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(2), 222-229.

Renewable Energy and Economic Growth: Investigating Their Effects on Carbon Emissions in ASEAN Countries

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Received: 01 July 2025 **Accepted:** 27 November 2025 **DOI:** https://doi.org/10.32479/ijeep.21026

ABSTRACT

This study investigates the relationship between renewable energy adoption, economic growth, and carbon emissions in ASEAN countries, focusing on the potential for sustainable development. ASEAN, comprising Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Vietnam, has seen significant economic growth, resulting in increased energy consumption and higher carbon emissions. The reliance on fossil fuels has raised concerns about environmental sustainability. This research employs a panel data analysis approach, by utilizing data from the period of 1990 to 2020 to explore the effects of renewable energy and economic growth on carbon emissions. The study uses a dynamic heterogeneous panel regression model (Panel ARDL) to capture the long-term and short-term dynamics between the variables. Findings reveal that renewable energy consumption has a positive but non-significant impact on carbon emissions in the long term, contradicting expectations that renewable energy reduces emissions. Economic growth similarly shows a positive but non-significant impact on carbon emissions in the long term. The study's results align with some previous research while challenging others, highlighting the complex and varied nature of these relationships. The research underscores the need for strategic policy interventions and coordinated efforts to balance economic development with environmental sustainability in the ASEAN region. Future research should focus on optimizing renewable energy policies and assessing the socio-economic benefits of transitioning to a low-carbon economy. The insights provided aim to inform policymakers and stakeholders on strategies for achieving sustainable development while fostering economic growth in one of the world's most dynamic regions.

Keywords: Renewable Energy, Carbon Emission, Economic Growth, ASEAN Region, ARDL
JEL Classifications: C23, 043, 044, Q53

1. INTRODUCTION

Globally, academic inquiry and policy dialogue have increasingly emphasized the interconnectedness of carbon emissions, economic development, and the utilization of renewable energy, especially within the framework of sustainable growth. The intensifying concern about climate change and its harmful environmental effects has accelerated the pursuit of energy alternatives that are both sustainable and economically feasible. Within this context, the ASEAN region emerges as a particularly significant case due to its distinctive economic momentum and environmental challenges. Comprising Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Vietnam, ASEAN member states have witnessed robust economic expansion in recent decades. This growth has led to escalating energy consumption and rising levels of carbon emissions. Economic activities spanning manufacturing, services, and agriculture have fueled energy demand, which remains predominantly satisfied by fossil fuels. However, the environmental cost of this energy reliance has raised critical concerns regarding the long-term viability of such development trajectories.

Figure 1 illustrates the co-evolution of carbon emissions and GDP across ASEAN from 1990 to 2020. It reveals a consistent increase in economic output throughout the period, accompanied by a surge in carbon emissions—from roughly 0.41 billion tonnes in 1990 to almost 1.9 billion tonnes in 2020. This parallel trend underscores the ongoing dependence on carbon-intensive energy sources, posing serious questions about the sustainability of the region's growth model. As ASEAN countries aim to align with broader sustainable development objectives, the need to decouple economic progress from emissions-intensive energy practices becomes more urgent.

A promising approach to address this issue lies in the adoption of renewable energy. Clean energy technologies such as solar, wind, hydro, and biomass offer pathways to reduce environmental harm while supporting economic advancement. These resources are abundantly available in several ASEAN countries and present opportunities to enhance innovation, increase employment, and bolster energy independence—thus offering both ecological and economic advantages.

As depicted in Figure 2, ASEAN countries vary considerably in their integration of renewable energy. Nations like Myanmar, Cambodia, and Laos derive more than half of their energy from renewable sources, largely due to traditional biomass use and hydropower, coupled with modest industrial energy needs. Conversely, more industrialized economies such as Singapore, Brunei, and Malaysia report minimal renewable energy uptake, with Singapore and Brunei sourcing <1% of their energy from renewables.

Figure 1: ASEAN carbon emission and GDP trajectory (1990-2020)

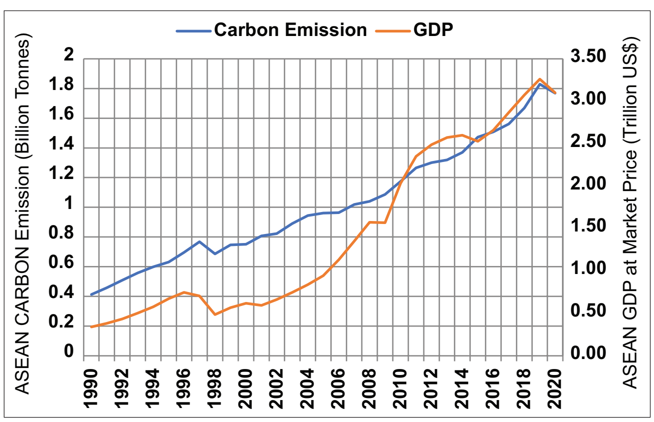
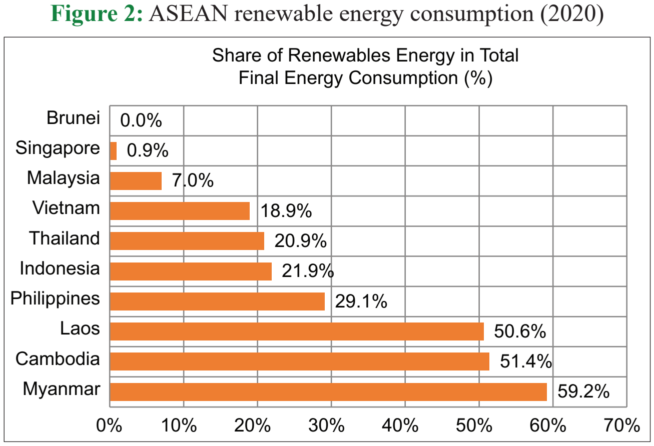


Figure 2: ASEAN renewable energy consumption (2020)



These differences point to disparities in resource availability, infrastructure readiness, and policy prioritization across the region. The figure highlights the urgency for inclusive and harmonized policy strategies to increase renewable energy deployment, particularly in member states with low current adoption, if ASEAN is to collectively progress toward a low-emission, sustainable future. The primary aim of this study is to assess how renewable energy usage and economic growth influence carbon emissions in ASEAN countries. Through a panel data methodology, this research seeks to analyze these dynamics over time, accounting for factors such as national energy strategies, technological progress, and regional partnerships.

Understanding the intricate linkages among economic growth, renewable energy deployment, and emissions reduction is essential for crafting effective policies to support sustainable development. This study aspires to enrich the existing literature with empirical findings specific to the ASEAN context, shedding light on both the opportunities and challenges tied to transitioning toward greener energy systems. Ultimately, the research is expected to inform policymakers, researchers, and practitioners about actionable pathways toward building a resilient and low-carbon ASEAN economy.

In conclusion, this study endeavors to explore how ASEAN nations can simultaneously pursue economic development and environmental preservation. By focusing on the contribution of renewable energy to reducing carbon emissions, the research aims to deliver strategic insights into achieving sustainability in one of the world's fastest-growing and most diverse regions.

2. LITERATURE REVIEW

Over the past 20 years, a considerable body of research has explored the interconnections between economic growth, energy consumption, and carbon dioxide (CO_2) emissions (Alper and Onur, 2016). Many of these studies have evolved incrementally, often lacking comprehensive integration (Dogan and Seker, 2016). When categorized by country contexts, most of this literature targets developed, developing, or underdeveloped economies. This study, however, narrows its focus to six ASEAN nations, thus requiring a specific review of research conducted within that regional scope.

2.1. Renewable Energy Consumption and Carbon Emissions

The ASEAN region, consisting of countries in the midst of rapid industrial and economic development, has experienced increasing energy demands, historically met by fossil fuel consumption. This trend has contributed significantly to rising carbon emissions and, consequently, climate change concerns. In recent years, several ASEAN countries have shifted attention toward renewable energy as a means of reducing their carbon footprint. Renewable energy includes resources that replenish naturally, such as solar, wind, hydro, and biomass. The potential for these sources is notable across the region; for example, Indonesia has considerable capacity in hydro and biomass, while the Philippines ranks among the world's leading geothermal energy producers.

Empirical studies suggest that renewable energy—particularly biomass—may be effective in curbing CO_2 emissions in ASEAN countries (Amin et al., 2023). Sulaiman et al. (2023) observed that biomass energy usage has a modest negative effect on emissions, suggesting that expanding the use and efficiency of clean biomass can further mitigate CO_2 output. Additionally, Tran et al. (2024) found both immediate and long-term environmental benefits associated with renewable energy adoption in ASEAN, reinforcing its role in emissions reduction. Wu et al. (2021) highlighted a bidirectional causal relationship between renewable energy use and carbon emissions, indicating a complex interplay between the two.

Despite this potential, ASEAN's journey toward carbon neutrality faces several challenges, including inconsistent energy policies and limited environmental awareness among the public. Yang and Li (2024) recommend addressing these obstacles through targeted investments in renewable infrastructure and technological innovations to enhance biomass energy use. Collectively, existing studies affirm that increasing renewable energy consumption can lead to emissions reductions, but meaningful progress also requires consistent policy direction and public engagement.

2.2. Economic Growth and Carbon Emissions

Economic advancement across ASEAN countries has improved living standards and infrastructure, but it also brings increased energy consumption, primarily from fossil fuels. This rise in energy use, in turn, contributes to greater carbon emissions. The link between economic development and emissions is nuanced. In the early stages of growth, CO_2 emissions tend to rise due to industrialization and higher energy needs. However, at more advanced economic stages, countries often begin to implement cleaner technologies and environmental regulations, which can help decouple growth from emissions.

Al-Mulali et al. (2015) found that in Vietnam, economic expansion has a significant positive impact on carbon emissions, whereas renewable energy use does not have a statistically significant mitigating effect. This suggests that the Environmental Kuznets Curve (EKC) hypothesis—which posits an inverted U-shaped relationship between income and environmental degradation—may not hold in this context, as emissions continue to rise with growth.

Several studies, including those by Heidari et al. (2015), Nuryartono and Rifai (2017), and Saboori and Sulaiman (2013), support the notion that economic growth is positively linked to energy use and emissions within ASEAN. The intensive use of energy to fuel expanding economies directly results in increased CO_2 output, pointing to a strong association between GDP growth and environmental stress. While Heidari et al. (2015) studies in ASEAN report a non-linear income–emissions relationship consistent with the Environmental Kuznets Curve (EKC), indicating that environmental degradation may rise in early development stages but decline after a threshold income level is reached. Furthermore, sectors such as electricity generation and heat production remain the leading contributors to greenhouse gas emissions, thereby exacerbating global warming trends (Jermsittiparsert, 2021).

3. DATA AND METHODS

3.1. Data

The analysis in this study is based on three key variables: economic growth, renewable energy utilization, and carbon dioxide (CO_2) emissions. CO_2 emissions refer to those resulting from the combustion of fossil fuels and cement manufacturing processes. This includes emissions from gas flaring as well as the burning of solid, liquid, and gaseous fuels. Renewable energy consumption is measured as the proportion of total final energy consumption derived from renewable sources. Economic growth is represented by the annual percentage change in Gross Domestic Product (GDP) at market prices, calculated using constant local currency. For consistency, the aggregates are standardized in constant 2015 US dollars. GDP is defined as the sum of value added by all resident producers in the economy, adjusted for product taxes and excluding subsidies not directly tied to production. It is measured without factoring in the depreciation of physical capital or the depletion of natural assets.

The dataset encompasses the years 1990-2020 and includes six ASEAN member states: Malaysia, Singapore, Thailand, the Philippines, Indonesia, and Vietnam. This 30-year period yields a balanced panel comprising 186 observations per country, covering critical economic events such as the 1998 Asian financial crisis and the 2020 COVID-19 pandemic. To reduce the influence of potential trends or seasonal effects, carbon emissions data have been logarithmically transformed in line with Koopman and Lee (2009).

3.2. Econometric Model

The study adopts a dynamic heterogeneous panel regression model, specifically the Panel Autoregressive Distributed Lag (ARDL) approach, as introduced by Pesaran et al. (1999). This methodology allows for an in-depth evaluation of both short-run and long-run effects of renewable energy consumption and economic expansion on carbon emissions across the selected ASEAN nations. One of the key advantages of the Panel ARDL framework lies in its ability to accommodate heterogeneity among countries and to reflect the temporal dynamics between variables more effectively than traditional static panel models (Eregha and Mesagan, 2020). The general functional representation of the empirical model used in this study is outlined below:

$$Emisi = f\,(REC,\, Growth) \quad (1)$$

$$lnEmisi_{i,t} = \alpha + \beta_1\, REC_{i,t} + \beta_2\, Growth_{i,t} + \varepsilon_{i,t} \quad (2)$$

According to Baltagi et al. (2005), panel modeling requires combining time series and cross-sectional dimensions to provide deeper insights into data sets. The methodology of Pesaran et al. (1999) is used in this study to estimate both short-run and long-run regressions. The following carbon emissions growth model, which incorporates lags of both dependent and independent variables and is written as follows, is used in the study inside the Autoregressive Distributed Lag (ARDL: p,q) framework, expressed as:

$$lnEmisi_{i,t} = \sum_{j=1}^{p} \omega_{ij} lnEmisi_{i,t-j} + \sum_{j=0}^{q} \beta_{ij} Z_{i,t-j} + \rho_i + \varepsilon_{i,t} \quad (3)$$

Here,

$$Z_{i,t} = (REC, Growth)$$

Where i = 1, 2,…, N indicates the number of countries, t = 1, 2,…, T indicates the period of years, $lnEmisi_{it}$ is the variable *Carbon Dioxide Emissions*, Zit is the k × i vector of explanatory variables for country -i, βij signifies the k × i coefficient vector, ρ_i is the unit of fixed effect, p and q are the order of lags. The lag length in this study is based on the literature, and each variable is given a single lag, which we term Panel ARDL (1, 1, 1).

Due to its distinct econometric benefits over conventional panel estimators, the ARDL cointegration methodology has been extensively employed by scholars in empirical literature. The capacity to handle endogeneity problems in econometric modeling and the ability to estimate both short-term and long-term parameter estimates in the same model are two of this methodology's distinctive qualities. Dickey and Fuller (1979) formally show that ordinary asymptotic inference is flawed and that differencing is necessary to restore stationarity when the autoregressive parameter equals unity. This encourages the use of unit root tests to ascertain the variables' order of integration. However, the ARDL cointegration test is recognized for its adaptability to scenarios with mixed integration orders among variables, whether I(0) or I(1) but not I(2). According to Pesaran et al. (1999), the Pooled Mean Group (PMG) estimator is more robust and trustworthy than other estimators when dealing with lag order and outliers. Equation (3) is estimated using the chosen PMG-ARDL model and an error correction form (ECM) as follows:

$$\Delta lnEmisi_{i,t} = \left(\theta_i lnEmisi_{i,t-1} + \lambda_i Z_{i,t-1}\right) + \sum_{j=1}^{p-1} \omega_{ij}^{*} \Delta lnEmisi_{i,t-j} + \sum_{j=0}^{q-1} \beta_{ij}^{*} Z_{i,t-j} + \rho_i + \varepsilon_{it}$$

Where $\theta_i\ lnEmisi_{i,t-1}$ in the ARDL model specification shows the convergence speed of carbon emissions when the explanatory variable experiences disequilibrium and $\lambda_i\ Z_{i,t-1}$ is the long-run coefficient of the explanatory variable. These two components are generated from the following calculations:

$$\theta_i = -\left(1 - \sum_{j=0}^{p} \omega_{ij}\right), \lambda_i = \sum_{j=0}^{q} \beta_{ij}^{*}, \Delta lnEmisi_{i,t} = lnEmisi_{it} - lnEmisi_{i,t-1}$$

In the two initial equations, $lnEmisi_{it}$ it is the dependent variable and shows carbon dioxide emissions, where Z_{ij} is a vector of explanatory variables, namely renewable energy consumption and economic growth.

In using the ARDL Panel, we use two estimators, namely Group Mean (Pesaran and Smith, 1995) and Panel Mean Group (Pesaran et al., 1999). This study uses both, Mean Group (MG) and Panel Mean Group (PMG) to estimate the research model. PMG is similar to MG, as both methods account for cross-sectional heterogeneity. However, the PMG method assumes long-run slope homogeneity and only allows short-run coefficients and error variances to vary across data groups, whereas the MG method allows all relevant coefficients, both long-run and short-run, to vary across data groups (Pesaran et al., 1999; Eregha and Mesagan, 2020). The MG and PMG models for the cointegration model approach assume the null hypothesis of no cointegration (H_0: $\theta_j = 0$). The alternative hypothesis for MG is H_1: $\theta_j < 0$, implying that at least one group is cointegrated. The alternative hypothesis for the PMG model is H_1: $\theta_j < 0$, indicating cointegration across all groups. In this work, the Hausman test, proposed by Pesaran et al. (1999), is used to select the best appropriate estimator, which is both the MG and PMG models. For the Hausman test the null hypothesis is that MG and PMG are consistent, but MG is inefficient against the alternative hypothesis while PMG is inconsistent against the alternative hypothesis. If the P > 5%, the PMG model is used, whereas if the P < 5%, the MG model is recommended.

The empirical approach employed in this study is organized as follows: (i) We use unit root test proposed by Maddala and Wu (1999), and Im Pesaran Shin test (Im et al., 2003), to assess the stationarity features of interest rate variables; Im et al., 2003). (ii) We explore the equilibrium relationship between variables using the Pedroni cointegration test (Pedroni, 1999) and the Kao cointegration test for robustness. (iii) We use Pesaran et al.'s (1999) pooled mean group estimator to examine long- and short-term equilibrium relationships. (iv) We also investigate short-term equilibrium linkages in each country.

Prior to estimating the model, econometric procedures typically advise evaluating the stationarity features among variables. This is critical for avoiding variables integrated at order two, i.e., I(2), as well as false analysis that may influence policy development. Within this approach, this study conducts panel unit root tests for the countries listed below:

Unit root tests are conducted at two orders, level and first difference, for the Im Pesaran Shin, ADF-Fisher, and PP-Fisher tests as shown in Table 1. At the level unit root test, the carbon emission variable is not statistically significant at any significance level. The renewable energy consumption variable is insignificant only in the Im Pesaran Shin method. The economic growth variable is statistically significant at all significance levels for all unit root test methods. However, differences are observed following the first differentiation employed in the panel unit root tests at the 1% significance level for all variables examined. The results show that all variables are integrated in mixed orders, at both the level and the first difference. Thus, the PMG-ARDL strategy is the optimal estimation technique, which adequately supports the panel unit roots test results.

This study continues by investigating the long-term equilibrium relationship to ensure convergence among the examined variables. The Pedroni cointegration test developed by Pedroni (1999)

Table 1: Unit root test results

Variable	Im, Pesaran, Shin		ADF-Fisher		PP-Fisher	
	Level	1st difference	Level	1st difference	Level	1st difference
lnEmisi	−1.8711***	−5.7425***	9.5687***	57.9028***	9.9427***	100.486***
REC	−0.8670***	−5.4233***	27.0449***	53.3042***	18.9304***	101.739***
Growth	−3.5680***	−9.5225***	33.5324***	97.2952***	43.2886***	154.980***

***Represents 1% statistical rejection level, ***Represents 10% statistical rejection level

Table 2: Cointegration test results

Pedroni cointegration test				
Test Statistics	Weighted			
	Statistic	Prob.	Statistic	Prob.
Alternative hypothesis: common AR coefficients (within-dimension)				
Panel v-Statistic	−1.455917	0.9273	−1.399629	0.9192
Panel rho-Statistic	1.811276	0.9650	1.759624	0.9608
Panel PP-Statistic	1.954746	0.9747	1.748874	0.9598
Panel ADF-Statistic	2.560431	0.9948	2.202827	0.9862
Alternative hypothesis: individual AR coefficients (between-dimension)				
Group rho-Statistic	2.512319	0.9940		
Group PP-Statistic	1.665729	0.9521		
Group ADF-Statistic	1.783546	0.9628		
Kao cointegration test				
ADF	−1.480890	0.0693*		
Residual variance	0.002784			
HAC variance	0.004730			

*Represents 10% statistical rejection level

Table 3: PMG-ARDL results

Model: lnEmisi=*f* (REC, Growth)				
Variable	Coefficient	Standard Error	t-stat	Prob.
Long run				
REC	0.0909***	0.1396	0.6503	0.5164
Growth	0.7052***	0.6934	1.0170	0.3107
Short run				
ECT(−1)	−0.0100***	0.0027	−3.6997	0.0003
ΔREC	−0.0085***	0.0112	−0.7559	0.4508
ΔGrowth	−0.0018***	0.0016	−1.1429	0.2548
Constant	0.0955***	0.0156	6.1323	0.0000

***Represents 1% statistical rejection level

combined with the Kao cointegration test (1999) is used to investigate the equilibrium relationship in this study, presented as follows:

The Pedroni cointegration test shown in Table 2 indicates no cointegration relationship between carbon emissions, renewable energy consumption, and economic growth. However, the Kao cointegration test reveals a cointegration relationship between the research variables in six ASEAN nations from 1990 to 2020, refuting the null hypothesis of no cointegration at the 10% statistical significance level. After meeting the cointegration test's preconditions (equilibrium relationship among variables), this study looks at the magnitude of the relationship in terms of coefficients. The Panel PMG ARDL is used to investigate the short-term and long-term dynamics of the dependent variable and its explanatory variables, which are provided as follows:

The fitted model is based on maximum lag 1 as suggested by Akaike Information Criterion with 180 observation (Appendix 1).

Table 4: Cross section short run coefficient results

Variable	Coefficient	Standard error	t-Statistic	Prob. *
Indonesia				
ECT(−1)	−0.0053	3.32E-05	−159.5251	0.0000
ΔREC	−0.0242	1.66E-05	−1453.530	0.0000
ΔGrowth	−0.0032	2.41E-06	−1326.899	0.0000
Constant	0.0444	0.0062	7.1470	0.0056
Malaysia				
ECT(−1)	−0.0096	8.76E-05	−109.7109	0.0000
ΔREC	−0.0192	0.000265	−72.5914	0.0000
ΔGrowth	0.0005	3.94E-06	135.2281	0.0000
Constant	0.1230	0.012575	9.7824	0.0023
Philipina				
ECT(−1)	−0.0198	0.000397	−49.8317	0.0000
ΔREC	−0.0256	8.85E-06	−2895.229	0.0000
ΔGrowth	−0.0091	7.65E-06	−1189.417	0.0000
Constant	0.1215	0.062940	1.9298	0.1492
Singapura				
ECT(−1)	−0.0089	8.16E-05	−108.5776	0.0000
ΔREC	0.0468	0.008626	5.4281	0.0123
ΔGrowth	0.0006	3.71E-06	172.8350	0.0000
Constant	0.0724	0.008712	8.3140	0.0036
Thailand				
ECT(−1)	−0.0149	0.000201	−73.9850	0.0000
ΔREC	−0.0130	1.17E-05	−1116.813	0.0000
ΔGrowth	−0.0012	1.65E-06	−726.8420	0.0000
Constant	0.1410	0.036451	3.8677	0.0306
Vietnam				
ECT(−1)	−0.0014	9.74E-06	−138.7193	0.0000
ΔREC	−0.0157	1.05E-05	−1491.655	0.0000
ΔGrowth	0.0014	4.12E-05	32.65032	0.0001
Constant	0.0705	0.000458	153.8867	0.0000

***Represents 1% statistical rejection level. **Represents 5% statistical rejection level. *Represents 10% statistical rejection level.

In the PMG ARDL results shown in Table 3, the independent variables converge in the long term with a value of −0.0100, which is statistically significant at the 1% level, with contributions from the explanatory variables (renewable energy consumption and economic growth). The statistically significant error correction term (ECT) affirms the equilibrium relationship between these variables, indicating that deviations from equilibrium are corrected by about 1% annually by the explanatory variables' contributions. The long-term panel model shows that renewable energy consumption and economic growth positively impact carbon emissions in the long term, while in the short term, the explanatory variables have a negative impact.

As shown in Table 4, in the short term the explanatory variables (renewable energy consumption and economic growth) have varying significant impacts on each country. Renewable energy consumption negatively impacts carbon emissions except in Singapore. Economic growth negatively impacts carbon emissions in Indonesia, Thailand, and the Philippines, while it has a positive impact in Malaysia, Singapore, and Vietnam. The explanatory variables for all observed countries show long-term convergence with a negative and significant ECT(−1) value.

4. RESULTS AND DISCUSSION

This analysis evaluates the long-term effects of renewable energy consumption and economic development on carbon emissions within six ASEAN countries. The results reveal a multifaceted and diverse relationship among the variables examined.

4.1. Renewable Energy and Carbon Emissions

The study identifies a positive but statistically insignificant relationship between renewable energy use and carbon dioxide emissions in the long run across the ASEAN countries analyzed. This outcome aligns with certain earlier studies that also observed a similar unexpected positive association between renewable energy deployment and emissions levels. For example, Altin (2024) documented such a trend in G7 nations, which contradicts the widely accepted belief that renewables contribute directly to emission reduction.

Contrastingly, several studies provide differing conclusions. Research by Güney and Üstündağ (2022) covering 37 countries from 2000 to 2019 found that renewable energy usage significantly decreased carbon emissions over time. Similarly, empirical findings from Sirbu and Albulescu (2020), based on 44 countries, suggest ambiguity in the impact of renewables, possibly due to insufficient renewable energy integration to drive global CO_2 reductions. Moreover, Khan et al. (2023), Boubaker and Omri (2022), Ito (2016), and Xue et al. (2024) reported strong negative effects of renewable energy consumption on emissions.

These varied findings imply that while some evidence supports a positive or neutral relationship, other results confirm the effectiveness of renewable energy in emission mitigation. Therefore, the connection between renewable energy use and carbon output in the long term is context-dependent and not universally significant.

4.2. Economic Growth and Carbon Emissions

The long-run influence of economic growth on carbon emissions in ASEAN was also found to be positive yet statistically insignificant. This suggests that while GDP growth is associated with increased emissions, the effect is not robust across all countries or periods studied. The impact of economic growth on emissions appears to vary based on national circumstances and stages of economic maturity. For instance, Zhang et al. (2023), Aye and Edoja (2017), and Kais and Sami (2016) found strong positive relationships between economic expansion and emissions, although Zhang et al. noted regional differences within China—emissions were more influenced by growth in western regions compared to the east.

Some researchers propose that this relationship is not linear, but rather follows an Environmental Kuznets Curve (EKC) pattern, where environmental degradation increases during early development stages but declines once income reaches a certain level. Therefore, while economic growth can initially drive pollution, green technologies and policies may later mitigate its environmental impacts.

In sum, while several studies suggest economic growth is a significant contributor to emissions, others point to a more complex or regionally specific dynamic. As such, ASEAN countries must carefully manage the balance between continued economic development and long-term environmental stewardship. Further investigations should examine the institutional and technological mechanisms that can help harmonize both objectives.

5. CONCLUSION

This research explored the influence of renewable energy consumption and economic development on carbon dioxide emissions in six ASEAN nations—Indonesia, Malaysia, Singapore, Thailand, the Philippines, and Vietnam—spanning the period from 1990 to 2020. The analysis uncovered the intricate and often inconsistent nature of these relationships.

It was found that renewable energy use exerts a long-term positive but statistically insignificant impact on CO^2 emissions in the countries studied. This outcome echoes findings from other scholars such as Yu-Ke et al. (2022) and Altin (2024), who also documented similar results in developed economies. These insights challenge the common presumption that an increase in renewable energy consumption automatically leads to emission reductions.

However, opposing viewpoints exist in the literature. For example, research by Güney and Üstündağ (2022) demonstrated that renewable energy significantly reduces emissions when applied at scale. Similarly, Sirbu and Albulescu (2020) acknowledged that the limited share of renewables in energy portfolios might explain the lack of a global decline in CO_2. Additional support for a negative association between renewables and emissions comes from Khan et al. (2023), Boubaker and Omri (2022), Ito (2016), and Xue et al. (2024).

Given the contrasting findings, one may conclude that the impact of renewable energy on emissions varies by region, technology type, and implementation scale. Thus, there is no definitive long-term trend that applies uniformly across all contexts.

Economic growth, likewise, was found to have a long-run positive but insignificant effect on emissions. Prior studies—such as those by Zhang et al. (2023), Aye and Edoja (2017), and Kais and Sami (2016)—reinforce the idea that economic growth can intensify carbon emissions, particularly in the absence of green innovation. Notably, Zhang et al. (2023) highlighted that this effect varies regionally within China, suggesting that local context matters greatly.

While some analyses uphold the notion that rising GDP contributes to greater emissions, others indicate a more nuanced or inverted

U-shaped pattern. These patterns underscore the importance of technological advancement and policy integration in reducing the environmental consequences of economic growth.

In conclusion, ASEAN countries must coordinate efforts and design informed policies to reconcile economic ambition with ecological responsibility. Moving forward, future studies should explore the specific drivers and policy tools that can enhance the efficiency of renewable energy programs and quantify the broader socioeconomic benefits of a sustainable, low-carbon development model.

REFERENCES

Alper, A., Onur, G. (2016), Environmental Kuznets curve hypothesis for sub-elements of the carbon emissions in China. Nat Hazards, 82, 1327-1340.

Altın, H. (2024), The impact of energy efficiency and renewable energy consumption on carbon emissions in G7 countries. International Journal of Sustainable Engineering, 17(1), 134-142.

Al-Mulali, U., Saboori, B., Ozturk, I. (2015), Investigating the environmental Kuznets curve hypothesis in Vietnam. Energy Policy, 76, 123-131.

Amin, N., Song, H., Ali, M. (2023), Role of information and communication technology, economic growth, financial development and renewable energy consumption towards the sustainable environment: Insights from ASEAN countries. Environmental Science and Pollution Research, 30(38), 89381-89394.

Aye, G.C., Edoja, P.E. (2017), Effect of economic growth on CO_2 emission in developing countries: Evidence from a dynamic panel threshold model. Cogent Economics and Finance, 5(1), 1379239.

Baltagi, B.H., Bratberg, E., Holmås, T.H. (2005), A panel data study of physicians' labor supply: The case of Norway. Health Economics, 14(10), 1035-1045.

Boubaker, S., Omri, A. (2022), How does renewable energy contribute to the growth versus environment debate? Resources Policy, 79, 103045.

Dickey, D.A., Fuller, W.A. (1979), Distribution of the estimators for autoregressive time series with a unit root. Journal of the American Statistical Association, 74(366a), 427-431.

Dogan, E., Seker, F. (2016a), Determinants of CO_2 emissions in the European Union: The role of renewable and non-renewable energy. Renew Energy, 94, 429-439.

Eregha, P.B., Mesagan, E.P. (2020), Oil resources, deficit financing and per capita GDP growth in selected oil-rich African nations: A dynamic heterogeneous panel approach. Resources Policy, 66, 101615.

Güney, T., Üstündağ, E. (2022), Wind energy and CO_2 emissions: AMG estimations for selected countries. Environmental Science and Pollution Research, 29, 21303-21313.

Heidari, H., Katircioğlu, S.T., Saeidpour, L. (2015), Economic growth, CO2 emissions, and energy consumption in the five ASEAN countries. International Journal of Electrical Power and Energy Systems, 64, 785-791.

Im, K.S., Pesaran, M.H., Shin, Y. (2003), Testing for unit roots in heterogeneous panels. Journal of Econometrics, 115(1), 53-74.

Ito, K. (2016), CO_2 emissions, renewable and non-renewable energy consumption, and economic growth: Evidence from panel data for developed countries. Economics Bulletin, 36(1), 553-559.

Jermsittiparsert, K. (2021), Examining the sustainable energy and carbon emission on the economy: Panel evidence from ASEAN. International Journal of Economics and Finance Studies, 13(1), 405-426.

Kais, S., Sami, H. (2016), An econometric study of the impact of economic growth and energy use on carbon emissions: Panel data evidence from fifty eight countries. Renewable and Sustainable Energy Reviews, 59, 1101-1110.

Kao, C. (1999), Spurious regression and residual-based tests for cointegration in panel data. Journal of Econometrics, 90(1), 1-44.

Khan, H., Weili, L., Khan, I., Zhang, J. (2023), The nexus between natural resources, renewable energy consumption, economic growth, and carbon dioxide emission in BRI countries. Environmental Science and Pollution Research, 30(13), 36692-36709.

Koopman, S.J., Lee, K.M. (2009), Seasonality with trend and cycle interactions in unobserved components models. Journal of the Royal Statistical Society Series C Applied Statistics, 58(4), 427-448.

Maddala, G.S., Wu, S. (1999), A comparative study of unit root tests with panel data and a new simple test. Oxford Bulletin of Economics and Statistics, 61, 631-652.

Nuryartono, N., Rifai, M.A. (2017), Analysis of causality between economic growth, energy consumption and carbon dioxide emissions in 4 ASEAN countries. International Journal of Energy Economics and Policy, 7(6), 141-152.

Pedroni, P. (1999), Critical values for cointegration tests in heterogeneous panels with multiple regressors. Oxford Bulletin of Economics and Statistics, 61(S1), 653-670.

Pesaran, M.H., Shin, Y., Smith, R.P. (1999), Pooled mean group estimation of dynamic heterogeneous panels. Journal of the American Statistical Association, 94(446), 621-634.

Pesaran, M.H., Smith, R. (1995), The role of theory in econometrics. Journal of Econometrics, 67(1), 61-79.

Saboori, B., Sulaiman, J. (2013), CO_2 emissions, energy consumption and economic growth in Association of Southeast Asian Nations (ASEAN) countries: A cointegration approach. Energy, 55, 813-822.

Sirbu, R.M., Albulescu, C.T. (2020), Carbon emissions, energy consumption, and managing investment in renewable energy. In: Innovation in Sustainable Management and Entrepreneurship: 2019 International Symposium in Management (SIM2019). Berlin: Springer International Publishing, p183-197.

Sulaiman, C., Abas, M.A., Hassin, N.H., Samad, N.S.A., Abdul-Rahim, A.S., Shaari, N.F. (2023), Effect of clean biomass energy use on carbon dioxide emissions in ASEAN Countries: An empirical investigation. BIO Web of Conferences, 73, 02009.

Tran, T., Bui, H., Vo, A.T., Vo, D.H. (2024), The role of renewable energy in the energy-growth-emission nexus in the ASEAN region. Energy Sustainability and Society, 14(1), 17.

Wu, S., Alharthi, M., Yin, W., Abbas, Q., Shah, A.N., Ur Rahman, S., Khan, J. (2021), The carbon-neutral energy consumption and emission volatility: The causality analysis of Asean region. Energies, 14(10), 2943.

Xue, M., Mihai, D., Brutu, M., Popescu, L., Sinisi, C.I., Bansal, A., Shabbir, M.S. (2024), Examining the impact of energy policies on CO2 emissions with information and communication technologies and renewable energy. Studies in Nonlinear Dynamics and Econometrics, 28, 1-8.

Yang, F., Li, C. (2024), The status quo, dilemma, and transformation path of the carbon neutrality-related policy of the ASEAN. Sustainability, 16(3), 1348.

Yu-Ke, C., Awan, R.U., Aziz, B., Ahmad, I., Waseem, S. (2022), The relationship between energy consumption, natural resources, and carbon dioxide emission volatility: Empirics from G-20 economies. Environmental Science and Pollution Research, 29, 25408-25416.

Zhang, Y., Xu, S., Zhang, J. (2023), How economic growth pressure impact carbon emissions: Evidence for China. Economic Research Ekonomska Istraživanja, 36(3), 2159473.

APPENDIX 1

Appendix 1: Akaike information criteria