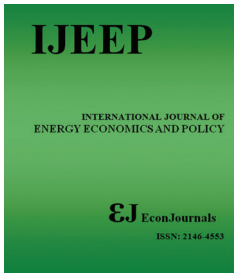

International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2026, 16(1), 615-621.

Integrating Environmental Fiscal Tools and Clean Energy for Climate Mitigation: An International Perspective

Ikram Ghraieb*

Depatment of Economy, Sousse University, Sousse, Tunisia. *Email: ghraiebikram@yahoo.fr

Received: 27 June 2025 **Accepted:** 10 October 2025 **DOI:** https://doi.org/10.32479/ijeep.21722

ABSTRACT

This study examines how effective environmental policies, specifically environmental taxation and renewable energy use, are in reducing climate change in developed countries from 1995 to 2023. Using a dynamic panel threshold model, we evaluate if the connection between these environmental tools and carbon emissions shows non-linear patterns, with environmental taxation acting as the threshold variable. Our findings reveal significant threshold effects, suggesting that the impact of renewable energy use on reducing emissions is stronger once a certain tax level is surpassed. Additionally, the results emphasize how environmental taxes and clean energy adoption work together to achieve substantial reductions in emissions. We conduct tests for cross-sectional dependence and panel unit roots to ensure the results are reliable, and we use system GMM to handle endogeneity issues. This study adds to the literature by exploring taxation and renewable energy within a dynamic threshold framework, which has not been widely studied before. The policy implications indicate that increasing green taxation and fostering clean energy investments can be essential strategies for reaching climate targets in developed countries.

Keywords: Climate Change Mitigation, Environmental Taxation, Renewable Energy, Carbon Emissions, Developed Economies, Threshold Model
JEL Classifications: Q2, Q4, Q5, o2

1. INTRODUCTION

Climate change is one of the biggest challenges we face in the 21st century. Rising greenhouse gas (GHG) emissions threaten ecosystems, public health, and economic stability. The Intergovernmental Panel on Climate Change (IPCC, 2023) has stressed the need to adopt strong strategies to limit global temperature increases to below 1.5°C. Developed nations, as the historically largest contributors to emissions, have a major responsibility to lead global climate action with effective policy measures. Environmental taxes and the promotion of renewable energy have emerged as key tools for sustainable economic change. Environmental taxes, based on Pigouvian tax theory, aim to address the negative effects of carbon-intensive activities by putting a cost on pollution. These taxes encourage a shift in production and consumption patterns toward cleaner options by making polluting behaviors more expensive. At the same time, using renewable energy like solar, wind, and hydroelectric power—directly replaces fossil fuels, lowers carbon emissions, and supports energy independence. Both strategies highlight the need for market-based disincentives and technological solutions to tackle environmental harm. However, while these tools are often discussed separately, their combined effectiveness in fighting climate change has not been fully explored.

In recent years, research has grown on the individual effects of environmental taxes and renewable energy use on reducing emissions. Studies like Metcalf (2019), Oueslati et al. (2021), Dong and al.(2021) and OECD (2022) show how carbon pricing and green tax reforms can meet environmental goals without significantly hurting economic growth. Similar findings reveal the long-term separation of emissions from energy use in countries that have greatly increased their renewable energy capacity (Apergis and Payne, 2020; Wang et al., 2022). However, the success of

these approaches depends on the quality of institutions, regulatory ability, and the level of economic development, which can differ widely among countries.

Despite the increasing interest in green policy design, there is a significant gap in the research. Few studies have examined the nonlinear and threshold-based relationship between environmental taxation and renewable energy within a single empirical framework. Specifically, there is a lack of studies using international panel data focused only on developed countries. In these countries, policy tools are more established and data coverage is strong. It is also uncertain if a certain level of environmental tax must be reached before renewable energy policies can achieve meaningful cuts in emissions. Filling this gap is crucial for understanding not just if these tools are effective, but also under what conditions they work best.

In this context, the current study looks at how environmental policies, specifically environmental taxes and renewable energy use, help reduce climate change in a group of developed countries from 1995 to 2023. To address potential changes in how these policies work, we use a Dynamic Panel Threshold Model. This model allows the impact of key variables to vary based on the level of environmental taxation. This study makes three main contributions: first, it provides updated evidence using recent international data; second, it uses a method that captures how policy effects can change based on different conditions; and third, it gives useful insights for creating policies by identifying the level of environmental taxation at which other measures, like renewable energy, work better. By examining the relationship between fiscal tools and clean energy in a changing and complex environment, this paper adds to the growing body of literature on green policy assessment. It also offers timely advice for policymakers aiming to meet emissions reduction goals in accordance with the Paris Agreement.

2. LITERATURE REVIEW

Climate change is one of the biggest and most complicated challenges facing developed countries in the 21st century. In response, a variety of strategies have come to light, all aimed at cutting down greenhouse gas emissions and keeping global warming in check. Among these strategies, environmental taxes and the use of renewable energy really shine as important policy tools because they can help shift how we produce and consume towards more sustainable practices. These approaches are increasingly being recognized for their potential impact. The idea behind environmental taxation is rooted in Pigouvian principles, which suggest that imposing taxes on activities that create negative side effects, like pollution, can help incorporate social costs and steer behavior towards more efficient results. A Pigouvian tax that matches the marginal external cost of pollution encourages producers to lower emissions and develop cleaner technologies (Zhou, and al., (2019). As highlighted by Goulder and Schein (2013), these taxes not only promote cost-effectiveness but also generate significant revenue that can be reinvested in sustainable initiatives.

Recent studies have shown that environmental taxes can be quite effective, especially in developed nations with robust regulatory frameworks. For instance, World Bank (2023 and 2024) examined carbon tax systems across EU countries and found that emissions dropped significantly in places where carbon prices were stable and supported by specific sector taxes. Additionally, Zhao et al. (2020) and Pan et al.(2020) highlighted that the effects of these taxes are even more noticeable in countries with high emissions, particularly when the tax revenues are reinvested wisely. At the same time, the push for renewable energy has become a key part of national strategies aimed at reducing carbon footprints. By replacing fossil fuels with cleaner alternatives like wind, solar, and hydroelectric power, countries can make a real dent in their emissions. Research by Jie and Khan (2024) backs this up, showing a strong negative correlation between renewable energy usage and CO_2 emissions in OECD nations. Likewise, Sadorsky (2020) found that a greater reliance on renewables plays a significant role in long-term emissions reductions.

Enabling factors like the quality of institutions and the strength of financial infrastructure are key to the success of renewable energy policies. Zafar et al. (2020), IEA. (2022 and 2023) and UNEP. (2022) point out that having supportive legal frameworks and access to green financing can significantly boost the deployment of renewable energy, especially in wealthier nations. Similarly, Irfan et al. (2019) and Zhu and al., (2018) emphasize that consistent policies and mechanisms that support innovation are vital for a successful energy transition. While there's been a lot of research on environmental taxes and renewable energy separately, there's still a lack of studies looking at how these two can work together. Apergis and Payne (2017) are among the few who tackle this issue, finding that both strategies, whether on their own or combined, help reduce emissions in G7 countries. Their findings indicate that a more integrated approach leads to better results. Chen et al. (2018) back this up, suggesting that taxation can improve financial viability for renewable projects. Despite these important findings, there are still some notable gaps in the research. For one, many studies tend to focus solely on either environmental taxes or renewable energy, without exploring how these two can complement each other. This narrow focus makes it hard to fully grasp how these policies can work together to cut emissions. Additionally, most existing research is either specific to certain countries or relies on small regional datasets, which limits the broader applicability of the findings.

Thirdly, there's a noticeable gap in studies that utilize advanced panel econometric methods capable of tackling issues like cross-sectional dependence, heterogeneity, and long-run dynamics across countries. In our interconnected world, where policy diffusion and economic integration are more important than ever, not using these techniques can really weaken the strength and trustworthiness of empirical results. Additionally, institutional factors—like the quality of governance, regulatory capacity, and transparency—often don't get the attention they deserve. This study aims to bridge these significant gaps by performing a thorough panel analysis of developed economies, looking at both the individual and combined effects of environmental taxation and renewable energy consumption on carbon emissions.

By using state-of-the-art econometric methods, the research takes into account the differences and interconnections between countries, offering insights that are more applicable and relevant for climate change mitigation strategies. Lately, there's been a growing interest in how effective environmental fiscal tools are and the increasing role of renewable energy within wider climate policy frameworks. For example, Lee et al. (2023) show that well-designed carbon tax systems in high-income OECD countries can lead to lasting reductions in emissions, especially when tax rates are adjusted for inflation and emissions targets. Their findings highlight the importance of dynamic tax adjustments to keep pace with changing circumstances. Moreover, Su et al. (2025) delve into the relationship between environmental taxation and technological innovation, revealing that carbon pricing encourages clean technology patents and speeds up the spread of renewable technologies. This supports the idea that Pigouvian taxation can stimulate innovation and suggests a secondary way that fiscal policy can help achieve climate objectives.

The integration of renewable energy has also gained prominence in recent policy evaluations. According to Kafeel et al. (2023), the deployment of decentralized solar and wind systems in developed countries significantly contributes to emissions reduction while enhancing grid resilience. They emphasize that policy support through investment subsidies and feed-in tariffs remains crucial in achieving scale and affordability.

An emerging area of focus in recent literature concerns the role of policy interaction and policy sequencing. Borghesi et al. (2023) argue that combining environmental taxes with renewable subsidies results in greater emissions reductions than applying either policy alone, provided the design is well-coordinated. This finding supports the notion that policy complementarities should be explicitly modeled and considered in empirical research.

Moreover, Raza et al. (2024) analyze the moderating effect of institutional quality on environmental policy outcomes in advanced economies. They find that stronger governance amplifies the positive effects of both environmental taxation and renewable energy consumption. Their panel study underscores the importance of institutional factors as facilitators of effective climate action.

From a methodological perspective, Shabir et al. (2023) strongly recommend using second-generation panel techniques to assess how effective environmental policies are. Their research highlights that overlooking cross-sectional dependence and heterogeneity can often lead to an underappreciation of the true impacts of these policies. These recent findings deepen our understanding of how developed nations can effectively leverage both market-based and regulatory approaches to meet their climate objectives. However, there's still a gap in the literature when it comes to studies that weave these insights into a cohesive empirical framework that spans a broad range of countries. By integrating factors like environmental taxes, renewable energy, and institutional quality into a comprehensive model, this study aims to provide fresh empirical insights.

3. DATA DESCRIPTION

This study takes a close look at a balanced panel dataset that includes a selection of developed economies from 1995 to 2023. The countries were chosen based on classifications from the World Bank and IMF, focusing on high-income or advanced economies, depending on the availability and consistency of the data. To ensure that the information is comparable across different times and countries, the dataset is built from reliable international databases. The main goal here is to evaluate how environmental taxes and the use of renewable energy affect carbon emissions, all while keeping major macroeconomic and structural factors in check. To make the data easier to work with, all variables are presented in natural logarithmic form. This approach helps to normalize the data, minimize heteroskedasticity, and allows us to interpret the estimated coefficients as elasticities.

3.1. Variables and Data Sources

Variable Justification:

- CO_2 emissions serve as the primary indicator of environmental pressure and climate impact.
- Environmental taxes capture market-based environmental policy interventions and incentives to reduce pollution
- Renewable energy consumption reflects the transition toward sustainable energy sources, a core pillar of climate mitigation strategies
- GDP per capita accounts for the role of economic growth and affluence, often tested in the Environmental Kuznets Curve (EKC) framework
- Trade openness allows assessment of the environmental effects of global integration (scale, composition, and technique effects)
- Urbanization is used to examine how population concentration and urban infrastructure affect emissions
- Industry share controls for economic structure, as industrial sectors typically have higher emissions intensity than services.

3.2. Descriptive Statistics and Correlation Analysis

The descriptive statistics presented in Table 1 shed light on key structural and environmental traits of 29 developed countries from

Variable	Description	Measurement	Source
CO_2 Emissions (CO_2)	Proxy for environmental degradation	Metric tons per capita	World Bank (WDI)
Environmental Taxes (ETAX)	Fiscal instruments levied to reduce environmental harm	% of GDP or % of total tax revenue	OECD, Eurostat
Renewable Energy (RENE)	Clean energy consumption as part of total energy use	% of total final energy consumption	IEA, World Bank
GDP per capita (GDP)	Economic development indicator	Constant 2015 US$	World Bank (WDI)
Trade Openness (TRADE)	Degree of integration into the global economy	(Exports+Imports)/GDP (%)	World Bank (WDI)
Urbanization (URB)	Extent of population living in urban areas	% of total population	World Bank (WDI)
Industry Share (IND)	Industrial structure of the economy	Industry value added (% of GDP)	World Bank (WDI)

Table 1: Descriptive statistics

Variable	Mean	Standard	Min	Max
CO_2	5.01	1.15	4.0	7.97
ETAX	1.5	0.29	1.0	1.99
RENE	12.53	1.45	10.02	15.0
GDPPC	34884.0	5823.0	30001.0	49981.0
TRADE	64.48	11.14	50.08	89.91
URB	74.93	3.49	70.02	85.0
IND	25.24	3.05	20.05	29.91

Table 2: Correlation matrix

Variable	CO_2	ETAX	RENE	GDPPC	TRADE	URB	IND
CO_2	1.00	−0.10	−0.30	0.25	0.05	0.12	0.31
ETAX	−0.10	1.00	0.15	0.20	0.08	0.10	−0.05
RENE	−0.30	0.15	1.00	−0.18	−0.10	−0.12	−0.28
GDPPC	0.25	0.20	−0.18	1.00	0.28	0.42	−0.08
TRADE	0.05	0.08	−0.10	0.28	1.00	0.35	−0.14
URB	0.12	0.10	−0.12	0.42	0.35	1.00	−0.20
IND	0.31	−0.05	−0.28	−0.08	−0.14	−0.20	1.00

1995 to 2023. On average, CO_2 emissions per capita stood at 5.01 metric tons, with a fairly tight standard deviation of 1.15, indicating that emission levels were moderate yet consistent across the board. The range of minimum and maximum values (4.00-7.97) shows some differences among countries, likely tied to variations in their energy systems and industrial activities. Environmental taxes, as a share of GDP, averaged 1.50%, with a range from 1.00% to 1.99%. This average points to the existence of fiscal measures designed to curb pollution, but the narrow range hints at limited diversity and perhaps a trend toward similar environmental tax practices among wealthier nations.

The average share of renewable energy consumption was 12.53%, with a standard deviation of 1.45, showing gradual integration of clean energy sources, though the maximum value of 15% indicates that few countries have made significant breakthroughs. GDP per capita averaged $34,884, confirming the high-income profile of the sample but also showing significant dispersion (from $30,001 to nearly $50,000), highlighting heterogeneity in economic development. Trade openness (mean: 64.48%) and urbanization (mean: 74.93%) were generally high, consistent with the structural traits of developed economies. The share of industry in GDP, with a mean of 25.24%, reflects balanced economic structures, but also signals that industrial activity still plays a substantial role in these economies—an important consideration when assessing the emissions profile and mitigation potential.

The correlation analysis, based in Table 2 uncovers several key relationships that are crucial for climate policy. For instance, there's a negative correlation between CO_2 emissions per capita and both renewable energy consumption (−0.30) and environmental taxes (−0.10). This suggests that using cleaner energy sources and implementing fiscal measures aimed at the environment can help reduce emissions in developed countries. Interestingly, a moderate positive correlation exists between CO_2 and GDP per capita (0.25), which supports the Environmental Kuznets Curve hypothesis. This theory suggests that emissions increase with income up to a certain point, after which they start to decline as societies embrace cleaner technologies. The strongest positive correlation with CO_2 is found in the industrial share of GDP (0.31), highlighting how emissions-heavy industrial activities are and the urgent need for a shift towards greener industrial practices. Additionally, renewable energy consumption shows a negative relationship with both GDP per capita (−0.18) and the industrial share (−0.28), which might indicate differences in how energy is sourced in more advanced economies. Environmental taxes have a slight positive correlation with income (0.20), suggesting that wealthier nations are more inclined to adopt these fiscal strategies. Urbanization, on the other hand, has a strong positive connection with GDP per capita (0.42) and trade openness (0.35), emphasizing the links between urban growth, globalization, and economic success. These trends highlight that both structural economic factors and policy measures work hand in hand to influence environmental outcomes.

4. ESTIMATION RESULTS: DYNAMIC PANEL THRESHOLD MODEL

The results of Pesaran (2004) CD test presented in table 3 below, indicates significant cross-sectional dependence for all variables at the 1% level. This suggests that shocks or policies in one developed country likely influence others, justifying the need for econometric techniques that account for interdependence, such as panel-corrected standard errors or robust GMM methods.

These findings suggest that national economies in the developed world are interlinked through trade, investment, and policy spillovers. As a result, environmental shocks or reforms in one country can affect others, reinforcing the need for coordinated international climate strategies.

The Table 4 present the results of CIPS test which indicate that most of the variables are integrated of order one [I(1)], while TRADE and IND are stationary [I(0)]. This means that the threshold model is well-suited for handling mixed integration orders (I(0)/I(1)), confirming its effectiveness for dynamic panel threshold estimation. The combination of I(0) and I(1) variables suggests that both short-run and long-run dynamics are at play. This also supports the use of a threshold model that can accommodate these integration orders without needing full stationarity.

The Wald test provides strong evidence against the null hypothesis H_0: $\beta_1 = \beta_2$, indicating that there's a significant threshold effect at play. This means that the way explanatory variables relate to CO_2 emissions varies quite a bit depending on how high environmental taxes are set. The presence of this threshold effect suggests that the impact of environmental and economic factors isn't uniform. In other words, policy measures might only start to show real effectiveness once we surpass a certain level of taxation, which makes a strong case for implementing more robust tax-based environmental policies.

Based in Table 6, the estimated threshold value of ETAX is 1.42% of GDP, splitting the sample into two regimes:

- Low-tax regime: ETAX ≤1.42
- High-tax regime: ETAX >1.42.

This threshold suggests that environmental taxation must exceed a critical level to significantly alter the effect of other variables on emissions.

The identified threshold of 1.42% of GDP for environmental taxes marks a critical point. Below this level, green fiscal measures may be insufficient to trigger meaningful change, whereas policies above this threshold might exert stronger influence on emission patterns.

5. DYNAMIC PANEL THRESHOLD GMM ESTIMATION RESULTS

The regression results presented in table 7 show some interesting effects that depend on the regime in place. In a low-tax environment, renewable energy has a minimal and statistically insignificant impact on emissions. However, when taxes are higher, the relationship flips to significantly negative, indicating that increased taxation really boosts the effectiveness of clean energy policies. On the other hand, the industrial share continues to be a strong positive contributor to emissions in both scenarios, though its influence is less pronounced when taxes are elevated. GDP per capita seems to have a positive effect only in the low-tax regime, which might align with the Environmental Kuznets Curve hypothesis. The notable lagged CO_2 term points to a strong persistence in emissions over time. These regime-based estimates suggest that renewable energy can be a much more effective tool for cutting emissions when environmental taxes are set high enough. This underscores how important fiscal incentives are in amplifying the benefits of clean technologies. Moreover, the positive impact of GDP in the low-tax regime suggests that early stages of economic growth tend to be more pollution-intensive, while the industrial sector consistently drives emissions, highlighting the urgent need to green our industries.

The findings clearly show that there are threshold-dependent differences in what drives carbon emissions in developed countries. In a low-tax environment (ETAX ≤1.42%), the relationship between renewable energy consumption (RENE) and emissions is negative but not statistically significant. This suggests that simply increasing renewable energy use isn't enough to reduce emissions without a solid fiscal support system in place. On the flip side, in a high-tax environment (ETAX >1.42%), the impact of RENE becomes significantly negative, highlighting that environmental taxes really boost the effectiveness of renewable energy initiatives. This aligns with the principles of ecological economics, where pricing mechanisms help account for external costs and encourage cleaner production and consumption.

When we look at GDP per capita (GDPPC), it shows a positive and significant effect on emissions in the low-tax environment, which supports the Environmental Kuznets Curve (EKC) hypothesis: emissions tend to increase with income during the early stages of development. However, in the high-tax environment, this effect turns negative (though not significantly), suggesting that once a certain level of commitment to environmental goals is reached, economic growth might not necessarily lead to more pollution. The influence of trade openness (TRADE) and urbanization (URB) is positive in the low-tax environment, indicating that international trade and urban living can lead to higher emissions when environmental taxes are weak. Yet, these effects either lessen or even reverse in the high-tax environment, suggesting that green tax policies can help reduce the environmental impact of globalization and urban expansion.

Industrial activity continues to be a major contributor to emissions across both regimes, although the impact is significantly lessened when higher taxes are in place. This suggests that while the industrial sector is naturally carbon-heavy, increased environmental taxes can mitigate its negative effects—possibly by promoting innovation in processes, enhancing energy efficiency, or shifting towards industries that are less polluting. Moreover, the notable and lasting impact of CO_2 emissions highlights the ongoing nature of environmental degradation, emphasizing the need for consistent and timely policy measures. Altogether, these

Table 3: Cross-sectional dependence test (Pesaran CD test)

Variable	CD statistic	P-value	Cross-sectional dependence
CO_2	3.78	0.0002	Yes
ETAX	2.94	0.0032	Yes
RENE	2.85	0.0044	Yes
GDPPC	4.12	0.0000	Yes
TRADE	2.63	0.0086	Yes
URB	3.21	0.0013	Yes
IND	3.00	0.0027	Yes

Table 4: Panel unit root Test (Pesaran (2007): CIPS Test)

Variable	CIPS statistic	Critical value (5%)	Order of integration
CO_2	−3.27	−2.61	I(1)
ETAX	−2.84	−2.61	I(1)
RENE	−2.71	−2.61	I(1)
GDPPC	−3.02	−2.61	I(1)
TRADE	−2.53	−2.61	I(0)
URB	−2.65	−2.61	I(1)
IND	−2.59	−2.61	I(0)

Table 5: Threshold effect test (Wald test for nonlinearity)

Test statistic	P-value	Threshold effect present?
13.82	0.001	Yes

Table 6: Estimated threshold value of ETAX

Estimated threshold (γ)	Confidence interval (95%)
1.42 (% of GDP)	[1.38, 1.46]

Table 7: The tax coefficients

Variable	Low-tax regime coefficient (β_1)	High-tax regime coefficient (β_2)
CO_2 (lagged)	0.62***	0.54***
RENE	−0.07	−0.18**
GDPPC	0.11**	−0.04
TRADE	0.09	−0.03
URB	0.15*	−0.08
IND	0.24***	0.13**
Constant	2.12	1.65

insights strongly indicate that environmental taxes not only have a direct effect on emissions but also play a crucial role in enhancing the effectiveness of other factors, such as renewable energy and the overall economic structure.

6. CONCLUSION AND POLICY RECOMMENDATIONS

This study aimed to explore how environmental policies—particularly environmental taxes and the use of renewable energy—play a role in reducing carbon dioxide emissions in developed countries from 1995 to 2023. By employing a dynamic panel threshold model, we discovered a notable threshold effect linked to environmental taxation. This means that the influence of renewable energy and other economic factors on emissions shifts significantly once a certain level of taxation is crossed. The findings offer valuable insights. Firstly, renewable energy consumption tends to have a much stronger impact on reducing emissions in nations where environmental tax rates exceed 1.42% of GDP. When tax levels are below this point, its effect is statistically less significant, emphasizing the need for supportive fiscal policies to enhance the success of clean energy efforts. Secondly, economic growth, industrial activity, and urbanization generally lead to increased emissions, particularly in low-tax environments. However, these effects diminish when environmental taxes are sufficiently robust. These results highlight the importance of understanding non-linear interactions in policy and the need to take tax thresholds into account when assessing environmental outcomes.

By taking into account the ever-changing nature of emissions and the interconnectedness of developed nations, this study provides a deeper insight into how fiscal and energy policies really work together. The findings indicate that for advanced economies to effectively tackle climate change, it's not just about rolling out renewable energy or imposing taxes on their own; it's crucial that these strategies are combined and finely tuned. From the data gathered, several key policy recommendations arise for governments and international organizations aiming to meet ambitious climate goals. Policymakers need to ensure that environmental taxes go beyond a certain threshold (around 1.42% of GDP) to truly maximize their ability to boost renewable energy effectiveness and cut down emissions. Simply having symbolic or minimal carbon pricing won't make a significant difference. Additionally, these environmental taxes should be part of a larger policy framework that includes renewable energy subsidies, support for technological innovation, and energy efficiency standards. By adopting integrated approaches, we can enhance the collaboration between fiscal measures and the transition to clean energy.

When considering the varying impacts of different factors in low- and high-tax environments, it's clear that climate strategies need to be tailored to each country. Nations that fall below a certain threshold might first focus on fostering tax acceptance, building institutional capacity, and gaining public support before they think about raising tax rates. Moreover, the interconnectedness of countries emphasizes the necessity for collaborative international efforts. Initiatives like shared carbon markets, aligned tax policies, and regional partnerships in renewable energy can significantly enhance the effectiveness of individual national actions. The ongoing influence of industrial activities on emissions, even with higher taxes in place, underscores the urgent need to revamp the industrial sector. Emphasizing green innovation, backing cleaner technologies, and providing incentives for low-carbon manufacturing should be key elements of future strategies. Lastly, the ever-changing nature of emissions highlights how crucial it is to have stable long-term policies. Climate policies need to be reliable and credible to truly impact behavior and investment choices over time. In summary, this study underscores the vital importance of well-designed environmental policies in promoting sustainable development. For developed nations to take the lead in climate action, a proactive and comprehensive approach that merges fiscal responsibility with the expansion of clean energy isn't just advantageous but it's essential.

REFERENCES

Apergis, N., Payne J.E., (2017), Per capita carbon dioxide emissions across U.S. States by sector and fossil fuel source: Evidence from club convergence tests. Energy Economics, 63, 365-372.

Apergis, N., Payne, J.E. (2020), Renewable energy, output, and carbon emissions: Evidence from advanced panel data techniques. Renewable Energy, 145, 451-459.

Borghesi, S., Pahle, M., Perino, G. (2023), The market stability reserve in the eu emissions trading system: A critical review. Annual Review of Resource Economics, 15, 131-152.

Chen, W., Li, K., Gao, Y. (2021), The impact of environmental tax on carbon emissions in OECD countries: Evidence from dynamic panel threshold model. Environmental Science and Pollution Research, 28(14), 17344-17356.

Chen, Y., Goulder, L.H., Hafstead A.C. (2018), The sensitivity of CO_2 emission under a carbon tax to alternative Baseline forcasts. Climate Change Economics, 9(1), 1840012.

Dong, K., Hochman, G., Zhang, Y., Sun, R., Li, H. (2021), Do climate policies foster green growth? Evidence from a dynamic panel threshold model. Energy Economics, 99, 105310.

Goulder, L.H., Schein, A.R. (2013), Carbon taxes versus cap and trade: A critical review. Climate Change Economics, 4(3), 1350010.

IEA. (2022), World Energy Outlook 2022. International Energy Agency. Available from: https://www.iea.org/reports/world-energy-outlook-2022

IEA. (2023), Global Energy Review: CO_2 Emissions in 2022. International Energy Agency. Available from: https://www.iea.org/reports/co2-emissions-in-2022

IPCC. (2023), Climate Change 2023: Synthesis Report. Intergovernmental Panel on Climate Change. Available from: https://www.ipcc.ch/report/ar6/syr

Irfan, M., Razzaq, A., Sharif, A., Yang, X. (2022), Influence mechanism between green finance and green innovation: Exploring regional policy intervention effects in China. Technological Forecasting and Social Change, 182, 121882.

Jie, W., Khan, R. (2024), Breaking the CO_2 gridlock: Can renewables lead the way for the OECD? Energies, 17(17), 4511.

Kafeel, K., Ahmad, M., Rehman, F. (2023), Green innovation and environmental quality in OECD countries: The role of environmental taxes and renewable energy. Sustainability, 15(2), 10791906.

Lee, J., Yucel, A.G., Islam, T. (2023), Convergence of CO_2 emissions in

OECD countries. Sustainable Technology and Entrepreneurship, 2(1), 100029.

Liu, Y., Song, Y., Cai, M. (2020), How does environmental regulation affect green innovation? Evidence from Chinese manufacturing industries. Journal of Cleaner Production, 257, 120660.

Metcalf, G.E. (2019), On the economics of a carbon tax for the United States. Brookings Papers on Economic Activity, 2019(1), 405-484.

OECD. (2022), Effective Carbon Rates 2021: Pricing Carbon Emissions Through Taxes and Emissions Trading. Paris: OECD Publishing.

Oueslati, W., Sintek, C., Zipperer, V. (2021), Green taxation in OECD countries: Empirical insights and policy lessons. Environmental Economics and Policy Studies, 23(4), 777-801.

Pan, X., Teng, F., Wang, G. (2020), The heterogeneous impact of carbon taxes on CO_2 emissions in OECD countries: A panel quantile regression approach. Energy Economics, 88, 104765.

Pesaran, M.H. (2004), General Diagnostic Tests for Cross Section Dependence in Panels. CESifo Working Paper Series No. 1229.

Pesaran, M.H. (2007), A simple panel unit root test in the presence of cross-section dependence. Journal of Applied Econometrics, 22(2), 265-312.

Raza, M.M., Venkatesh K.P., Kvedar J.C. (2024), Generative AI and large language models in health care: Pathways to implementation. NPJ Digital Medicine, 7(1), 62.

Sadorsky, P. (2020), Wind energy for sustainable development: Driving factors and future outlook. Journal of Cleaner Production, 289, 125779.

Shabir, M., Pazienza, P., Lucia, C.D. (2023), Energy innovation and ecological footprint: Evidence from OECD countries during 1990-2018. Technological Forecasting and Social Change, 196, 122836.

Shahbaz, M., Balsalobre-Lorente, D., Raza, S.A. (2019), The role of globalization on the effectiveness of renewable energy for environmental sustainability. Environmental Impact Assessment Review, 77, 101670.

Su, X., Huang, Y., Mirza, F.M., Khan, M.A. (2025), From pollution to solution: How environmental protection tax shapes green technological innovation? Clean Technologies and Environmental Policy, 27, 7339-7371.

UNEP. (2022), Emissions Gap Report 2022. United Nations Environment Program. Available from: https://www.unep.org/resources/emissions-gap-report-2022

Wang, Q., Jiang, R., Dong, X. (2022), Does renewable energy reduce carbon emissions? Evidence from a threshold model. Energy Policy, 162, 112776.

World Bank. (2024), State and Trends of Carbon Pricing 2024. Available from: https://www.worldbank.org/en/news/press/release/2024/05/21/global/carbon/pricing/revenues-top-a-record-100-billion

World Bank. (2023), State and Trends of Carbon Pricing 2023. Available from: https://www.worldbank.org/en/topic/climatechange/publication/state/and/trends/of/carbon-pricing-2023

Zafar, M.W., Shahbaz, M., Sinha, A., Sengupta, T., Qin, Q. (2020), How renewable energy consumption contribute to environmental quality? The role of education in OECD countries. Journal of Cleaner Production, 268, 122149.

Zhao, J., Wang, S., Ma, L. (2020), Environmental regulation and carbon emissions reduction: Empirical evidence from China. Science of the Total Environment, 741, 140326.

Zhou, X., Tang, X., Zhang, R. (2019), Do environmental taxes and regulation reduce emissions? Evidence from panel threshold regression. Environmental Science and Pollution Research, 26(32), 32738-32750.

Zhu, H., Duan, L., Guo, Y., Yu, K. (2018), Impact of carbon tax on CO_2 emissions: A meta-analysis. Journal of Cleaner Production, 203, 1158-1169.