TAXPEDIA
Journal of Tax Policy, Economic, and Accounting

Volume 03 Number 2 November 2025
e-ISSN 2987-5366

MUC TAX RESEARCH INSTITUTE
www.muctaxpedia.com

CARBON TAX AND CARBON EMISSIONS IN ASEAN: EXPLORING THE MODERATING ROLE OF RENEWABLE ENERGY PENETRATION

[1)] Fajriyatul Abadiyah [2)] Irna Bontor Febyola

[1)]Economics Study Program University of Bangka Belitung, fajriyatul-abadiyah@ubb.ac.id

[2)]Accounting Study Program, University of Bangka Belitung, irna-bontor@ubb.ac.id

Abstract

This study examines the impact of carbon tax implementation on per capita carbon emissions in ASEAN countries, highlighting the moderating role of renewable energy within the national energy mix. Motivated by the urgent need to balance economic growth with emission reduction in developing regions, the research applies a quantitative approach using Dynamic Panel Generalized Method of Moments (GMM) with secondary data from the World Bank, OECD, IMF, and IEA covering 2010–2023. The findings reveal that adopting a carbon tax significantly reduces carbon emissions, confirming its effectiveness as a fiscal environmental policy instrument. Moreover, the share of renewable energy not only directly reduces emissions but also enhances the effectiveness of the carbon tax, indicating a strong synergistic effect when both policies are implemented simultaneously. The interaction between carbon tax and renewable energy proves to be significantly negative, suggesting that countries with higher renewable energy penetration benefit more from carbon tax policies. Among control variables, economic growth and urbanization are associated with higher emissions, while trade openness shows no significant effect. These results provide critical implications for ASEAN policymakers to integrate carbon taxation with renewable energy expansion strategies and reinvest tax revenues in green technology development. The study contributes novel evidence to environmental economics by validating Pigouvian Tax theory and policy mix frameworks in the context of Southeast Asian economies.

***Keywords: carbon tax, carbon emissions, renewable energy,* ASEAN**

Abstrak

Penelitian ini menganalisis pengaruh penerapan pajak karbon terhadap emisi karbon per kapita di negara-negara ASEAN, dengan mempertimbangkan peran moderasi energi terbarukan dalam bauran energi nasional. Latar belakang penelitian didasari oleh meningkatnya tekanan global terhadap negara-negara berkembang, termasuk ASEAN, untuk menekan emisi karbon tanpa mengorbankan pertumbuhan ekonomi. Dengan menggunakan pendekatan kuantitatif melalui metode Dynamic Panel Generalized Method of Moments (GMM), penelitian ini mengolah data sekunder dari World Bank, OECD, IMF, dan IEA selama periode 2010–2023. Hasil penelitian menunjukkan bahwa penerapan pajak karbon berpengaruh negatif signifikan terhadap emisi karbon, yang berarti bahwa kebijakan ini efektif menurunkan tingkat pencemaran lingkungan. Selain itu, pangsa energi terbarukan terbukti tidak hanya berpengaruh langsung dalam mengurangi emisi, tetapi juga memperkuat efektivitas pajak karbon. Interaksi antara pajak karbon dan energi terbarukan menghasilkan efek sinergis yang signifikan, terutama di negara-negara dengan penetrasi energi bersih lebih tinggi. Di sisi lain, variabel kontrol menunjukkan hasil beragam; pertumbuhan ekonomi dan urbanisasi meningkatkan emisi, sedangkan keterbukaan perdagangan tidak signifikan. Temuan ini memberikan implikasi kebijakan penting bagi negara ASEAN untuk mengintegrasikan pajak karbon dengan strategi percepatan energi terbarukan, sekaligus mengarahkan pendapatan pajak pada investasi teknologi ramah lingkungan. Penelitian ini juga menegaskan relevansi teori Pigouvian Tax dan *policy mix* dalam konteks negara berkembang.

Kata kunci: pajak karbon, emisi karbon, energi terbarukan, ASEAN

INTRODUCTION

The issue of climate change has occupied the center of attention of global policymakers and economists over the past two decades. Increasing carbon emissions caused by human activities, particularly the fossil fuel sector, have prompted countries to develop policies capable of reducing emissions without hindering economic growth. One instrument that has increasingly received widespread attention is the implementation of a carbon tax (Lolo et al., 2022). This tax is considered capable of internalizing the negative externalities of carbon emissions and encouraging the transition to clean energy (Rasiah & Vijayaraghavan, 2025). Empirical studies such as those conducted by Shaari et al. (2025) found that the implementation of a carbon tax in Singapore significantly reduced coal consumption and increased energy efficiency, making it a model policy for other ASEAN countries.

Based on the ASEAN State of Climate Change Report (ASCCR, 2025), it shows that greenhouse gas (GHG) emissions in the ASEAN region have increased significantly in line with industrialization and economic growth, where the projection of the ASEAN Center for Energy (ACE) estimates an increase in energy emissions of 34–147% in the period 2017–2040. The report also asserts that without strong policy interventions, the region could face an increase in global temperatures of 2.1–3.9°C by the end of the century. This condition is exacerbated by the low penetration of renewable energy in many ASEAN countries, which are below the regional target of reaching 23% of the primary energy mix by 2025. These numerical findings reinforce the urgency of examining the effectiveness of policy instruments such as the carbon tax in reducing emissions, especially given that Singapore is the only country that has fully implemented a carbon tax, while other countries are still in the preparation phase or limited implementation.

In Southeast Asia, responses to the climate crisis vary widely. Countries like Indonesia and Malaysia remain reliant on fossil fuels, while the Philippines and Vietnam are beginning to increase their renewable energy capacity (Shidiq et al., 2024). Several countries have implemented carbon pricing schemes, including carbon taxes and emissions trading schemes (ETS), but their effectiveness remains debated. Previous research by Anbumozhi et al. (2025) showed that the effectiveness of carbon pricing is highly dependent on interactions with domestic energy policies, institutional capacity, and technological readiness. This suggests the need for an approach that considers moderating variables, such as renewable energy adoption, in evaluating the impact of carbon taxes on emissions.

Several cross-country studies have underscored the importance of integrating fiscal policy and energy transition to achieve more significant results in emissions mitigation (Shaikh et al., 2024). A study by Shaari et al. (2025) also highlights that the effects of environmental policies such as carbon taxes are often moderated by structural factors, including national energy composition and the effectiveness of public policies. However, there is a gap in the literature that specifically examines the relationship between carbon taxes and carbon emissions, empirically considering the moderating role of renewable energy, particularly in the ASEAN region. Most previous studies have focused on OECD countries or the European region, leaving a gap in the context of the economically dynamic Southeast Asian region with its high dependence on fossil fuels.

Based on this, this study aims to evaluate the impact of carbon tax implementation on carbon emissions in ASEAN countries, considering the moderating role of renewable energy in total energy production. In terms of novelty, this study adopts a quantitative approach using the Generalized

Method of Moments (GMM) dynamic panel that can handle the potential endogeneity and heterogeneity in data across countries and time. By focusing on ASEAN countries that are included in the region that has been relatively less exposed in carbon tax studies due to the still low penetration of renewable energy, this study is expected to provide a strong empirical contribution in supporting the formulation of effective and evidence-based environmental policies in the Southeast Asian region. The combination of models, the context of developing regions, and rarely used moderation variables makes this study different from previous studies that generally focused on OECD countries or only analyzed the partial relationship between variables.

LITERATURE REVIEW

Carbon Tax and Carbon Emissions

A carbon tax is an environmental policy instrument aimed at internalizing the negative externalities of greenhouse gas emissions into the price of fossil fuels. Theoretically, this approach aligns with the Pigouvian tax, which requires economic actors to pay the social costs of their polluting activities (Pigou, 1920). Pigouvian tax is a tax designed so that decision-makers take into account social costs arising from negative externalities reflected in market prices (Mankiw, 2015; Pratama et al., 2022). Thus, a carbon tax provides a price signal that encourages industry players and consumers to reduce fossil-based energy consumption and switch to clean energy sources. An empirical study by Metcalf & Stock, (2020) shows that the implementation of a carbon tax in OECD countries significantly reduced per capita CO_2 emissions without hindering long-term economic growth.

In the ASEAN context, the implementation of the carbon tax is still limited to several countries, such as Singapore that began implementing a carbon tax in 2019 and Indonesia that began to impose a carbon tax in the coal-based steam power plant (PLTU) sector in 2022. Shidiq et al. (2024) emphasize that the impact of this policy is greatly influenced by the design of tax rates, sector coverage, and integration with other energy policies. Therefore, other ASEAN countries such as Malaysia, Thailand, and the Philippines are still in the stage of policy consultation, tariff modeling, or the preparation of a carbon market framework. But ultimately, its effectiveness in the region is still highly dependent on fossil energy and requires comprehensive empirical testing.

Carbon Emission as an Environmental Performance Indicator

Carbon emissions are a widely used indicator to measure a country's pollution intensity. This indicator allows for cross-country comparisons, taking population size into account. According to World Bank data (2023), ASEAN countries have shown an increasing trend in per capita emissions since the 1990s, although the extent varies across countries. Vietnam and Indonesia have experienced rapid increases, while Singapore has remained relatively stable due to its transition to natural gas and energy efficiency policies (Shaari et al., 2025). Several relevant studies emphasize that reducing per capita emissions requires a combination of carbon pricing policies, environmental regulations, and green technology investments (Palupi et al., 2023; Yu et al., 2022), as well as foreign direct investment (Huang et al., 2022).

The Moderating Role of Renewable Energy Share

The share of renewable energy in the national energy mix is considered a key factor in the energy transition. Renewable energy (RE) includes energy sources such as solar, wind, hydro, biomass, and geothermal. Increasing the share of renewable energy is believed to strengthen the effect of carbon tax policies in reducing emissions. According to (Saddler et al., 2020), carbon taxes encourage the substitution of fossil fuels for renewable energy, so countries with a high share of renewable energy tend to experience greater emissions reductions.

Furthermore, in the context of moderation, a study by Shaikh et al. (2024) found that the relationship between environmental taxes and emission reductions was strengthened in countries with renewable energy penetration above 20% of total energy production. This aligns with the Porter Hypothesis, which states that stringent environmental policies can encourage technological innovation that improve energy efficiency (Ambec & Barla, 2002).

Macroeconomics as a Control

Control variables are used to isolate the effect of carbon tax and renewable energy on carbon emissions. GDP per capita describes the level of economic prosperity of a country. A study by Apergis & Payne (2010) shows a long-term relationship between economic growth and carbon emissions in developing countries, in accordance with the Environmental Kuznets Curve (EKC) hypothesis. Trade openness reflects the integration of a country's economy into the global market. Hossain (2012) found that international trade can worsen or reduce carbon emissions depending on the trade structure and the level of technology adopted. Urbanization represents the percentage of the urban population which also influences energy consumption and transportation patterns. According to Liddle (2014), urbanization that is not balanced with environmentally friendly transportation policies can increase carbon emissions.

Based on theory and empirical findings, the relationship between variables can be formulated as follows:

H1: The implementation of carbon tax has a significant negative effect on carbon emissions in ASEAN countries.

H2: Renewable energy share moderates the effect of carbon tax on carbon emissions, where the negative relationship becomes stronger in countries with a higher share of renewable energy.

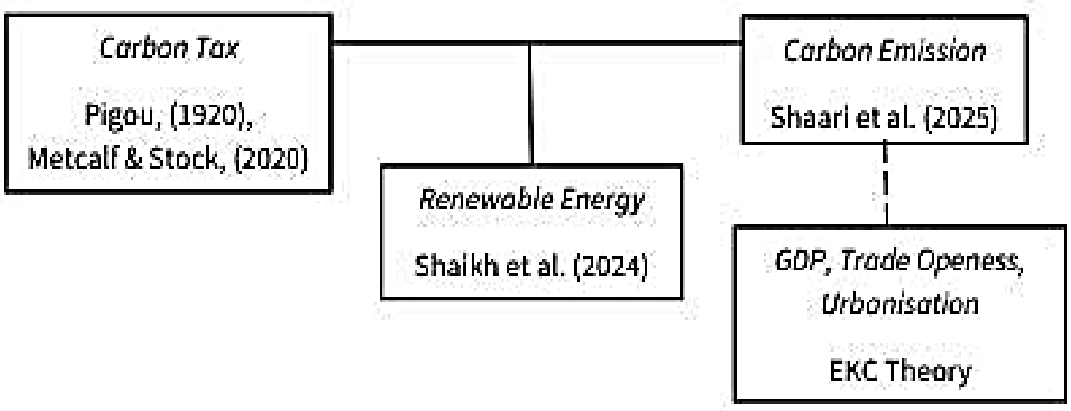

Figure 1 Conceptual Framework of the Research

Source: Data processed by researchers, 2025

RESEARCH METHODS

This study uses a quantitative approach with the Generalized Method of Moments (GMM) Panel Dynamic estimation model to analyze the effect of carbon tax implementation on carbon emissions per capita, with the share of renewable energy as a moderating variable, in ten ASEAN member countries during the period 2010–2023. The selection of the GMM method is based on the characteristics of dynamic panel data involving lagged dependent variables and potential endogeneity problems between variables (Arellano & Bond, 1991). This method is also relevant to address heterogeneity between countries and autocorrelation in cross-country time series data.

The object of this research is the relationship between policy carbon tax and renewable energy composition on carbon emission levels, while the research subjects are ASEAN member countries consisting of Brunei Darussalam, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Vietnam. The research data is secondary obtained from official international sources to maintain reliability. The dependent variable is carbon emission (CO_2 metric tons per person) taken from the World Development Indicators (WDI). The independent variable of carbon tax implementation is measured by a dummy variable (1 for countries and years that have implemented carbon tax, 0 for those that have not), sourced from the OECD Tax Database and the IMF Fiscal Monitor. The moderating variable of renewable energy share is measured from the percentage of renewable energy to total energy production, sourced from the International Energy Agency (IEA) and the World Bank. Furthermore, additional control variables include GDP per capita, trade openness (% GDP), and urbanization (% population), all obtained from WDI data.

The empirical model is estimated to use the System GMM (two-step) approach with lagged values of endogenous variables as instruments. Instrument validity is tested using the Hansen test, while autocorrelation is tested using the Arellano–Bond test for AR(1) and AR(2). Estimation is performed using Stata 17 software.

Empirical Model Specifications

This research model was designed to test the effect of carbon tax implementation on carbon emissions, with renewable energy as a moderating variable, and GDP per capita, trade openness, and urbanization as control variables. A dynamic model was used to account for the path dependency effect of carbon emissions in the previous period. The dynamic GMM model equation used in this study is as follows:

$$CO2pc_{it} = \alpha + \beta_1 CO2pc_{i,t-1} + \beta_2 CTax_{it} + \beta_3 RE_{it} + \beta_4 (CTax_{it} \times RE_{it}) + \beta_5 GDPpc_{it} + \beta_6 Trade_{it} + \beta_7 Urban_{it} + \mu_i + \epsilon_{it}$$

Where: $CO2pc_{it}$ = Carbon emission per capita in country i in year t, $CO2pc_{i,t-1}$ = Carbon emission per capita lagged one period , $CTax_{it}$ = Application of carbon tax (dummy), RE_{it} = Share of renewable energy, $CTax_{it} \times RE_{it}$ = Interaction to test the moderating effect, $GDPpc_{it}$ = GDP per capita (constant USD), $Trade_{it}$ = Trade openness (% GDP), $Urban_{it}$ = Urbanization (% population).

Table 1 Operational Definition of Variables

Variables	Code	Definition	Indicator	Data source
Carbon emissions per capita	CO2pc	Total CO_2 emissions divided by population	Metric tons per person	World Bank – WDI
Carbon tax	Ctax	Carbon tax policy	Dummy (1=apply, 0=no)	OECD Tax Database, IMF Fiscal Monitor
Renewable energy share	RE	Contribution of renewable energy to total energy production	% of total energy	IEA, World Bank – WDI
GDP per capita	GDPpc	GDP value divided by population	USD constant 2015	World Bank – WDI
Trade openness	Trade	(Exports + Imports) / GDP	% GDP	World Bank – WDI
Urbanization	Urban	Percentage of population living in urban areas	% of population	World Bank – WDI

Source: Data processed by researchers, 2025

RESEARCH RESULT

The analysis was conducted using a two-step System GMM to estimate the relationship between carbon tax implementation, renewable energy, and carbon emissions in ASEAN countries during the period 2010–2023. Table 2 presents the results of the main coefficient estimation, including instrument validity and autocorrelation tests.

Table 2 System GMM Estimation Results (Two-step)

Variables	Coefficient	Std. Error	z-statistic	p-value
CO2pc (t-1)	0.642***	0.057	11.26	0.000
Carbon Tax Implementation (CTax)	-0.215**	0.095	-2.26	0.024
Renewable Energy Share (RE)	-0.034**	0.015	-2.27	0.023
CTax × RE	-0.006***	0.002	-3.00	0.003
GDP per capita (GDPpc)	0.00021***	0.00007	3.00	0.003
Trade Openness (Trade)	0.0012	0.0010	1.20	0.231
Urbanization	0.008*	0.004	2.00	0.046
Constant (C)	1,752***	0.436	4.02	0.000
Hansen Test (p-value)	0.321			
Arellano–Bond AR(1) p-value	0.012	first-order autocorrelation detected (reasonable)		
Arellano–Bond AR(2) p-value	0.284	no second-order autocorrelation		

Note: *** p<0.01, ** p<0.05, * p<0.1

The estimation results show that the dependent variable carbon emissions (CO2pc) have a significantly positive lag coefficient (0.642, p<0.01), indicating path dependency in carbon

emissions. This means that current emission levels are strongly influenced by emissions in previous periods, thus supporting the use of a dynamic model.

Furthermore, the implementation of a carbon tax (CTax) showed a significant negative effect on carbon emissions (-0.215, $p<0.05$). This finding indicates that ASEAN countries implementing a carbon tax tend to have lower carbon emissions per capita than countries that do not.

Meanwhile, the moderating variable renewable energy (RE) has a significant negative effect (-0.034, $p<0.05$), which means that an increase in the proportion of renewable energy in the national energy mix is correlated with a decrease in carbon emissions. Furthermore, the CTax × RE interaction has a significant negative coefficient (-0.006, $p<0.01$), which indicates that the emission reduction effect of carbon tax is stronger in countries with higher renewable energy.

Meanwhile, the three control variables showed varying results. Economic growth had a significant positive effect (0.00021, $p<0.01$), indicating that economic growth is associated with increased carbon emissions. Trade openness was insignificant ($p>0.1$), while urbanization had a significant positive effect at the 10% level ($p<0.1$).

Table 3 Average Research Variables in ASEAN (2010–2023)

Country	CO2pc (tons)	CTax (dummy)	RE (%)	GDPpc (USD)	Trade (% GDP)	Urban (%)
Brunei Darussalam	17.8	0	2.1	31,200	104	78
Indonesia	1.9	1	12.5	4,250	38	56
Malaysia	8.2	0	6.8	11,300	130	76
Singapore	7.5	1	3.4	65,000	320	100
Thailand	4.6	0	8.9	7,800	123	52
Vietnamese	2.3	0	10.2	3,800	190	38
Philippines	1.2	0	21.4	3,500	63	48
Laos	0.8	0	31.2	2,350	80	35
Myanmar	0.7	0	40.1	1,650	44	31
Cambodia	0.5	0	55.3	1,500	120	24

Source: Data processed by researchers, 2025

DISCUSSION

Impact of Carbon Tax on Carbon Emissions

The GMM estimation results show that the implementation of a carbon tax has a significant negative impact on carbon emissions per capita in ASEAN countries. A coefficient of -0.215 ($p<0.05$) confirms that countries implementing a carbon tax experience a decrease in emissions compared to countries that have not implemented it. This finding aligns with the theoretical framework of environmental economics, specifically Pigouvian Tax Theory, which states that environmental taxes can internalize the negative externalities of carbon emissions (Pigou, 1920). This is because the carbon tax works by increasing the cost of using fossil fuels, thereby encouraging a shift to cleaner and more efficient energy sources (Abadiyah, 2023).

Empirically, these results align with those of Metcalf & Stock, (2020), who analyzed carbon tax policies in 27 OECD countries and found significant emission reductions after tax implementation. Similar findings were also found in China, as reviewed by Chen & Lei, (2018). However, this study

differs in its focus on the ASEAN region, which has heterogeneous policies, development levels, and a more diverse energy mix. These differences in regional contexts indicate that despite the relatively low level of renewable energy infrastructure readiness in most ASEAN countries, the carbon tax remains an effective emission control mechanism.

This finding is also consistent with studies by Andersson (2019); and Barus & Wijaya (2022), which demonstrated the effectiveness of Sweden's carbon tax in reducing per capita emissions by 11% in a decade. However, effectiveness in ASEAN is likely influenced by compliance and tax rates, which in some countries are still below the IMF's recommendation of USD 75/ton CO_2 to achieve the Paris Agreement target (IMF, 2019). Therefore, carbon tax policies in this region require additional regulatory support such as Emission Trading Schemes (ETS) or clean energy subsidies to maximize their impact.

From the perspective of the Environmental Kuznets Curve (EKC) theory, the negative impact of carbon tax on emissions can be seen as evidence that fiscal intervention can accelerate the transition of developing countries to a phase of emissions reduction without having to wait for a certain level of income. This is relevant for ASEAN countries, most of whose members are still in the industrial catch-up phase.

In the ASEAN region, carbon tax implementation is still partial, with countries like Singapore implementing it in 2019 and Indonesia planning to implement it in 2022. This difference in implementation timing is reflected in the carbon tax dummy variable estimation results, which show a significant but modest effect. This result is consistent with studies in OECD countries, which found that the initial impact of a carbon tax is usually moderate, but increases over time as industry and consumer behavior adjust (Metcalf & Stock, 2020).

However, this is different from research in Europe that reported emission reductions of up to 10–15% in the first decade of carbon tax implementation. Andersson (2019); and Böhringer et al. (2017), estimates in ASEAN show a lower average reduction. This could be due to the high dependence on fossil fuels in some countries, weak policy enforcement mechanisms, and relatively low carbon tax rates. In other words, the findings in this study emphasize the urgency of implementing a carbon tax across ASEAN countries as part of a climate change mitigation strategy.

The Impact of Renewable Energy on Carbon Emissions

The estimation results show that renewable energy share has a significant negative effect (-0.034, $p<0.05$) on carbon emissions. This result means that every 1% increase in the share of renewable energy in total energy production is associated with a decrease in carbon emissions. This finding is in line with the Energy Transition Theory, which states that diversifying energy sources towards cleaner ones will reduce carbon intensity in the economy (Hasni et al., 2023).

This research aligns with the findings of Ibrahim et al. (2022), who found that increased renewable energy use in developing countries significantly reduced CO_2 emissions. However, these findings highlight that the negative impact occurred even though the contribution of renewable energy in ASEAN was still relatively small compared to Europe or North America. This suggests that despite the low initial contribution, emission reduction effects are already visible when policies and investments are directed towards increasing the share of renewable energy. One factor explaining this relationship is the substitution effect of coal-based power plants with solar, wind, or hydropower plants. In ASEAN, this trend is evident in Vietnam, with the massive expansion of solar

power since 2019, which has significantly reduced the carbon intensity of the electricity sector (IEA, 2023).

However, structural challenges exist, such as limited energy transmission infrastructure and intermittent supply from renewable energy sources. This means that the negative impact of renewable energy on emissions will be stronger if accompanied by the development of energy storage technology and a stable feed-in tariff policy. Therefore, these findings are valid and support the importance of energy transition as a pillar of climate policy in ASEAN.

The Moderating Role of Renewable Energy Share in the Relationship between Carbon Tax and Carbon Emissions

The interaction between carbon tax and renewable energy share (CTax × RE) shows a significant negative coefficient (-0.006, $p<0.01$). This value means that the implementation of carbon tax becomes more effective in reducing emissions when the share of renewable energy in a country is higher. This result supports the policy mix theory framework that emphasizes that the combination of fiscal policy (carbon tax) and energy policy (renewable energy share) produces a synergistic effect on emission reduction (Haites & Proost, 2018). This finding shows that the share of renewable energy has a significant negative effect on carbon emissions while strengthening the effect of carbon tax in reducing carbon emissions. This moderating effect indicates that the success of carbon tax in reducing emissions will be more optimal if accompanied by the availability and utilization of renewable energy sources.

These findings support the Porter Hypothesis, which states that strict environmental regulations, combined with technological innovation, can improve environmental performance and economic competitiveness (Ambec & Barla, 2002). In the ASEAN region, countries such as the Philippines and Laos, which have a high share of renewable energy (>30%) tend to show greater emission reductions even without a carbon tax. Conversely, countries such as Brunei Darussalam and Singapore, with a low share of renewable energy (<5%), show a limited effect of the carbon tax (IEA, 2019).

This finding is consistent with a study by Best et al. (2020), which analyzed 142 countries and found that the effectiveness of carbon taxes increased significantly in countries with a minimum renewable energy share of 20% in their energy mix. Meanwhile, in ASEAN, Singapore and Indonesia, which have begun increasing their solar and bioenergy capacity, showed a sharper decline in emissions after carbon tax implementation compared to countries with a low renewable energy share (IEA, 2019). Therefore, this study provides evidence that climate change mitigation strategies should be implemented with an integrated policy approach.

Economic and Demographic Factors in Carbon Emission Dynamics

The control variables in this study provide important insights into the determinants of carbon emissions. GDP per capita has a significant positive effect on carbon emissions (0.00021, $p<0.01$), supporting the Environmental Kuznets Curve (EKC) hypothesis in the early stages, where economic growth in developing countries tends to increase emissions due to intensive industrialization and urbanization (Grossman & Krueger, 1995). This phenomenon is seen in Malaysia and Thailand, which experienced rapid economic growth accompanied by increased emissions.

Urbanization also shows a significant positive effect at the 10% level on carbon emissions, indicating that urban population growth in the ASEAN region tends to increase demand for fossil-

based energy if not balanced with green infrastructure. In other words, urbanization that is not accompanied by low-carbon transportation policies and residential energy efficiency can increase fossil-based energy consumption (Khan et al., 2023). Meanwhile, trade openness has no significant effect ($p>0.1$), indicating that trade globalization in ASEAN does not directly affect per capita emissions, this could be due to mutually canceling effects: on the one hand, international trade can increase emissions through increased production, but on the other hand, it can facilitate the transfer of low-carbon technology (Bibi, 2022). For example, manufacturing-based exports in Vietnam versus service-based exports in Singapore.

Policy Implications

The results of this study provide several important policy implications. First, carbon taxes have proven effective in reducing carbon emissions, but their effectiveness depends heavily on adequate tariffs and broad policy coverage. This is because most ASEAN countries still set tariffs below the IMF recommendation (USD 75/ton CO2), requiring gradual increases to achieve the Paris Agreement target. Second, carbon taxes should be integrated with renewable energy development policies to create stronger synergies in reducing carbon emissions. The synergistic effect of both has been proven significant, allowing the allocation of carbon tax revenues to be directed towards subsidizing clean energy investments. Third, carbon emission reduction strategies in ASEAN need to consider economic and demographic factors, particularly GDP growth and urbanization, so that the resulting policies can reduce emissions without hindering development.

Table 4 Summary of Variable Effects on Carbon Emissions per Capita

Variables	Effect on Emissions	Significance	Information
Carbon tax	Negative	$p<0.05$	Effectively reduce emissions
Renewable energy	Negative	$p<0.05$	Reducing emissions directly
Carbon tax × Renewable Energy Interaction	Negative	$p<0.01$	Carbon tax effect is stronger in countries with a high share of renewable energy.
GDP per capita	Positive	$p<0.01$	Increasing emissions in the early stages of EKC
Urbanization	Positive	$p<0.1$	Increased consumption of fossil fuels in urban areas
Trade Openness	Not significant	$p>0.1$	Mutually canceling effects

Source: Author's processed results, 2025

In contrast to studies in OECD countries, this study shows that the carbon tax effect in ASEAN is relatively smaller, which can be explained by low tax rates, limited clean energy infrastructure, and incompletely integrated environmental policies. This difference suggests that carbon tax policies cannot be expected to work optimally without the support of clean energy technologies and a robust regulatory framework (World Bank, 2022).

Therefore, this finding provides a novel contribution by examining the moderating role of renewable energy share on the carbon tax effect in the ASEAN region, an area that has not been widely explored in previous literature. Furthermore, by using the dynamic GMM method, this study is able to control endogeneity and lag effects in panel data, providing more reliable estimates than common methods such as ordinary least squares or traditional fixed effects (Blundell & Bond, 1998).

CONCLUSION

Carbon tax implementation plays a significant role in reducing carbon emissions in the ASEAN region, although its effect is relatively smaller compared to findings in developed countries. This indicates that carbon tax remains effective as an emission control instrument in developing countries, but its effectiveness is highly dependent on several factors, including tariff size, compliance level, and supporting policies. The study's findings also confirm that renewable energy share acts as a moderating factor that strengthens the impact of carbon tax on emission reduction. The higher the contribution of renewable energy in the national energy mix, the greater the ability of carbon tax to encourage the transition to low-carbon energy. Therefore, environmental policy strategies in ASEAN should not only focus on implementing carbon tax separately but also integrate it with policies to accelerate the adoption of renewable energy.

The practical implication of these findings is the need for ASEAN governments to gradually increase carbon tax rates toward levels recommended by international institutions such as the IMF, while ensuring that carbon tax implementation is accompanied by investment policies for clean energy infrastructure. Therefore, carbon tax revenues should be allocated strategically, such as to fund research, development, and implementation of renewable energy technologies, and to improve energy efficiency in the industrial and transportation sectors. The moderation finding suggests that without support for the energy transition, the effects of the carbon tax may not be optimal in the long term.

Furthermore, the theoretical contribution of this research lies in strengthening the empirical evidence regarding the Pigovian Tax framework and policy mix theory in the context of developing countries, especially in the Southeast Asian region that has different economic, energy, and regulatory characteristics from developed countries. Through the Dynamic Panel GMM approach, this study provides more robust evidence regarding the causal relationship between carbon tax, renewable energy, and carbon emissions, while also addressing the potential endogeneity problem often encountered in environmental policy research.

However, this study is limited by using dummy variables to measure carbon tax, thus not capturing the variation in rates between countries. Furthermore, the limited study period of 2010–2023 is considered insufficient to capture the long-term impacts of carbon tax policies. Therefore, it is recommended that further research consider using nominal tax rate data, extending the observation period, and adding structural variables such as energy efficiency, fossil fuel intensity, and energy subsidy policies. By addressing these limitations, future studies are expected to provide a more comprehensive understanding of effective climate policy design for both the ASEAN region and the global region.

REFERENCES

Aditya Abadiyah, F. (2023). Peran Pajak Lingkungan, Pembangunan Keuangan, Dan Pertumbuhan Ekonomi Terhadap Lingkungan Berkelanjutan Di Negara D-8. *Taxpedia; Journal of Tax Policy, Economics, and Accounting*, *1*(2), 70–84. https://doi.org/10.61261/muctj.v1i2.38

Ambec, S., & Barla, P. (2002). A theoretical foundation of the Porter hypothesis. *Economics Letters*, *75*(3), 355–360. https://doi.org/10.1016/S0165-1765(02)00005-8

Anbumozhi, V., Kalirajan Emeritus Professor, K., & Pratiwi Muyasyaroh, A. (2025). Putting a Price on Carbon in ASEAN and East Asia: Are Consumers Willing to Pay? *ERIA Discussion Paper Series*, *549*. https://www.eria.org/uploads/Putting-a-Price-Carbon-ASEAN-Are-Consumers-Willing-to-Pay.pdf

Andersson, J. J. (2019). Carbon taxes and Co2 emissions: Sweden as a case study. *American Economic Journal: Economic Policy*, *11*(4), 1–30. https://doi.org/10.1257/pol.20170144

Apergis, N., & Payne, J. E. (2010). Renewable energy consumption and economic growth: Evidence from a panel of OECD countries. *Energy Policy*, *38*(1), 656–660. https://doi.org/10.1016/j.enpol.2009.09.002

Arellano, M., & Bond, S. (1991). Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations. *The Review of Economic Studies*, *58*(2), 277–297. https://doi.org/10.2307/2297968

Barus, E. B., & Wijaya, S. (2022). Penerapan Pajak Karbon Di Swedia Dan Finlandia Serta Perbandingannya Dengan Indonesia. *JURNAL PAJAK INDONESIA (Indonesian Tax Review)*, *5*(2), 256–279. https://doi.org/10.31092/jpi.v5i2.1653

Best, R., Burke, P. J., & Jotzo, F. (2020). Carbon Pricing Efficacy: Cross-Country Evidence. *Environ Resource Econ*, *77*, 69–94. https://doi.org/10.1007/s10640-020-00436-x

Bibi, R. (2022). The relationship between trade openness, financial development and economic growth: evidence from Generalized method of moments. *Journal of Environmental Science and Eco- Nomics*.

Blundell, R., & Bond, S. (1998). Initial conditions and moment restrictions in dynamic panel data models. *Journal of Econometrics*, *87*(1), 115–143. https://doi.org/10.1016/S0304-4076(98)00009-8

Böhringer, C., Landis, F., & Rutherford, T. F. (2017). Carbon tax alternatives for the European Union: A general equilibrium perspective. *Climate Policy*, *17*(S1), S1–S16. https://doi.org/10.1080/14693062.2016.1266546

Chen, W., & Lei, Y. (2018). The impacts of carbon tax on carbon emission reduction and economic development in China. *Energy Policy*, *119*, 515–523. https://doi.org/10.1016/j.enpol.2018.04.056

Grossman, G. M., & Krueger, A. B. (1995). Economic Growth and the Environment. *The Quarterly Journal of Economics*, *110*(2), 353–377. https://doi.org/10.2307/2118443

Haites, E., & Proost, S. (2018). Policy mixes for reducing greenhouse gas emissions. *Climate Policy*, *18*(8), 1025–1037. https://doi.org/10.1080/14693062.2018.1446987

Hasni, R., Dridi, D., & Ben Jebli, M. (2023). Do financial development, financial stability and renewable energy disturb carbon emissions? Evidence from asia–pacific economic cooperation economics. *Environmental Science and Pollution Research*, *30*(35), 83198–83213. https://doi.org/10.1007/s11356-023-28418-8

Hossain, M. S. (2012). An econometric analysis for CO_2 emissions, energy consumption, economic growth, foreign trade and urbanization of Japan. *Low Carbon Economy*, *3*(3), 92–105. https://doi.org/10.4236/lce.2012.33014

Huang, Y., Chen, F., Wei, H., Xiang, J., Xu, Z., & Akram, R. (2022). The Impacts of FDI Inflows on Carbon Emissions: Economic Development and Regulatory Quality as Moderators. *Frontiers in Energy Research*, *9*(January), 1–11. https://doi.org/10.3389/fenrg.2021.820596

Ibrahim, R. L., Al-mulali, U., Ozturk, I., Bello, A. K., & Raimi, L. (2022). On the criticality of renewable energy to sustainable development: do green financial development, technological innovation, and economic complexity matter for …. *Renewable Energy*. https://www.sciencedirect.com/science/article/pii/S0960148122012769

IEA. (2019). *ASEAN Renewable Energy Integration Analysis*. Iea.Org. https://www.iea.org/reports/asean-renewable-energy-integration-analysis

IEA. (2023). *ASEAN Renewables Investment: Opportunities and Challenges*. Iea.Org. https://www.iea.org/search?q=ASEAN

Khan, H., Chen, T., Bibi, R., & Khan, I. (2023). Dose institutional quality influences the relationship between urbanization and CO2 emissions? *PLoS ONE*, *18*(10), 1–25. https://doi.org/10.1371/journal.pone.0291930

Liddle, B. (2014). Urbanization and energy use in Asian developing countries: A panel cointegration analysis. *Asian Development Review*, *31*(1), 1–26. https://doi.org/10.1162/ADEV_a_00019

Lolo, L. D. F. A., Maulana, A. D., & Pasaribu, D. N. (2022). Transparansi Pajak Karbon: Digitalisasi Pajak Karbon Sebagai Katalisator Dalam Pembangunan Rendah Karbon di Indonesia. *Jurist-Diction*, *5*(1), 205. https://doi.org/10.20473/jd.v5i1.32981

Metcalf, G. E., & Stock, J. H. (2020). Measuring the macroeconomic impact of carbon taxes. *American Economic Review*, *110*(12), 3917–3954. https://doi.org/10.1257/aer.20190621

Palupi, P. G. S., Muchtar, M., & Sihombing, P. R. (2023). Pengaruh Pajak Karbon, Penggunaan Bahan Bakar Fosil, Dan Pertumbuhan PDB Terhadap Emisi Karbon. *Jurnalku*, *3*(2), 119–127. https://doi.org/10.54957/jurnalku.v3i2.385

Rasiah, R., & Vijayaraghavan, G. K. (2025). *Greening in Southeast Asia* (O. Academic (ed.); online edn). The Oxford Handbook on the Greening of Economic Development. https://doi.org/10.1093/oxfordhb/9780198883487.013.25

Saddler, H., Diesendorf, M., & Denniss, R. (2020). Greenhouse solutions with sustainable energy. *UNSW Press*. https://doi.org/10.4324/9780203044012

Shaari, M. S., Hussain, N. E., Rahim, R. A., Ridzuan, A. R., & Masnan, F. (2025). Coal consumption as a moderator in the link between industrial output and life expectancy in ASEAN nations. *Carbon Research*, *4*(1). https://doi.org/10.1007/s44246-025-00202-y

Shaikh, S. S., Amin, N., Shabbir, M. S., & Song, H. (2024). Going Green in ASEAN: Assessing the Role of Eco-Innovation, Green Energy, Industrialization, and Environmental Taxes in Achieving Carbon Neutrality. *Sustainability Development*. https://doi.org/10.1002/sd.3305

Shidiq, M., Htet, H., Rakhiemah, A. N., Abdullah, A., Pradnyaswari, I., & Suryadi, B. (2024). How effective is the carbon pricing implementation in ASEAN Member States to reduce regional emissions. *IOP Conference Series: Earth and Environmental Science*, *1395*(1). https://doi.org/10.1088/1755-1315/1395/1/012032

Yu, X., Xu, Y., Zhang, J., & Sun, Y. (2022). The Synergy Green Innovation Effect of Green Innovation Subsidies and Carbon Taxes. *Energy for the Future: Participatory and Multidisciplinary Approaches to Sustainable Post-Carbon Cities and Societies*, *14*(6), 3453. https://doi.org/10.3390/su14063453