The Impact of Economic Factors on CO_2 Emissions: The Moderating Effect of Renewable Energy

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ABSTRACT

This study examines the economic factors that influence carbon emissions in Vietnam and the moderating role of renewable energy use from 2010 to 2024 using mixed-effects maximum likelihood regressions. The results indicate that economic growth can lead to increased CO_2 emissions, whereas renewable energy significantly reduces CO_2 emissions in ASEAN countries. The moderating effect of renewable energy lessens the impact of economic growth on CO_2 emissions. Additionally, the moderating role of renewable energy also plays a key part in lowering emissions when considering the effects of foreign direct investment. This study is valuable for future research on emissions in countries, focusing on how economic factors influence CO_2 emissions and the moderating role of renewable energy.

KEYWORDS

CO_2 emissions, economic growth, trade openness, foreign direct investment.

1. INTRODUCTION

In 1992, in Rio de Janeiro, the Conference on Environment and Development by the United Nations (UNCED) reaffirmed sustainable development and sent a clear message to all levels of government about the urgency of promoting economic and social development in harmony with environmental protection (UN, 1992). Recent studies highlight the correlation between rapid economic growth and increased consumption of fossil fuels, leading to significant CO_2 emissions (He et al., 2020; Jebabli et al., 2023). Achieving economic development alongside environmental sustainability is considered a crucial goal in governments' policies worldwide. Additionally, globalization is an international phenomenon affecting people's lives globally, influencing economics and socio-politics. Globalization links the world's economies through trade and foreign direct investment. He et al. (2020) argue that globalization is connected to worldwide trade liberalization, financial development, economic growth, and environmental quality. Countries pursue maximum economic growth through foreign trade and investment, primarily driven by industrialization and urbanization, which often result in environmental degradation. This degradation is mostly due to increased dependence on traditional energy sources for economic activities, such as industrial production. In these cases, efforts to reduce CO_2 emissions could harm economic growth, a consequence many countries are hesitant to face.

The Asian Development Bank (ADB), in collaboration with the ASEAN Catalytic Green Finance Facility (ACGF), organized the Southeast Asia Development Solutions (SEAD) Workshop 2023 with the theme "Imagining a Net-Zero ASEAN" in Bali. ASEAN countries are currently working toward achieving net-zero emissions by 2050. However, their strategies have faced certain limitations (Asian Development Bank, 2023). According to a report by Bain & Company, GenZero, Standard Chartered, and Temasek Southeast (2024) through "Asia's Green Economy 2024 Report: Moving the needle," Southeast Asia needs to cut carbon dioxide emissions by at least 45 percent by 2030. The report also emphasizes that Southeast Asia still emits 3 million tons of carbon dioxide annually from approximately 647 million cars on the road, making the 2030 goal seem distant. Some countries' investment strategies aimed at reducing carbon emissions have also been ineffective. Current investments total less than USD 20 million, which falls far short of the USD 1-3 trillion needed to effectively lower emissions. The report recommends increasing investments 15-20 times by 2030.

Furthermore, policies aimed at reducing dependence on fossil fuels in some countries in the region have yet to produce the desired results. Indonesia, for example, will implement a coal tax in July

2022. However, with a projected rate of 30,000 rupiahs, the report predicts that Indonesia will not achieve the intended outcome. Another challenge for several Southeast Asian countries in tackling climate change is rapid urbanization in coastal areas, which makes environmental protection more difficult. Many scientists believe that the population in coastal regions is growing, especially in Thailand and the Philippines, where fast coastal urbanization threatens the environment and obstructs climate change mitigation efforts.

Recent studies have shown significant interest in the economic factors influencing CO_2 emissions. However, the results still need clarification, especially in ASEAN countries. Furthermore, the moderating role of renewable energy in these impacts has yet to be fully established. This study aims to contribute to the understanding of emissions related to economic factors and the moderating effect of renewable energy.

2. LITERATURE REVIEW

Despite the crucial link between economic growth and green growth, more research is needed. Since the existing literature on this topic is limited, we review studies that, although they may differ in focus, are related to environmental issues and their influence on economic growth. Ahmed and Ahmed (2018) research on data in China shows that the CO_2 emission situation is worsening. The authors highlight that GDP contributes to CO_2 emissions in this country, while strict environmental policies can help reduce emissions. Similarly, Rahman et al. (2023) found that although the short-term effects of GDP and population on South Asian countries are positive but not significant, GDP becomes significant over the long term.

Additionally, renewable and nuclear energy are essential for reducing pollution in these countries. In contrast, Zhang and Zhang (2018) studied the EKC curve with data from China; the results showed that trade openness harms CO_2 emissions, while foreign direct investment positively affects emissions. Meanwhile, using data from Bangladesh, Islam et al. (2023) concluded that globalization, foreign direct investment, and innovation help reduce CO_2 emissions and improve environmental quality. Conversely, trade openness, economic growth, and energy consumption positively influence CO_2 emissions, leading to both short- and long-term environmental degradation.

Several studies have shown that high energy consumption is linked to poorer environmental quality (Shahzad, 2020; Khan et al., 2021). Saidi and Omri (2020) argue that countries need to promote and increase the use of renewable energy in production to prevent economic and environmental harm. Meanwhile, Jebli and Youssef (2017) suggest that renewable energy consumption could potentially raise CO_2 emissions, as certain renewable sources, such as biomass and waste, can be highly pollution-intensive. Therefore, a fully integrated renewable energy system may effectively reduce carbon emissions (Pata, 2018). Kahouli (2018) also reports that higher renewable energy consumption might boost energy-intensive economic activities. Pata and Samour (2023) recommend that OECD countries prioritize policies that promote renewable energy use rather than incentivize the insurance market.

Many studies have focused on the economic factors affecting CO_2 emissions; while this relationship remains relatively complex, the use of fossil energy versus renewable energy remains a topic of controversy. At the same time, using renewable energy can mitigate the impact of economic factors on CO_2 emissions, just as green energy reduces the negative environmental impact. However, the aggregate data for ASEAN countries to verify this relationship, especially regarding the moderating role of renewable energy, has not been entirely conclusive. This study aims to find convincing answers to these issues. Research has shown a complex relationship between economic factors, particularly economic growth, foreign direct investment attraction, trade openness, and renewable energy use, and CO_2 emissions. There is still much debate on this topic. Based on these findings, the authors propose the following research model:

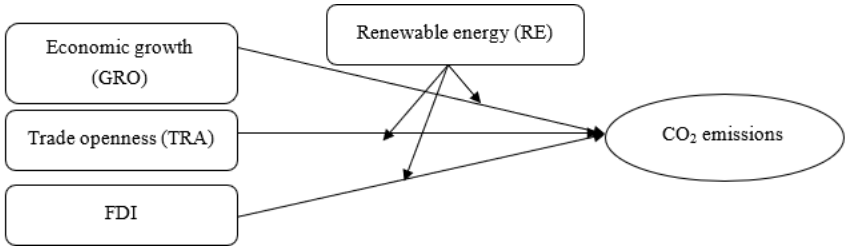

Figure 1: Research model *Source: The author*

The model suggests that CO_2 emissions are affected by economic growth, foreign direct investment net inflows, trade openness, and the moderating influence of renewable energy. It indicates that adopting renewable energy can reduce emissions influenced by economic factors such as growth, foreign investment, and trade openness.

3. METHODOLOGY

Building on previous research (Ahmed & Ahmed, 2018; Zhang & Zhang, 2018; Jebli & Youssef, 2017; Islam et al., 2023), this study analyzes data from 10 ASEAN countries covering the period from 2010 to 2024. The annual data was obtained from the World Bank, and the moderating role of renewable energy use in these countries during the same period is examined using Mixed-effects Maximum Likelihood regressions. The authors propose the following econometric model:

$$CO_2\ emissions_{it} = a + \beta_1.(GRO_{it}.RE_{it}) + \beta_2.(TRA_{it}.RE_{it}) + \beta 3.(FDI_{it}.RE_{it}) + u_i$$

In which:

CO_2 emissions denotes carbon dioxide emissions (tons), GRO stands for the GDP growth (%), FDI represents foreign direct investment net inflows ($million), TRA denotes trade openness (%), RE represents renewable energy (%).

4. RESULTS AND DISCUSSION

The research results include descriptive statistics, correlation matrix tests, necessary tests, and regression analyses, including a mixed-effects model (Model 1) and mixed-effects regression with the moderating role of renewable energy (Model 2).

Table 1: Descriptive Statistics

Variables	Obs	Mean	Std. Dev.	Min	Max
GRO	250	5.26833	3.63721	-9.38422	14.5729
TRA	250	134.322	87.5689	32.75953	438.4953
FDI	250	-3829.313	8679.453	-58482.034	23748.495
RE	250	35.393	27.8905	0	85.7
CO_2	250	121.273	128.472	0.98374	606.3739

Source: Analysis results from Stata

The descriptive statistics show that CO_2 emissions, FDI, and TRA have relatively high standard deviations (128.472, 8679.453, and 87.5689, respectively), indicating a wide range of values. GRO has a moderate standard deviation (3.63721). The mean values of CO_2 emissions (121.273) and TRA (134.322), are positive, while the mean value of FDI (-3829.313) is negative. Descriptive statistics, such as minimum and maximum values, offer valuable insights into a dataset's range and distribution of data points. For instance, examining the variable CO_2 reveals a minimum value of 0.98374 in Lao PDR in 2010 and a maximum value of 606.3739 in Indonesia in 2024.

Similarly, FDI net inflows range from -58482.034 in Singapore in 2020 to 23748.495 in Thailand in 2022. Additionally, the variable GRO demonstrated a minimum of -9.38422 in the Philippines in 2022 and a maximum of 14.5729 in Singapore in 2010. Furthermore, TRA values span from 32.75953 in Indonesia in 2010 to 438.4953 in Singapore in 2018. Finally, the variable RE ranges from 0 in Brunei Darussalam to 85.7in Myanmar in 2024.

Table 2: Collinearity Matrix

	CO_2	GRO	TRA	FDI	RE
CO_2	1.000				
GRO	-0.1324	1.000			
TRA	-0.2372	0.0356	1.000		
FDI	-0.1563	-0.0212	-0.3823	1.000	
RE	-0.2726	0.5217	-0.3782	0.2533	1.000

Source: Analysis results from Stata

The correlation coefficients of the variables are minimal when their values are all below 0.7, indicating that the variables do not display perfect multicollinearity and are suitable for inclusion in the analysis model.

Table 3: The results of the economic factor's impact on CO_2 emissions in the moderating role of renewable energy in ASEAN

	Model 1	Model 2
	CO_2 emissions	CO_2 emissions
GRO	5.847*	9.273**
TRA	-0.935***	-0.673***
FDI	-0.004839***	-0.000473
RE	-2.654***	-1.536***
c.RE#c.GRO		-0.189*
c.RE#c.TRA		0.0000407
c.RE#c.FDI		-0.000475***
Cons	294.3***	225.4***
N	250	250
*Notes: *significant at p < 0.05, **significant at p < 0.01, ***significant at p < 0.001*		

Source: Analysis results from Stata

The regression model results include a mixed-effects model (Model 1) and a mixed-effects regression model with moderation (Model 2). This analysis uses a mixed-effects model with maximum likelihood estimation (ML) to examine the relationship between the dependent variable, CO_2 emissions, and several independent variables, such as renewable energy (RE), economic growth (GRO), foreign direct investment net inflows (FDI), and trade openness (TRA). The model incorporates both fixed effects, which represent the average impact of the independent variables on the dependent variable, and random effects, which account for variations in the relationship across different groups or individuals.

The results are shown in Table 3. Renewable energy helps reduce carbon dioxide emissions, with an average decrease of 1.536 tons in carbon dioxide emissions when the renewable energy rate increases by 1 percent. This finding aligns with previous studies (Rahman et al., 2023; Pata & Samour, 2023).

In Table 3, the results indicate that the GRO variable is statistically significant and positively influences carbon dioxide emissions in ASEAN countries; a 1% increase in economic growth results in an increase of 9.273 tons of CO_2. Similar findings are reported in previous studies (Ahmed & Ahmed, 2018; Islam et al., 2023), showing a positive effect of economic growth on CO_2 emissions in these countries. Meanwhile, global trade and investment tend to decrease CO_2 emissions. As countries gain access to and adopt advanced technology, deep globalization has created a greater need for emissions reductions in ASEAN nations.

In particular, the moderating effect of renewable energy on the relationship between economic growth and foreign direct investment is that it decreases the influence of economic factors on emissions. Meanwhile, the moderating role of renewable energy resulted in a decline of 0.189 tons and 0.000475 tons, respectively. These findings also align with previous studies (Pata & Samour, 2023), but differ from others (Jebli & Youssef, 2017; Saidi & Omri, 2020) due to differences in scope and research focus.

5. CONCLUSION

Policy implications have arisen from the findings of this study. First, our results show that renewable energy in ASEAN reduces carbon dioxide emissions, thus improving environmental quality in these countries. Meanwhile, economic growth tends to increase CO_2 emissions, so it is important to carefully weigh the economic benefits against environmental concerns for our future prospects. Second, by adopting renewable energy, production activities contribute to gradually decreasing the impact of economic factors on emissions.

Furthermore, the results indicate that promoting renewable energy significantly reduces the impact of economic growth and foreign direct investment inflows on CO_2 emissions in ASEAN. This highlights the need to address emission issues and increase the share of renewable energy in the economy. Transitioning to renewable energy lessens dependence on finite fossil fuels, stabilizes energy prices, and improves energy security. As an endless resource, renewables protect the environment and support sustainable development for future generations.

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