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# How does Green Finance affect the environment in the ASEAN emerging countries?

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**Abstract**

**Purpose —** This study examines how economic growth, green finance, and renewable energy affect environmental quality (CO2 emissions) under the Environment Kuznets Curve (EKC) hypothesis framework.

**Methods** — This study uses data from ASEAN-6 developing countries, including Indonesia, Malaysia, Thailand, Vietnam, the Philippines, and Cambodia, from 2000 to 2020. It employs Panel Autoregressive Distributed Lag (ARDL), which is widely used for time series analysis since it can capture the short-run and long-run effects among variables.

**Findings —** The result shows the presence of the EKC Hypothesis in ASEAN developing countries. Green Finance and Renewable Energy reduce CO2 emissions only in the long run. In contrast, in the short run, Green Finance shows no effect in lowering CO2 Emissions due to initial costs, infrastructure challenges, market dynamics, and delayed policy implementation; the effect seems to increase in the long run as economies evolve, technologies mature, and awareness of environmental issues rises within emerging economies.

**Implication** — This study suggests that ASEAN developing countries should enhance their green finance efforts and expedite the transition to renewable energy by attracting additional investments in green finance and renewable energy transition. Governments in the Southeast Asian region must improve their policies and laws.

**Originality —** Revisiting the EKC hypothesis by including Green Finance within the ASEAN-6 emerging countries, which has been scarcely conducted in recent literature, this study contributes to the region's policymakers regarding green finance allocation and its relationship to environmental quality.

**Keywords —** EKC Hypothesis, environment quality, $CO_2$ emissions, green finance, renewable energy

## Background

During the last decade, Economic growth in the Southeast Asia (ASEAN) region has shown a remarkable average growth rate of 4% to 5%. Strengthened by the economic growth in 2022, which reached 5.7%, the ASEAN region has become the 5th largest economy and the 4th largest exporter globally. In addition, the ASEAN region was also used as a destination for investment, with the second-highest investment in the world (Limanseto, 2023). Progress in various sectors, such as commerce, investment, household consumption, and the industrial sector, undeniably bolsters

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economic growth. Industrialization significantly contributes to the economic prosperity of developing countries in the ASEAN region.

However, the rapid growth of industrialization, especially in the manufacturing sector, can also have adverse environmental consequences. Most manufacturing industries essentially use fossil fuels like natural gas, coal, and oil, especially in emerging countries where technological innovation has not been well-developed. Thus, the use of resources in the form of fossil fuels will also increase, leading to adverse environmental consequences, such as $CO_2$ emissions. The increase in $CO_2$ emissions is due to the increasing population, the greenhouse gas effect, and the use of fossil fuels like natural gas, coal, and oil for industrial activities, motor vehicle use, and electricity generation (Bhutta et al., 2022; Ridwan et al., 2024). Industry is the main contributor to the increase in CO2 emissions in ASEAN developing countries due to aggressive industrialization to improve their national economies.

Based on data, 5 of the 6 ASEAN developing countries are ranked in the top 5 with the highest $CO_2$ emissions in Southeast Asia because of their aggressive efforts to improve their national economy. Indonesia is ranked first with a $CO_2$ emissions figure of 619.28 million tons, arguably high compared to the second position occupied by Vietnam, with a $CO_2$ emissions figure of 326.01 million tons. Responding to high levels of $CO_2$ emissions, ASEAN members are striving to achieve zero carbon emissions through decarbonization. For emerging ASEAN countries, the primary demand is to use energy sources that are more environmentally friendly, and assessing the pace of renewable energy implementation has become a significant concern (Hidranto, 2023). Furthermore, the poorer nations of ASEAN also ratified the Paris Agreement in 2015, which mandates all United Nations (UN) member states to decrease their greenhouse gas emissions and fulfill the agreement's objectives of attaining carbon neutrality by 2050. Net zero emissions refers to a state in which the quantity of carbon dioxide ($CO_2$) released into the atmosphere is lower than the amount of $CO_2$ absorbed by the Earth (Novia & Candy, 2023).

According to Johnson et al. (1997), environmental quality is a pair of characteristics and properties of an environment that will impact humans and organisms. It involves the natural environment, including water and air cleanliness, pollution, and noise disturbance that potentially cause physical and mental health problems (Nguyen et al., 2020). Several proxies, such as $CO_2$ and greenhouse gas emissions, can measure environmental quality. $CO_2$ emissions are generated from fossil fuel combustion and the cement production process, which includes using fuels in liquid, solid, and gas form (World Bank, 2023).

Regarding climate change and environmental issues, Kuznets (1955) investigated the relationship between economic growth and income inequality. Their study revealed a correlation between economic growth and income disparity that follows an inverted U-shaped curve. Specifically, as economic growth rises, income inequality likewise grows. However, as economic growth progresses, there will be specific turning points when income inequality diminishes. The inverted U-shaped Environment Kuznets Curve (EKC) studied by Grossman and Krueger (1995) is utilized to assess the relationship between the deterioration of the environment and economic growth. According to the EKC hypothesis, there is a positive correlation between environmental degradation and income growth in the initial phases of economic development, illustrated by an upward-sloping curve. There is a positive correlation between economic growth and environmental degradation. Once the economy reaches a turning point, the correlation between economic growth and environmental degradation will turn negative, implying increasing income levels associated with simultaneous reductions in $CO_2$ emissions.

Research examining EKC in G7 countries conducted by Raza and Shah (2018) shows that economic growth (GDP) has a significant positive impact, while $GDP^2$ has a negative and significant effect on $CO_2$ emissions, which supports the U-shaped EKC hypothesis. Likewise, subsequent studies proved the existence of the EKC hypothesis as implied by the negative effect of $GDP^2$ on environment quality, specifically in OECD countries (Zafar et al., 2019), Pakistan (Wang et al., 2022), South Asian countries (Tahir et al., 2021), and Africa (2022). Research by Ibrahiem (2020) shows that economic growth has a significant positive effect on $CO_2$ emissions. If economic growth increases by 1%, $CO_2$ emissions increase by about 1.1%, which is consistent

with the case in Egypt, as one of the developing countries struggling to achieve high levels of economic growth. In line with what has been done by Raza and Shah (2018) and Tahir et al. (2021), research conducted by Usman et al. (2022) shows that income level is statistically significantly positively related to $CO_2$ emissions across all quantiles. Khan et al. (2022) revealed that the overall GDP in a region has a significant positive effect on $CO_2$ emissions, where an increasing GDP will worsen environmental quality.

Producers of greenhouse gas emissions include energy use from fossil fuels, agriculture, industrial processes, deforestation, and waste. The highest producer of Greenhouse Gas (GHG) emissions comes from the use of fossil fuel energy (Filonchyk et al., 2024; Putri, 2023; Wang & Azam, 2024). ASEAN countries must face up to achieving a balance point between economic growth and environmental quality (Claire & Widyawati, 2023). This balance requires that transitioning from traditional to renewable energy is essential since it reduces CO2 emissions, mitigates climate change, enhances environmental sustainability, and fosters long-term socioeconomic benefits, including consistent economic growth (Altaf et al., 2025).

Numerous studies have proved that renewable energy significantly negatively affects environmental quality. Khan and Hou (2021) found that renewable energy has a negative effect on environmental quality in the United States, where every 1% increase in renewable energy will help reduce $CO_2$ emissions by 0.062% using the ROBUSTLS measurement tool and 0.057% using the GLM measurement tool. This shows that environmental quality in the United States can improve with renewable energy in the long term. Triki et al. (2023) stated that renewable energy significantly negatively affects the ecological footprint, which measures environmental quality both in the long and short term. These results imply that every level of improvement in environmental quality in Saudi Arabia is concrete, with 18.4% of renewable energy use. Usman et al. (2022) concluded that renewable energy significantly negatively affects $CO_2$ emissions in all quantiles. Wei et al. (2023) noted that renewable energy has a significant negative effect on $CO_2$ emissions, where an increase in the use of renewable energy by 1% will decrease $CO_2$ emissions by 0.09% in the short term and by 0.66% in the long term in the top 10 green future countries.

Despite studies indicating that this energy type can mitigate CO2 emissions and facilitate climate adaptation, the percentage remains minimal in many countries, with a significant portion of energy derived from fossil fuels, resulting in environmental challenges such as increasing CO2 levels and adverse effects on the global climate (Kassi & Li, 2025). Consequently, transitioning from traditional to renewable energy is essential as it reduces CO2 emissions, mitigates climate change, enhances environmental sustainability, and fosters enduring socioeconomic benefits, including consistent economic growth (Ahmed et al., 2025). The shift from fossil fuel-based energy to renewable energy is a top priority for developing countries in the ASEAN region. Renewable energy will likely reduce $CO_2$ emissions within the ASEAN region. Delays in energy transition will exacerbate the detrimental impacts of climate change, rendering future mitigation endeavors more challenging and expensive.

On the other hand, the energy transition requires financial support to finance renewable energy manufacturing. In this case, green finance plays a significant role (Sadiq et al., 2024; Candy et al., 2022). Green finance is financial services and products that support sustainable and environmentally friendly infrastructure. By increasing the amount of financial resources allocated to renewable energy projects, green finance plays a critical role in influencing ecosystems, production methods, and consumption patterns, serving as a significant catalyst for achieving a more sustainable and resilient economy (Yadav et al., 2024). Studies by Wang and Ma (2022), Guo et al. (2022), Hu et al. (2023), and Zhang et al. (2023) found that green finance has a significant negative impact on carbon emissions, implying that green finance can reduce $CO_2$ emissions in China. Likewise, Zhan et al. (2023) illustrate that a 1% increase in green finance will reduce $CO_2$ emissions by 0.492% and greenhouse gas emissions by 0.456% in China. These results show that green finance effectively reduces carbon emissions intensity and carbon emissions per capita in China, both in the short and long term. These findings imply that green finance investment in China is effective in the process of mitigating $CO_2$ emissions in China. In another region, Altaf et al. (2025) and Ahmed et al. (2025) recently proved that green finance implementation had a

substantial marginal impact on the environmental quality in OECD, Azerbaijan, and BRICS countries, respectively. On the contrary, Chan et al. (2024) pointed out that Green Finance and transitions to green technologies are inadequate. Attempts to achieve carbon neutrality need greater collaborative efforts among emerging Asian nations, such as China, to safeguard the sustainable environment. Likewise, Kassi and Li (2025) revealed that Green Finance is only efficient in less polluted regions in China.

Considering the results, it is urgent to perform studies to harness the potential of renewable energy and green finance to separate economic factors from CO2 emissions. Numerous studies indicate a substantial impact of Green Finance and Renewable Energy use on environmental quality (Hu et al., 2023; Zhan et al., 2023; Zhang et al., 2023; Wang & Ma., 2022; Guo et al., 2022; Altaf et al., 2025; Kassi & Li., 2024). However, most studies focus on China and developed countries, while research on emerging countries within the ASEAN region is scarcely available.

The environment and economic growth nexus in emerging countries might be distinctive from developed economies because of the financial and technological gaps (Ahmed et al., 2025). The study (Yang & Tang, 2024) In the ASEAN region, a linear model was used, excluding the EKC hypothesis, which is widely applied to assess the relationship between environmental factors and economic growth. As explained above, the situation might be more pertinent given that ASEAN nations have pursued rapid industrialization in recent decades, resulting in significant regional environmental degradation. This study aims to address the gap by scrutinizing the relationship between green finance and renewable energy on environmental quality in developing ASEAN countries within the framework of the EKC hypothesis. This study offers policymakers, investors, and other ASEAN-6 stakeholders insight into addressing environmental issues.

The rest of the paper is designed with section 2, comprising methodologies, which includes information on data sources, recommended variables, and econometric methodology; section 3 delves into the findings and results. Lastly, the concluding section, comprising a summary and recommendations, is discussed in section 4.

## Methods

### Data

This study examined the effects of GDP, $GDP^2$, green finance, and renewable energy on environmental quality proxied by $CO_2$ emissions. Using data from 2000 to 2020, we focused on ASEAN developing countries, including Indonesia, Malaysia, Thailand, Vietnam, the Philippines, and Cambodia. The data were obtained from Our World in Data World Development Indicators. Table 1 provides detailed information on the data source.

**Table 1.** Measurement of Variables

| Variable | Operational Definition | Units | Source |
|---|---|---|---|
| Environment Quality ($CO_2$ Emissions) | Environment quality (CO2 emissions) refers to the level of environmental quality affected by $CO_2$ emissions. | Tonnes | Our World in Data (https://ourworldindata.org/co2-emissions) |
| GDP per Capita | GDP is the measurement of a country's nominal GDP divided by population. | 2015 US$ | WDI - World Bank (https://data.worldbank.org/indicator/NY.GDP.PCAP.KD) |
| Green Finance | Green finance refers to financing environmentally friendly and sustainable projects to reduce $CO_2$ emissions. It is measured by Adjusted Net Saving, including particulate Emission Damage | 2020 US$ | Our World in Data (https://ourworldindata.org/grapher/international-finance-clean-energy) |
| Renewable energy | Renewable energy refers to the transition from using fossil fuels to renewable sources. | Percent (%) | WDI - World Bank (https://data.worldbank.org/indicator/EG.FEC.RNEW.ZS) |

According to the variables used, the following is the model specification of this study:

$$CO_{2t} = \beta_0 + \beta_1 GDP_t + \beta_2 GDP^2{}_t + \beta_3 RE_t + \beta_4 GF_t + \varepsilon_t \quad (1)$$

Where $CO_2$ refers to $CO_2$ Emissions, β is a constant, GDP refers to Gross Domestic Product, $GDP^2$ refers to the square of Gross Domestic Product, GF refers to Green Finance, RE represents Renewable Energy, and ε represents the error term. The inclusion of the $GDP^2$ in the model is to prove the existence of the EKC hypothesis in the form of an inverse U-shaped curve. The positive influence of GDP, accompanied by the negative influence of GDP squared, indicates that the EKC hypothesis is proven (Kuznets, 1955; Grossman & Krueger, 1995). The variables used in this study refer to the studies of Ahmed et al. (2022), Baskaya et al. (2022), Han and Jun (2023), and Massagony and Budiono (2023).

### Data analysis method

The method of data analysis employed in this study is a Panel Autoregressive Distributed Lag (ARDL) method with Pooled Mean Group Estimators by Pesaran et al. (1999). The reason for using this method is that it can be applied using a mixture of I(0) and I(1) variables (Bahmani-Oskooee et al., 2020; Sohail et al., 2022; Zhan et al., 2023). The ARDL method is more suitable for small sample sizes and offers different estimates at different lag sequences; thus, this approach provides reliable estimates that significantly eliminate the endogeneity problem in the model (Raghutla & Kolati, 2023). In addition, Pooled Mean Group estimation allows for heterogeneity in short-run coefficients across different panels while assuming that the long-run coefficients are the same across all panels.

## Results and Discussion

### Descriptive Statistics

**Table 2.** Descriptive Statistics

| | $CO_2$ | GDP | $GDP^2$ | GF | RE |
|---|---|---|---|---|---|
| Mean | 1.97E+08 | 3689.842 | 2,053,6415 | 1.06E+08 | 32.597 |
| Median | 1.82E+08 | 2873.436 | 8257510. | 10750000 | 30.095 |
| Maximum | 6.59E+08 | 11114.54 | 1.24E+08 | 1.09E+09 | 81.580 |
| Minimum | 1974896. | 488.003 | 238,146.6 | 10,000.00 | 1.960 |
| Std. Dev. | 1.55E+08 | 2640.893 | 28275906 | 1.91E+08 | 20.552 |
| Skewness | 0.897 | 1.118 | 1.991 | 2.848 | 0.598 |
| Kurtosis | 3.509 | 3.423 | 6.302 | 12.401 | 2.933 |
| | | | | | |
| Jarque-Bera | 19.131 | 28.477 | 147.164 | 664.485 | 7.898 |
| Probability | 0.000 | 0.000 | 0.000 | 0.000 | 0.019 |
| | | | | | |
| Sum | 2.60E+10 | 487059.2 | 2.71E+09 | 1.40E+10 | 4302.750 |
| Sum Sq. Dev. | 3.14E+18 | 9.14E+08 | 1.05E+17 | 4.80E+18 | 55331.35 |
| Observations | 132 | 132 | 132 | 132 | 132 |

Table 2 summarizes the statistics of the key variables analyzed in this research. The findings show that CO2 Emissions, GDP, its squared term, Green Finance, and Renewable Energy exhibit positive skewness, implying that most data points are clustered towards the lower end of the distribution. The standard deviations for most variables were much lower than the mean, indicating that the model variables were stable. The Jarque-Bera test indicates significant deviations from normality for renewable energy utilization and population, as evidenced by their low P-values.

### Panel Unit Root Test

The results of the unit root test, as presented in Table 3, show that only the Green Finance variable is stationary at a 1% significance level, indicating that it is of I(0). The same tests for all other

variables using the first differenced data indicate that they are stationary at 1%, 5%, and 10% significance levels or are of I(1). The mixed results of the tests confirm the appropriateness of using ARDL to estimate the model.

**Table 3.** Results from the Panel Unit Root Test

| Test | Variables | Level | First Difference |
|---|---|---|---|
| Levin, Lin, and Chu | $CO_2$ Emissions | -0.285 | -4.403*** |
| | GDP | -0.404 | -1.499* |
| | $GDP^2$ | 1.297 | -1.669** |
| | Green Finance | -110.015*** | -53.217*** |
| | Renewable Energy | -0.013 | -4.436*** |
| Im, Pesaran and Shin W-Stat | $CO_2$ Emissions | 2.205 | -3.899*** |
| | GDP | 2.286 | -2.162** |
| | $GDP^2$ | 3.545 | -1.857** |
| | Green Finance | -44.014*** | -31.526*** |
| | Renewable Energy | 1.5822 | -4.142*** |
| ADF – Fisher Chi-square | $CO_2$ Emissions | 7.578 | 38.530*** |
| | GDP | 3.310 | 22.121** |
| | $GDP^2$ | 1.534 | 19.928* |
| | Green Finance | 296.393*** | 347.678*** |
| | Renewable Energy | 4.443 | 39.473*** |
| PP - Fisher Chi-square | $CO_2$ Emissions | 14.590 | 67.539*** |
| | GDP | 2.656 | 59.680*** |
| | $GDP^2$ | 1.095 | 60.261*** |
| | Green Finance | 138.822*** | 621.914*** |
| | Renewable Energy | 3.883 | 65.718*** |

Notes: ***, **, and * indicated statistically significant at 1%, 5%, and 10%, respectively.

## Cointegration Test

**Table 4.** Pedroni Residual Cointegration Test

| Test Statistic | t-Statistic | Prob. |
|---|---|---|
| Panel PP-Statistic | -2.577*** | (0.005) |

Notes: Symbol ***, **, and * indicated statistically significant at 1%, 5%, and 10%, respectively.

Table 4 shows the results of the Pedroni residual cointegration test. Using the Panel PP-Statistic, the outcome indicates that the error correction parameter is negative and significant at the 1% level. This explains that the cointegration test rejects the null hypothesis, indicating long-term cointegration.

## Long Run and Short Run Outcomes in ASEAN Developing Countries

Table 5 shows the findings of the panel ARDL model, where in the long run, GDP has a positive significant effect on $CO_2$ emissions, while $GDP^2$ has a negative significant effect on $CO_2$ emissions. The high economic growth most likely arises from a higher level of industrialization, which will, in turn, increase the level of $CO_2$ emissions, which will deteriorate the environmental quality in the region (Claire & Widyawati, 2023; Dong et al., 2019; Dong et al., 2021; Rehman et al., 2021). The quadratic effect of GDP on CO2 emissions confirms an inverted U-shaped curve, indicating the presence of the Environmental Kuznets Curve (EKC) Hypothesis, which has been substantiated in developing ASEAN countries. This finding aligns with Kuznets's (1955) proposal, subsequently expanded by Grossman and Krueger (1995). The existence of the EKC hypothesis in developing ASEAN countries supports that of previous studies (Adeel-Farooq et al., 2020; Anwar et al., 2021; Claire & Widyawati, 2023; and Guzel & Okumus, 2020).

**Table 5.** Result of ARDL Model

| Variable | Coefficient | Std. Error | t-Statistic | Prob.* |
|---|---|---|---|---|
| | Long Run Equation | | | |
| LNGDP | 1.405 | 0.031 | 40.643 | 0.000*** |
| LNGDP2 | -0.702 | 0.017 | -40.643 | 0.000*** |
| LNGF | -0.014 | 0.006 | -2.523 | 0.014** |
| LNRE | -0.171 | 0.035 | -4.811 | 0.000*** |
| | Short Run Equation | | | |
| COINTEQ01 | -0.298 | 0.174 | -1.711 | 0.091* |
| D(LNGDP) | 0.705 | 0.280 | 2.522 | 0.014** |
| D(LNGDP(-1)) | 0.243 | 0.301 | 0.807 | 0.422 |
| D(LNGDP$^2$) | -0.714 | 0.347 | -2.056 | 0.042** |
| D(LNGDP$^2$ (-1)) | -0.236 | 0.256 | -0.920 | 0.360 |
| D(LNGF) | -0.001 | 0.001 | -0.827 | 0.411 |
| D(LNGF (-1)) | -0.000 | 0.001 | -0.302 | 0.764 |
| D(LNRE) | -0.599 | 0.266 | -2.254 | 0.027** |
| D(LNRE(-1)) | -0.222 | 0.117 | -1.899 | 0.061* |
| C | 2.200 | 1.270 | 1.733 | 0.087* |
| Root MSE | 0.032 | Mean dependent var | | 0.053 |
| S.D. dependent var | 0.068 | S.E. of regression | | 0.041 |
| Akaike info criterion | -3.012 | Sum squared resid | | 0.137 |
| Schwarz criterion | -1.898 | Log likelihood | | 249.784 |
| Hannan-Quinn criterion. | -2.559 | | | |

Table 5 reports the long-term negative and significant effects of green finance variables on $CO_2$ emissions. The relationship is significant at a 5% level. In terms of its strength, an increase in the use of Green Finance by 1% tends to reduce the CO2 emission by 1.36%, indicating a positive role of Green Finance in improving environmental quality. This further entails that when an economy undertakes strategies in green finance aimed at enhancing environmental quality, it will achieve its intended purposes (Guo et al., 2022; Hu et al., 2023; Wang & Ma, 2022; Sadiq et al., 2024; Yadav et al., 2024; Zhan et al., 2023; Zhang et al., 2023; Yang & Tang, 2024)However, in the short run, Green Finance has an insignificant effect on CO2 emissions, implying that immediate changes in financing may not lead to quick emissions reductions. This could be due to various factors, such as the uncertain time required to implement the projects or behavioral shifts among businesses and consumers. It emphasizes the importance of patience and sustained investment in green finance initiatives (Chan et al., 2024; Kasi and Li., 2025).

Additionally, Table 6 presents diagnostic tests for each specific group's empirical model. The results indicate the absence of heteroskedasticity, serial correlation, non-normally distributed residuals, and omitted variable bias. Therefore, the estimated results are valid for interpretation.

**Table 6.** Post Estimation Diagnostics Tests

| Country | Heteroskedasticity (Breusch-Pagan-Godfrey) | Normality (Jarque Bera) | Serial Correlation (Breusch-Godfrey) | Specification (Ramsey Reset) |
|---|---|---|---|---|
| Indonesia | 0.185 | 0.546 | 2.209 | 0.682 |
| | (0.950) | | (0.142) | (0.188) |
| Malaysia | 1.247 | 0.535 | 0.195 | 1.240 |
| | (0.322) | | (0.825) | (0.082) |
| Thailand | 1.922 | 0.448 | 1.006 | 1.188 |
| | (0.162) | | (0.084) | (0.554) |
| Vietnam | 0.008 | 1.699 | 3.511 | 0.503 |
| | 0.999 | | 0.054 | (0.622) |
| Philippines | 0.525 | 0.359 | 2.074 | 1.781 |
| | (0.671) | | (0.158) | (0.093) |
| Cambodia | 0.561 | 0.844 | 1.247 | 1.734 |
| | (0.647) | | (0.501) | (0.083) |

Further discussion, renewable energy hurts $CO_2$ emissions both in the long and short run. In the long run, this relationship is significant at a 1% significance level. In terms of its strength, it reflects that through renewable energy, there will be an eradication of the level of carbon emission by 17.04%, which reflects an appreciable role of Renewable Energy use towards environmental quality. In the short run, the effect of renewable energy is more marginally significant, at 5% and 10% levels. This suggests that while renewable energy can contribute to emissions reductions quickly, the extent of this impact may be limited initially. Several factors might be responsible, including existing reliance on fossil fuels, infrastructure constraints, or the time needed for the renewable sector to scale up. These results corroborate the studies by Khan and Hou (2021), Raghutla and Kolati (2023), Triki et al. (2023), Usman et al. (2022), Wei et al. (2023), and Altaf et al. (2025).

In summary, the results of this study underscore the critical relationship between green finance, renewable energy, and carbon emissions. The findings reveal that green finance and renewable energy are pivotal in reducing carbon emissions, highlighting the importance of integrating these elements into national and regional policies. The results indicate that renewable energy has a significantly higher impact on carbon emissions reduction than green finance, with a reduction of 17.04% versus 1.36% for green finance. This disparity suggests that while both factors are crucial for improving environmental quality, renewable energy is currently a more potent tool in the fight against carbon emissions. The significant long-run effect of green finance on carbon emissions indicates that sustained investment in environmentally friendly initiatives can lead to lasting changes in energy consumption and production patterns. In the rapidly industrializing context of ASEAN countries, where economic growth often comes at the expense of environmental degradation, green finance can provide the necessary capital to transition to cleaner technologies (Yang & Tang, 2024). For instance, Indonesia and Vietnam, which have been heavily reliant on fossil fuels, can benefit from green financial instruments that encourage investments in sustainable projects. By fostering a supportive regulatory environment and ensuring access to green finance, these countries can mitigate the carbon footprint associated with their industrial activities over time.

The dual impact of both short and long-run renewable energy highlights its role as a versatile solution for carbon emission reductions. As countries like Thailand and the Philippines ramp up their solar and wind energy investments, immediate benefits appear in reduced dependency on coal and other fossil fuels. This transition is particularly vital in the face of rapid industrialization, which often leads to increased emissions. Malaysia's commitment to enhancing its renewable energy capacity can significantly reduce carbon emissions, foster a cleaner environment, and support sustainable economic growth. Most investments in renewable energy are going to Vietnam due to its advanced industrialization and rapid growth, making it an attractive destination for many investors. Significant financial resources and expenditures are required to enhance renewable energy sources, facilitate the transition to sustainable energy, and implement waste reduction programs (Sadiq et al., 2024).

## Conclusion

The present analysis quantifies the influence of GDP, green finance, and renewable energy on CO2 emissions for the ASEAN-6 emerging. Several statistical tests, including the unit root test, Pedroni Residual Cointegration Test, descriptive statistics, Panel ARDL analysis, and post-estimation diagnostic testing, have been used to analyze the relationship among the variables in the network. The study's findings indicate that ASEAN enhances the UN's efforts to mitigate CO2 emissions and address climate change. The study aims to offer relevant policy implications for the ASEAN countries' ambitions to reduce CO2, together with a crucial lesson for the future of the global community. The study's conclusions will assist policymakers in strategically allocating investments to achieve environmental sustainability. Our findings have significant policy implications. Firstly, prioritizing renewable energy utilization is essential for ASEAN nations to address the environmental challenges climate change poses. Establishing strong objectives for renewable energy and feasible laws is crucial to this process. Secondly, policymakers should leverage the

study's insights to develop green finance structures that optimize CO2 reduction efficacy. Thirdly, comprehending the inverted U-shaped relationship enables policymakers to prioritize measures that speed up the attainment of the turning point, expediting the transition to the beneficial phase of renewable energy. The government's main objective is to ensure companies switch to renewable energy. Green Finance can facilitate the transition to green energy. Attractive financing interest rates, lower than the market rate, and simplified terms might incentivize corporations to engage in renewable energy or other sustainability sectors. All this would also be crucial in supporting economic growth while achieving environmental sustainability.

This study has determined that the EKC Hypothesis is valid in ASEAN developing countries when considering green finance and renewable energy variables. However, it only establishes a non-linear relationship between economic growth and environmental quality without identifying the possibility of a non-linear relationship between green finance and renewable energy on CO2 emissions. This is imperative since the energy transitions in ASEAN countries are still in progress in recent and upcoming decades. Secondly, future studies might consider the turning point at which a country will achieve improved environmental quality, as the economic and industrial disparities among countries might lead to gaps between countries.

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