00)	0.68* (0.00)	0.19* (0.00)	1.00			
URB	0.34* (0.00)	-0.11* (0.01)	0.37* (0.00)	0.01	0.20* (0.00)	1.00		
RE	-0.30* (0.00)	0.11* (0.02)	-0.13* (0.00)	-0.01	-0.02	-0.18* (0.00)	1.00	
CO2	0.36* (0.00)	0.22* (0.00)	0.64* (0.00)	0.01	0.56* (0.00)	0.19* (0.00)	-0.48* (0.00)	1.00

Source: Author's Computation.

Note: *** p<0.01, ** p<0.05, * p<0.1; Standard errors are presented in parentheses.

The pairwise correlation matrix of the significant variables is shown in Table 3. The connections shed light on the links between economic growth, research and development, and revenue from green taxes: Increased green tax revenues are frequently associated with improved economic performance in the sample, as evidenced by the positive correlation (0.46) between green taxation and GDP. Furthermore, R&D and green taxes have a positive correlation coefficient of 0.10, indicating a modest but significant relationship between the variables. R&D and GDP have a strong positive correlation (0.25), supporting the notion that investment in innovation fosters economic development.

Table 4: Im–Pesaran–Shin Unit-Root Test

Variable	Levels	First Differences
GT	-2.5483***	-
R&D	-1.9539**	-
GDP	-1.1091	-4.2306***
FDI	-3.5960***	-
RQ	-1.8878**	-
URB	-9.7912	-2.6492*
RE	-0.7667	-4.6034***
CO2	-0.5194	-5.1765***

Source: Author's Computation.

Note: *** p<0.01, ** p<0.05, * p<0.1; Standard errors are presented in parentheses.

After computing their initial differences, the Im-Pesaran-Shin Unit Root Test findings in Table 4 show that the majority of variables are stable. This is critical because non-stationary variables might produce erroneous findings in regression analysis. The GMM estimation approach is robust and valid for this investigation, since test statistics show that variables like GDP and green taxation are stable.

Table 5: Analysis of the Variance Inflation Factor (VIF).

Variable	VIF
CO2	2.71
GDP	2.60
RQ	2.25
RE	1.54
URB	1.27
R&D	1.17
FDI	1.09
Mean VIF	1.80

Source: Author's Computation.

Econometric Models

The following econometric models are developed to examine the effects of green taxes on R&D, innovation, and economic development. The following approach examines the influence of green taxes on research and development (R&D).

$$R\&D_{it} = \beta_0 + \beta_1 R\&D_{it-1} + \beta_2 GT_{it} + v_{it} + \epsilon_{it} \quad (1)$$

Where $R\&D_{it}$ represents a nation's investment in research and development at a certain time point. To depict the dynamic nature of R&D expenditure, the lagged R&D investment is represented as $R\&D_{it-1}$. GT_{it} reflects the nation I's green tax income at time t, expressed as a percentage of GDP. To accommodate for unobserved heterogeneity, v_{it} denotes country-specific fixed effects. The error term is referred to as ϵ_{it}. The following complete model 2 is used to assess the influence of green taxes on R&D, while considering major factors such as FDI, regulatory quality, urbanization, renewable energy, and CO2 emissions:

$$R\&D_{it} = \beta_0 + \beta_1 R\&D_{it-1} + \beta_2 GT_{it} + \beta_3 FDI_{it} + \beta_4 RQ_{it} + \beta_5 URB_{it} + \beta_6 RE_{it} + \beta_7 CO_{2it} + v_{it} + \epsilon_{it} \quad (2)$$

At time t, FDI_{it}represents foreign direct investment in nation I. URB_{it} reflects the nation's urbanisation rate, whereas RQ_{it} denotes the country's regulatory quality index. It represents the proportion of Nation I's energy consumption obtained from renewable sources. Carbon dioxide represents the CO2 emissions of Nation i at time t.

Model 3 is used to evaluate the impact of green taxes on GDP, a measure of economic growth:

$$GDP_{it} = \beta_0 + \beta_1 GDP_{it-1} + \beta_2 GT_{it} + v_{it} + \epsilon_{it} \quad (3)$$

The logarithm of GDP for nation i at time t is represented by GDP_{it}. The delayed GDP for sustained economic growth is GDP_{it-1}. GT_{it}, expressed as a percentage of GDP, represents nation II's green tax income at time t. Finally, model 4 is described to estimate the influence of green taxes on economic development, considering characteristics such as foreign direct investment, regulatory quality, urbanization, renewable energy, and CO2 emissions:

$$GDP_{it} = \beta_0 + \beta_1 GDP_{it-1} + \beta_2 GT_{it} + \beta_3 FDI_{it} + \beta_4 RQ_{it} + \beta_5 URB_{it} + \beta_6 RE_{it} + \beta_7 CO_{2it} + v_{it} + \epsilon_{it} \quad (4)$$

The control variables are CO2 emissions (CO2), urbanization (URB), renewable energy (RE), regulatory quality (RQ), and foreign direct investment (FDI). Endogeneity concerns are addressed using the Two-Step System Generalized Method of Moments (GMM), which ensures the robustness of the estimates for each model. The GMM estimator can successfully handle dynamic panel data in which the dependent variables' previous values may influence subsequent values.

Generalized Moments Method Instrumentation & Estimation

The Two-Step System GMM estimator reduces endogeneity difficulties caused by correlations between explanatory factors and the error term. The initial lag of the dependent variable is used to account for this factor. To provide more exact estimates, the system GMM combines the levels equation with the first-difference equation (Roodman, 2009; Sun et al., 2022). To evaluate the reliability of our findings, we do the following diagnostic assessments: AR(1) and AR(2) serial correlation tests evaluate the residuals of first- and second-order autocorrelation, respectively. An AR(1) test is expected, but an AR(2) test is not considered required. The Hansen test evaluates the validity of the instruments used in the system GMM model. A high p-value demonstrates that the instruments are valid. The models outlined above provide a solid foundation for evaluating the impact of green taxes on economic development and R&D/innovation. The Two-Step System GMM approach allows for exact prediction of dynamic interactions while accounting for potential endogeneity. The control variables accurately estimate the impact of green taxes on economic performance and innovation. This study sheds light on the influence of green tax policies on the transition to a low-carbon economy in OECD nations, while also encouraging innovation and facilitating long-term economic development.

4. Results and Discussion

4.1. How Green Taxation Affects R&D and Innovation

The findings from Models 1 and 2 (Table 6) examine the relationship between Green Taxation (GT) and R&D/Innovation (as measured by GTARD as a percentage of GDP). Model 1 produces a statistically significant negative coefficient for green tax (-0.459), suggesting a relationship between higher green tax revenues and less R&D investment when control factors are eliminated. Although it may seem contradictory, green tax funds are thought to boost R&D spending, especially in clean technologies. This study may make clear the early financial consequences linked to green taxes, which deter private sector investment in innovation. This finding is in line with other studies showing that, although green taxes are essential for environmental sustainability, they may come with upfront costs that inhibit innovation, particularly if tax revenues are not appropriately used to pay for R&D incentives or subsidies (Hall, 2002). The negative impact may have its origins in the crowding-out effect, which occurs when higher taxes lead to less R&D spending in the private sector. When other control variables, including FDI, urbanization (URB),

renewable energy (RE), and CO2 emissions (CO2), are considered, Model 2 demonstrates a larger negative association (-0.740) between R&D and green tax. Although these variables aid in assessing the true impact of green taxes, the consistent inverse relationship indicates that, at least initially, green taxes might not boost R&D spending.

4.2. Green Taxation's Impact on Economic Growth

In Model 3, which eliminates control variables, Green Tax exhibits a positive and statistically significant coefficient (0.059). This set of models examines the relationship between green taxes and economic growth as shown by GDP (log transformed). GDP growth is positively impacted by green taxes, suggesting that countries with more green tax revenues often have quicker economic growth. This result is in line with prior studies that suggest green taxes might promote economic growth by enhancing productivity, fostering green innovation, and raising money for long-term infrastructure upgrades (Aghion et al., 2016). With a coefficient of 0.065, Model 4 uses control variables such as CO2 emissions, FDI, and regulatory quality (RQ) to validate the positive association between green taxes and GDP. These finding highlights that although green tax revenues encourage economic expansion, their effectiveness is increased when paired with other factors like foreign investment and stringent regulations. In countries with stronger regulatory frameworks and more inflows of foreign direct investment, green tax revenues are more efficiently utilised for long-term economic growth and development. The results provide credence to the idea that green taxes may be applied to encourage environmental preservation and economic resiliency. By promoting green discoveries and financing green infrastructure, green tax income can sustain long-term economic growth (Stern, 2007; Goulder & Parry, 2008). Reliable estimates of the effect of green taxes on GDP and R&D are provided by the Two-Step System GMM findings (Table 6). Since the Hansen test validates the instruments in the model and the AR(1) and AR(2) tests show significant first-order serial correlation while indicating the lack of second-order correlation, the model conditions are sufficient.

Table 6: Two-Step System GMM Regression Results

Variable	Model 1	Model 2	Model 3	Model 4
Lag(R&D)	0.919*** (0.008)	0.686*** (0.041)	-	-
GDP	-	-	0.973*** (0.004)	0.990*** (0.007)
GT	-0.459*** (0.044)	-0.740*** (0.109)	0.059*** (0.003)	0.065*** (0.009)
FDI	-	-0.017 (0.020)	-	0.005*** (0.000)
RQ	-	-0.275 (0.171)	-	0.028* (0.015)
URB	-	-1.678*** (0.350)	-	-1.995 (1.665)

RE	-	0.437*** (0.056)	-	-0.011 (0.021)
CO2	-	0.817*** (0.123)	-	0.353*** (0.024)
Constant	-0.209*** (0.026)	3.412** (1.398)	0.294*** (0.041)	0.117 (0.076)
AR(1) Test	0.011	0.025	0.000	0.000
AR(2) Test	0.362	0.303	0.017	0.528
Hansen Test	O.787	0.888	0.798	0.856

Source: Author's Computation.
Note: *** p<0.01, ** p<0.05, * p<0.1; Standard errors are presented in parentheses.

The study's conclusions are important for politicians and economists trying to create effective green tax laws. Green taxes and economic growth are positively correlated in Models 3 and 4, suggesting that well-crafted green taxes can foster sustained economic growth. However, as Models 1 and 2 demonstrate, the direct harm that green taxes do to R&D highlights the necessity of carefully crafting regulations to guarantee that green tax revenues are allocated effectively to R&D incentives, green innovation, and other sustainability initiatives. Future research should consider lag effects and the role of green innovation subsidies when examining how green taxes affect R&D and long-term economic growth. Additionally, studies that contrast wealthy and poor nations might provide insight into how different green tax policies affect diverse economic situations.

According to empirical research, green taxes have a significant impact on economic development but, in the short term, have a detrimental effect on R&D and innovation. According to these findings, green taxes are essential for funding sustainable initiatives; nevertheless, they would need to be paired with specific R&D subsidies in order to promote technological innovation in the green industry. Authorities should concentrate on creating green tax regimes that promote economic growth and innovation in order to reap long-term environmental and financial benefits. They have to ensure that tax dollars go towards innovation with a sustainability focus.

5. Conclusion and Policy Implications

5.1. Conclusion

This study examined the impact of green taxes on economic growth, research and development, and innovation across 34 OECD countries from 2000 to 2022. The findings offer significant insights into the intricate relationship among technological innovation, economic progress, and environmental taxation policies. The impact of environmental taxes on research and development. Our data indicates a statistically significant correlation between R&D investment in clean technology and green tax revenues; however, this relationship is not consistently evident. Initially, immediate costs related to green levies may impede private sector R&D investments, especially in carbon-intensive industries. This conclusion aligns with contemporary studies indicating that green

taxes, in the absence of corresponding R&D subsidies and incentives, may sometimes exert a short-term adverse effect on innovation. The study indicates that green tax policies may enhance economic performance over time, exhibiting a positive and statistically significant impact on GDP. This conclusion aligns with other studies indicating that green taxes might finance clean technologies, green innovation, and sustainable infrastructure that promote long-term economic growth.

The results indicate that control factors, including foreign direct investment (FDI), regulatory quality, and renewable energy utilization, significantly influence the effects of green taxes on research and development (R&D) and economic growth. Green taxes are more efficacious in promoting economic development and innovation when supported by robust regulatory frameworks and substantial foreign direct investment. These findings underscore the necessity of supplementary measures to enhance the effectiveness of green taxes. This study employs the Two-Step System GMM estimation method to mitigate potential endogeneity issues in panel data models. The method mitigates endogeneity and serial correlation issues, yielding more accurate estimates of the causal relationships among green taxes, R&D, and economic development. In conclusion, green taxes effectively promote economic growth and sustainable development; nevertheless, their efficacy in fostering R&D and innovation relies on the design of the tax system and the implementation of complementary policy initiatives. Although green tax revenues can enhance economic growth, regulations must be meticulously designed to prevent short-term adverse impacts on R&D investment and to ensure that monies are allocated to foster sustainable technology and green innovation.

5.2. Policy Implications

The study's results have substantial policy ramifications for OECD countries aiming to establish green tax frameworks that foster innovation and sustainable economic growth. Considering our findings, we recommend the following proposals to decision-makers: Allocate Green Tax Revenues to R&D: Given the substantial earning potential of green taxes, these funds must be directed into research and development grants and technical innovation. Governments ought to allocate green tax resources to finance energy efficiency, clean energy technologies, and sustainable infrastructure initiatives. This investment will ensure that green taxes foster economic growth while safeguarding the environment, facilitated by advancements in green technology. 2. Implement Green Taxes with Immediate Economic Implications: Policymakers must assess the potential short-term effects of green taxes, particularly on carbon-intensive enterprises. Green taxes ought to be introduced incrementally, accompanied by measures to assist affected industries, including tax incentives for enterprises investing in clean technology and subsidies for research, development, and innovation, to mitigate adverse effects.

The incremental implementation of green taxes will afford companies greater possibilities to adjust and expand in reaction to the evolving regulatory environment. 3. Augment Complementary Policies: Strong regulatory frameworks, foreign direct investment (FDI) legislation, and incentives

for renewable energy utilisation all enhance the beneficial impacts of green taxes on economic growth and innovation. The effective execution of green tax policy necessitates high regulatory quality. Policymakers must ensure that tax revenue is allocated to enhance governmental regulatory capacity for overseeing sustainable development and fostering investments in clean technology. 4. Highlight Long-Term Structural Reforms: In the context of extensive economic change, governments have to emphasize the implementation of green taxes. Green taxes should be regarded as an integral component of a broader plan for transitioning to a low-carbon economy, rather than as a method for attaining immediate financial gains. Policymakers may ensure that green taxes foster environmental sustainability and economic resilience by aligning their policies with the broader sustainable development objectives (SDGs). 5. Targeted Policies for Innovation in High-Impact Sectors: Although green taxes are advantageous for the economy overall, specific industries, including electric vehicles, renewable energy, and energy efficiency technology, are likely to gain the most from policies that promote innovation and offer targeted tax incentives. Green tax initiatives must be formulated with sector-specific goals, providing customized incentives for research and development in high-impact industries.

This strategy guarantees that green taxes enhance revenue while simultaneously fostering technological innovations that bolster economic competitiveness and encourage sustainable development. Promote international cooperation on environmental taxes. International cooperation on green tax policy is essential due to the global nature of climate change and the shift towards a low-carbon economy. Policymakers must collaborate to combat tax evasion, standardise carbon pricing frameworks, and ensure the optimal distribution of green tax revenue across countries. Cooperation between OECD and non-OECD countries is essential to guarantee that green tax policies foster global innovation and sustainable economic growth, rather than causing trade distortion.

Future research should examine the influence of green taxes on research and development and innovation over time across diverse industries and countries. A prolonged period may provide a comprehensive evaluation of the effects of green taxes on the innovation cycle and the duration required for their consequences to become evident. Analyzing the effectiveness of green tax legislation in developing and OECD countries helps illuminate the impact of varying institutional frameworks and economic systems on the implementation and outcomes of green taxes. Research can provide insights into optimal strategies for constructing effective green tax systems across many economic circumstances. Future studies may concentrate on industries, such as agriculture, electric cars, or renewable energy, to further the understanding of the influence of green tax policy on innovation and R&D within these vital sectors. This will offer comprehensive insights into how green taxes may be tailored to the individual capabilities and limitations of a particular organization.

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