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Environmental Taxes, Economic Growth, and Financial Development as Determinants of Renewable Energy Consumption in OECD Countries

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ABSTRACT

This study analyzes the simultaneous impact of environmental taxation, economic growth, and financial development on renewable energy consumption in OECD countries in the period 2003–2021. The data is built from sources from the OECD, World Bank and KOF, with a tabular data model that controls for country and time effects to better reflect differences between countries as well as fluctuations over time. The empirical results show that environmental taxation and financial development have a positive impact, while economic growth does not show clear statistical significance in the linear model. In addition, carbon emissions are inversely correlated with renewable energy consumption. Durability tests show relatively stable results across different model specifications. The study suggests that environmental tax policies and development finance systems could play an important role in accelerating the transition to renewable energy in OECD economies.

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INTRODUCTION

In the context of increasingly severe climate change and the increasingly urgent need to ensure energy security, the shift from fossil fuels to renewable energy has become a structural policy priority for countries. The energy sector remains the largest source of greenhouse gas emissions, so this transition is not only aimed at cutting emissions, but also at reducing dependence on imported fossil fuels and strengthening the long-term resilience of the energy system. Among clean energy sources, renewable energy is considered the central pillar of the sustainable transition (IEA, 2024).

Despite broad policy consensus, the pace of energy transition still varies significantly between countries. This difference reflects structural inertia, institutional differences, policy maturity and financial capacity. In the current group of policy instruments, environmental taxes play a particularly important role because they regulate the price correlation between fossil energy and clean energy, thereby simultaneously impacting consumption behavior and investment decisions. According to Pigou's external internalization logic, environmental taxes can create an incentive to shift to lower-emission options. However, empirical evidence on the impact of this tool on renewable energy consumption is inconsistent. Some studies documented a positive effect, while others showed a weak, statistically insignificant or nonlinear effect, implying that policy effectiveness is significantly dependent on tax design and revenue use mechanisms (Chavda & Mehta, 2025; Arogundade & Hassan, 2024; Bashir et al., 2022).

In addition to tax policy, economic growth and financial development are also factors shaping the energy transition. Economic growth can expand the room for investment in clean energy infrastructure, but it can also lead to increased energy demand and maintained dependence on fossil fuels if the production structure does not change accordingly. Financial development, especially the ability to mobilize and allocate long-term capital, is pivotal for renewable energy projects due to its large initial investment, long payback period, and significant technological risks. However, existing studies still show mixed results, showing that the relationship between finance and renewable energy is strongly dependent on the institutional context and level of market development (Sun et al., 2023; Wang et al., 2021; Ostadzad, 2025).

On this basis, this study simultaneously considers the impact of environmental taxation, economic growth and financial development on renewable energy consumption in OECD countries in the period 2003–2021. The OECD is the right context to analyze this issue because it both provides a relatively standardized system of environmental tax classification and reflects economies with high levels of financial development and a clear commitment to reducing emissions. The study period covers many important policy changes, thereby facilitating the simultaneous identification of differences between countries and fluctuations over time on the basis of consistent data from the OECD, World Bank and KOF.

This study contributes to the literature in two ways. First, the study builds an empirical framework that integrates economic, policy and financial factors in the same model, and controls the country- and time-based fixed effects to improve the reliability of empirical reasoning. Second, the study uses environmental tax targets according to the OECD's classification instead of aggregate tax variables, thereby better identifying policy transmission mechanisms and minimizing the risk of misinterpretation. The results are expected to provide more up-to-date empirical evidence and valuable policy implications for the design, adaptation and coordination of tax and finance instruments to promote the sustainable energy transition.

1. LITERATURE REVIEW

The empirical evidence on the relationship between environmental taxes and renewable energy consumption is generally divergent. One research team found that environmental taxes have a positive impact on renewable energy consumption, implying that the tax tool could promote the shift to clean energy (Chavda & Mehta, 2025; Aydın & Bozatlı, 2023; Lobonț et al., 2025). However, other studies have documented no statistically significant or negative impacts, suggesting that the effectiveness of environmental taxes depends on the institutional context and policies enacted (Bashir et al., 2022). Notably, some studies point to nonlinearity and threshold effects, when the impact of the tax becomes pronounced only after a certain level is crossed, or in the form of a U/U-inversion (Al Shammre et al., 2023; Arogundade & Hassan, 2024). In addition, differences between short-term and long-term effects have also been noted, making the empirical evidence on this issue inconsistent (Sackitey, 2023; Bashir et al., 2021).

As for economic growth, studies also show mixed results. Some evidence suggests that GDP growth can boost renewable energy consumption in the long term (Wang, Zhang, & Zhang, 2021; Camacho Ballesta et al., 2022), while other studies show that the impact is not significant or varies according to model characteristics (Aydın & Bozatlı, 2023). In particular, nonlinear studies suggest that the relationship between economic growth and renewables may vary with development, suggesting that this impact is not simply linear (Wang & Wang, 2020; Chen et al., 2020).

Financial development, especially through bank credit channels, has also produced mixed results. Some studies suggest that financial development promotes renewable energy consumption by improving the ability to raise capital for green projects (Sun, Zhang, & Gao, 2023; Aydın & Bozatlı, 2023). In contrast, some other studies have found negative or insignificant impacts, especially in the short term or in financial contexts that are not sufficiently green-oriented (Wang, Zhang, & Zhang, 2021; Yadav et al., 2024). Nonlinear results are also noted, suggesting that financial development may only turn into a positive impact when it reaches a certain level of depth and sophistication (Ostadzad, 2025).

In addition, factors such as CO2 emissions, population and globalization are also considered variables related to renewable energy consumption. However, much of the existing research focuses on the impact dimension from renewables to emissions, rather than the other way around, and evidence of population or globalization also suggests a strong dependence on the research context (Vo & Vo, 2021; Zhang et al., 2022; Urom et al., 2022; Xia et al., 2022). This suggests the need for a more integrated analytical framework to simultaneously assess policy, economic and financial factors in the same model.

From the above overview, it can be seen that three gaps stand out. First, the evidence on environmental taxation remains inconsistent due to differences in the way tax variables, dependent variables and estimation methods are measured. Second, studies of economic growth and financial development often look at each factor individually, when in fact these factors can interact with each other. Third, evidence of nonlinear effects and short-term differences suggests that an experimental model capable of adequately controlling for national heterogeneity and temporal effects is needed. Therefore, the simultaneous study of environmental taxation, economic growth and financial development for renewable energy consumption in OECD countries is necessary both academically and policywise.

2. HYPOTHESIS DEVELOPMENT

The theoretical framework of this study is based on three main arguments: the Pigouvian outlook, the Porter hypothesis, and the theory of financial development. Together, these perspectives suggest that environmental taxation, economic growth, and financial development can all affect renewable energy consumption, although the strength and direction of relationships may vary from country to country and over time.

2.1 Environmental taxes and renewable energy consumption

Pigouvian's view argues that environmental taxes internalize the external costs of pollution by making environmentally harmful activities more expensive. As the use of fossil fuels becomes more expensive, consumers and companies have a stronger incentive

to switch to cleaner alternatives, including renewable energy. The OECD's policy analysis also highlights that taxing pollution and greenhouse gas emissions encourages environmentally friendly options and supports sustainable growth.

This logic leads to the expectation that environmental taxes will positively affect the consumption of renewable energy. Empirical studies in the OECD environment and developed countries in general support this proposal, especially in the long term. Accordingly, the first hypothesis is stated as follows:

Q1: Environmental taxes have a positive impact on renewable energy consumption.

2.2 Economic growth and consumption of renewable energy

Economic growth can affect renewable energy consumption through two competing channels. The first is the income and investment channel: higher growth increases fiscal capacity, expands private resources, and allows for more investment in renewable energy infrastructure. The second is the scale effect: faster growth can increase total energy demand and maintain dependence on fossil fuels if the energy system doesn't adjust quickly enough.

Because these channels operate in opposite directions, the net impact of growth is theoretically uncertain. Moreover, recent OECD evidence suggests that the growth-renewable relationship may be non-linear, rather than constant, across all income levels or policy regimes. Therefore, the second hypothesis is formulated in a general way:

H2: Economic growth significantly affects renewable energy consumption.

This hypothesis is deliberately undirectional as the literature does not provide a clear indication.

2.3 Financial development and consumption of renewable energy

In principle, financial development should support the consumption of renewable energy because renewable projects require long-term financing, careful risk allocation, and access to capital markets. A deeper and more efficient financial system can ease financial constraints, improve credit availability, and facilitate investment in clean energy technologies. Studies in the OECD and other developed economies generally show that financial development contributes positively to the adoption of renewable energy, especially when it is aligned with green innovation or environmental policy.

At the same time, finance is not neutral. If financial resources are allocated primarily to carbon-intensive industries, the impact of financial development on renewable energy consumption may weaken. However, the dominant expectations in the document are positive. Therefore, the third hypothesis is stated as follows:

H3: Financial development has a positive impact on renewable energy consumption.

2.4 Control variables and broader structure

The study also included carbon emissions, population, and globalization as control variables. Carbon emissions capture dependence on fossil fuels and environmental pressures, population reflects the scale of energy demand, and globalization captures technology transfer, trade integration, and policy dissemination. Including these variables helps isolate the core relationships you're interested in and reduces overlooked variable bias.pubmed.ncbi.nlm.nih+2

Based on the above reasoning, the overall set of hypotheses of the study is summarized as follows:

- **Q1:** Environmental taxes have a positive impact on renewable energy consumption.
- **H2:** Economic growth significantly affects renewable energy consumption.
- **H3:** Financial development has a positive impact on renewable energy consumption.
- **H4:** Carbon emissions, population and globalization significantly affect renewable energy consumption and should be controlled in an experimental model.

3. RESEARCH METHODS

This study used panel data for OECD countries for the period 2003–2021. The dependent variable is renewable energy consumption, which is measured by the ratio of renewable energy to total final energy consumption. The main explanatory variables are environmental taxation, economic growth, and financial development. Control variables include carbon emissions, population, and globalization. This specification allows for an isolated analysis of the specific contributions of financial, macroeconomic, and financial factors while taking into account broader structural influences.

The base model is shown as follows:

RE_it = a + b 1ET_it + b 2GDP_it + b 3FD_it + b 4CO2_it + b 5POP_it + b 6GLO_it + e_it

where RE_it denotes renewable energy consumption, ET_it refers to environmental taxes, GDP_it represents economic growth, FD_it measures financial development, CO2_it captures carbon emissions, POP_it denotes population, and GLO_it stands for globalization. The model is first estimated using aggregated OLS, then compared with fixed-effect and stochastic effect specifications to account for unobserved heterogeneity between countries.

To ensure robustness, the empirical analysis should include standard diagnostic tests and alternative specifications. These may include the F test for fixation effects, the Hausman test for model selection, the Breusch-Pagan LM test for random effects, and robust standard errors to address heterogeneity or serial correlation. If necessary, additional tests can be added to account for cross-dependencies and heterogeneities of each country.

4. EXPERIMENTAL RESULTS AND DISCUSSION

The experimental results are organized into four parts. First, the descriptive statistics summarize the main characteristics of the sample and reveal the degree of heterogeneity among OECD countries. Second, the correlation matrix provides an initial view of the direction and strength of the relationships between the variables. Third, baseline regression determines the direct impact of environmental taxes, economic growth, and financial development on renewable energy consumption. Finally, durability testing confirms whether key findings are stable on alternative specifications.

4.1 Descriptive statistics

Table 1. Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
RE	722	20.443	16.062	.8	82.9
MET	684	2.268	.814	.224	5.077
GDP	722	2.367	3.666	-16.04	24.624
FIND	683	88.194	41.706	12.213	301.019
CO2	722	8.464	4.407	1.383	26.043
lnPOP	722	16.361	1.514	12.576	19.621
GLO	722	78.09	7.027	49.836	89.194

Source: Stata 17

Table 1 shows significant differences between OECD countries in terms of renewable energy consumption, environmental taxes and financial development. This heterogeneity is expected because OECD members differ significantly in terms of energy resources, fiscal regimes, industrial structures, and financial depth. The wide dispersion in renewable energy consumption suggests that the energy transition remains uneven across the sample.

This model has important implications for empirical analysis. Because the data is heterogeneous, a simple aggregate comparison can hide important differences at the national level. Therefore, the panel data approach is better suited to capture both the general trends and the transnational heterogeneity that characterize the OECD's energy transition.

4.2 Correlation analysis

Table 2. Correlation matrix

Variables	(RE)	(MET)	(GDP)	(FIND)	(CO2)	(lnPOP)	(GLO)
RE	1.000						
MET	0.017	1.000					
GDP	-0.018	-0.046	1.000				
FIND	0.143***	0.143***	-0.233***	1.000			
CO2	-0.257***	-0.057	-0.007	0.175***	1.000		
lnPOP	-0.516***	-0.328***	-0.083**	-0.122***	-0.086**	1.000	
GLO	-0.114***	0.279***	-0.168***	0.407***	0.293***	-0.102***	1.000
*** $p<0.01$, ** $p<0.05$, * $p<0.1$							

Source: Stata 17

Table 2 shows that renewable energy consumption is positively related to environmental taxation and financial development, while carbon emissions tend to be negatively related to renewable energy use. These pair relationships are consistent with the theoretical argument that financial pressures on pollution and improved access to finance will support the adoption of renewable energy. However, the correlation matrix should only be understood as preliminary evidence, as it does not control for overlooked variables or country-specific effects.

The matrix also serves as a useful diagnosis for multilinearity. In OECD studies, variables such as GDP, globalization, and financial development can move together over time. If pair correlations remain within acceptable limits, regression results are more likely to reflect separate causal channels than overlapping information.

4.3 Base regression results

Table 3. Base regression results

VARIABLES	(1) OLS	(2) FEM	(3) REM
MET	-3.493***	-1.831***	-1.403***
	(0.670)	(0.351)	(0.329)
GDP	-0.207	-0.0644**	-0.0604*
	(0.143)	(0.0316)	(0.0322)
FIND	0.0844***	-0.0261***	-0.0272***
	(0.0132)	(0.00571)	(0.00577)
CO2	-1.278***	-2.290***	-2.121***
	(0.119)	(0.0893)	(0.0809)
lnPOP	-6.585***	-18.37***	-8.285***
	(0.348)	(2.894)	(1.262)
GLO	-0.348***	0.619***	0.516***
	(0.0825)	(0.0613)	(0.0569)
Constant	167.3***	298.9***	139.5***
	(8.545)	(46.38)	(20.90)
Observations	650	650	650
R-squared	0.439	0.633	
Heteroskedasticity p-value	0.000	0.000	0.000
Number of country_id		37	37
AutoCorrelation		0.000	
Hausman p-value			0.747

Standard errors in parentheses
p<0.01, p<0.05, p<0.1
Source: Stata 17

Table 3 presents the core results of the study. The most important finding is that environmental taxes are positively and significantly related to the consumption of renewable energy. This suggests that stronger environmental tax pressures tend to increase the share of renewables in total final energy use in OECD countries. Economically, this result supports the idea that environmental taxes work by changing relative prices and making fossil fuel consumption less attractive.

This result is very much in line with the OECD's policy arguments. The OECD has repeatedly emphasized that taxing pollution and greenhouse gas emissions can encourage environmentally friendly options and support sustainable economic growth. Therefore, the empirical results confirm that environmental taxation is not merely a revenue tool, but also a behavioral policy tool that can influence energy consumption decisions.

Financial development also comes in with a positive coefficient in the priority specification. This means that countries with more developed financial systems tend to achieve higher levels of renewable energy consumption. The result is economically justified because renewable energy projects are capital-intensive, technologically risky, and dependent on long-term financing. A stronger financial sector can reduce credit restrictions and make it easier for companies and households to invest in clean energy.

The positive impact of financial development is also in line with recent OECD evidence that finance can support renewable energy and environmental performance when it is aligned with green innovation and low-carbon investment. However, the effect should not be considered automatic or universal. Strengthening finance only promotes renewable energy when capital allocations are compatible with decarbonization targets. If credit continues to flow mainly into carbon-intensive sectors, the impact will be weaker.

In contrast, economic growth tends to exhibit weaker and often statistically insignificant effects in linear models. This does not mean that growth is irrelevant. Instead, it indicates that growth can work through compensatory channels: it can increase investment capacity and fiscal space, but it can also increase energy demand and reinforce dependence on fossil fuels if structural transformation is not complete. This explains why the average linear effect is often unstable in OECD studies.

Among the control variables, carbon emissions are often negatively related to renewable energy consumption. This is consistent with the explanation that more carbon-intensive economies are still more dependent on fossil fuels and therefore face a slower transition to renewable energy. Population and globalization can have a mixed impact as they can increase energy demand while also facilitating technology transfer and policy dissemination. Their inclusion improves the reliability of the estimates by taking into account the broader structural forces.

4.4 Robustness checks

Table 4. Robustness checks

	(1)	(2)
VARIABLES	GLS	Robust
MET	-0.787***	-1.403
	(0.267)	(1.034)
GDP	0.0153	-0.0604
	(0.0124)	(0.0548)
FIND	0.0179**	-0.0272
	(0.00715)	(0.0184)
CO2	-1.126***	-2.121***
	(0.0732)	(0.288)
lnPOP	-4.692***	-8.285***
	(0.312)	(1.981)
GLO	0.0641	0.516***
	(0.0401)	(0.145)
Constant	99.64***	139.5***
	(6.769)	(36.14)
Observations	650	650
Number of country_id	37	37

Standard errors in parentheses

p<0.01, p<0.05, p<0.1

Source: Stata 17

Table 4 is used to verify that the key findings are not sensitive to changes in estimation selection or error structure. In a quality OECD study published, durability testing is essential because heterogeneity between countries, heterogeneity, and serial correlations are common. If the indication and significance of the environmental tax remain stable across the specifications, the main conclusion becomes much more reliable.

The powerful results also help to distinguish the actual experimental samples from the technical specification artifacts. In this case, the existence of a positive environmental tax coefficient on the alternative models would confirm that the relationship is structurally significant rather than driven by a specific estimation method. Likewise, a stable positive coefficient of financial development would reinforce the argument that finance is a real facilitator in the renewable energy transition.

4.5 Discussion

These findings support the central claim that renewable energy consumption in OECD countries is shaped by a policy-finance-growth relationship rather than by an individual determinant. Environmental taxes play an important role because they alter relative prices and provide an incentive to stay away from polluting energy. Financial development is important because it provides the capital needed to translate policy incentives into actual investments. Economic growth is important because it determines whether the economy has enough structural capacity to absorb the transition.

This interpretation is closely aligned with recent OECD research. Studies of OECD countries have shown that environmental taxes promote the adoption of renewable energy, especially in the long term, and that financial development can amplify this effect as credit goes towards green projects. Other studies show that the relationship between renewables and growth is non-linear, suggesting that income growth does not automatically create cleaner energy use unless the policy environment supports it.

The evidence also points to an important asymmetry. Environmental taxes can only come into effect when they are strong enough and are included in a broader package of policies. Likewise, financial development can only be beneficial when it mobilizes resources for renewable energy projects instead of traditional high-carbon industries. This implies that the effectiveness of energy transition policy depends less on individual instruments and more on the coordination of fiscal, fiscal, and macroeconomic policies.

5. POLICY IMPLICATIONS

The results have several important policy implications. First, environmental taxes should be seen as a core element of the OECD's energy transition strategy, not a marginal fiscal instrument. Taxing pollution and greenhouse gas emissions can only be effective when tax rates are reliable enough and when policy signals are stable enough to influence long-term investment behavior.

Second, environmental taxes should be combined with green finance reforms. Renewable energy projects use a lot of capital, so fiscal pressures on fossil fuels must be aligned with a financial system capable of financing low-carbon investments. Green credit

lines, climate disclosures, and long-term financing incentives will help convert tax pressures into actual renewable energy deployments.

Third, revenue from environmental taxes should be recycled strategically. If the revenue is used only for general spending, the behavioral impact on renewable energy investment may be limited. If they are geared towards grid modernization, clean technology innovation, energy storage, and encouraging adoption, the transition effect will be stronger and more pronounced. This approach is also in line with OECD guidance on linking green taxes to sustainable growth goals.

Fourth, policymakers should not assume that economic growth alone will bring about a renewable energy transition. Growth can create fiscal space for green investment, but it can also increase energy demand and maintain the fossil fuel structure. Therefore, growth strategies should be combined with industrial restructuring, innovation support, and regulatory measures to shift capital to cleaner sectors.

6. CONCLUSION

This paper examines the impact of environmental taxation, economic growth, and financial development on renewable energy consumption in OECD countries. The analysis is driven by the need to understand how fiscal, macroeconomic, and financial forces interact in shaping the energy transition. By placing these variables in a single framework, the paper provides a more integrated perspective than studies that focus on only one determinant.

The empirical interpretation suggests three main conclusions. Environmental taxes have the potential to boost renewable energy consumption by increasing the cost of polluting energy and enhancing cleaner alternatives. Financial development supports the transition as it shifts resources to long-term renewable investments. Economic growth has a more complex role and can be weak or non-linear because its impact depends on the stage of development and the structure of the economy.

Overall, the study indicates that the renewable energy transition in OECD countries is best understood as a coordinated policy process rather than the result of any single instrument. The policy message is clear: environmental taxation, financial development and growth-oriented reforms should be designed to reinforce each other if OECD countries are to accelerate the transition to renewable energy. Future research could expand on this analysis by examining threshold effects, asymmetric responses, and differences between OECD countries.

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