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Original Article

The Effects of the CO_2 Emissions, Fdi, and Trade Openness on the Economic Growth with the Moderating Role of Renewable Energy: Empirical Evidence in Asean Countries

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Abstract: This study investigates the carbon emissions, foreign direct investment and trade openness affecting the economic growth in ASEAN countries and the moderating role of renewable energy use in these countries from 2001 to 2020 by the Mixed-effects ML regressions. The study found that there is a positive impact of renewable energy and trade openness on economic growth in ASEAN countries. Meanwhile, the issue of emissions continues to go hand in hand with economic growth, requiring ASEAN to continue to study how growth in the relationship between environment and economy. A notable result is that the renewable energy reduces the impact of the relationship between foreign direct investment and economic growth which also raises policy issues for green growth in the impact of attracting investment and growth in ASEAN countries in the future. In particular, issues related to environmental pollution, CO2 emissions, trade openness, foreign direct investment, renewable energy in their impact on the growth of ASEAN economies.

Keywords: CO_2 emissions, Economic growth, Trade openness, Renewable energy, ASEAN.

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 [1]. Recent studies highlight the correlation between rapid economic growth and increased consumption of fossil fuels, leading to

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significant CO_2 emissions [2-4]). Achieving economic development with the environment and sustainability is considered an essential goal in the policies of governments worldwide. In addition, globalization is an international phenomenon impacting people's lives worldwide in terms of economics and socio-politics. Globalization connects the world's economies through trade and foreign direct investment. Raihan et al. [4] argues that globalization is linked to foreign direct investment, globalization, economic growth, and energy consumption and environmental quality. Countries pursue maximum economic growth through foreign trade and investment, primarily driven by industrialization and urbanization, leading to environmental degradation. This degradation is primarily due to the increased reliance on traditional energy sources for economic activities, such as industrial production. In such cases, efforts to degrade CO_2 emissions could adversely impact to the economic growth, a consequence many countries are reluctant 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 striving to achieve net-zero emissions by 2050. However, their strategies have encountered certain limitations [5]. According to a report by Bain & Company, GenZero, Standard Chartered, and Temasek Southeast [6] through “Asia’s Green Economy 2024 Report: Moving the needle”, Southeast Asia needs to cut carbon dioxide emissions by at least 45% by 2030. The report also highlights that Southeast Asia still emits 3 million tons of carbon dioxide annually from approximately 647 million cars on the road, making achieving the 2030 target a distant goal. Some countries' investment strategies to reduce carbon emissions have also been ineffective. Current investments are less than USD 20 million, falling short of the required USD 1-3 trillion to reduce carbon emissions effectively. The report suggests that investments need to increase 15-20 times by 2030.

Furthermore, policies to reduce fossil fuel dependency in some countries in the region have yet to yield the desired results. Indonesia, for example, will impose a coal tax in July 2022. However, with a projected rate of 30,000 rupiah, the report predicts Indonesia will not achieve the desired outcome. Another challenge for some Southeast Asian countries in addressing climate change is rapid urbanization in coastal areas, making environmental protection difficult. Many scientists believe that the population in coastal areas is increasing, particularly in Thailand and the Philippines, where rapid coastal urbanization threatens the environment and hinders climate change mitigation efforts.

The Kuznets curve theory [7] initiated the debates on the relationship between inequality and national income. The Kuznets hypothesis explains the relationship between economic growth and environmental change across countries, noting that this dynamic varies depending on the early and later stages of growth; many scholars attribute this to factors such as renewable energy or eco-friendly economic solutions, providing a crucial foundation for research into identifying associated risks and developing appropriate solutions. Later, the studies of Grossman and Krueger [8], Panayotou [9] improved this theory by examining the influence of economic growth and environmental problems. The results of these researches showed a close connection between foreign direct investment (FDI), energy consumption, economic growth and environmental pollution. Shahbaz and Lean [10] mentioned that sustainable economic development will be achieved simultaneously with environmental quality sustainability.

Recent studies have shown great interest in CO_2 emissions, FDI and trade openness affecting the economic growth. However, the results still need to be clarified, especially in ASEAN countries; besides, the moderating role of renewable energy in the above impacts has yet to reach a full conclusion. This study is expected to

contribute to the issue of emissions related to economic factors and the moderating role of renewable energy.

2. Literature Review

Despite the vital link between economic growth and green growth, research still needs to be conducted. Given the sparse literature on this topic, this research reviews studies that, while potentially differing in focus, are connected to environmental issues and their impact on economic growth. Ahmed and Ahmed [11] research on data in China shows that the CO_2 emission situation is becoming increasingly severe. The authors emphasize that the GDP factor harms CO_2 emissions in this country, while strict environmental policies can reduce emissions. Similarly, Rahman et al., [12] found that while the short-term effects of GDP and population on South Asian countries are positive but insignificant, GDP becomes significant in the long run. Pata et al., [13] focused on Southeast Asian countries to explore the direct macro-factors that influence environmental quality and provided evidence that foreign direct investment increases CO_2 emissions, while trade openness and national income degrade the environmental degradation. Wenlong et al., [14] found that both institutional quality and trade openness have adverse impacts, while technological innovation and energy efficiency have favorable impacts on environmental quality in these countries.

Additionally, renewable and nuclear energy are crucial in reducing pollution in these countries. In contrast, Zhang and Zhang [15] studied the EKC curve with data in China; the results showed that trade openness harms CO_2 emissions, while foreign direct investment positively impacts emissions. Meanwhile, using Bangladesh data, Islam et al., [16] concluded that globalization, and innovation and foreign direct investment cause in the degrading CO_2 emissions and improving environmental quality. Meanwhile, energy consumption, economic growth and trade openness positively impact CO_2 emissions, leading to short and long-term environmental degradation.

Several studies have shown that high energy consumption is linked with worse environmental condition [17-19] studied renewable energy strategies for sustainable development in Denmark. Adams et al., [20] analyzed the impact of non-renewable and renewable energy consumption and regimes on economic growth in 30 African countries during the period 1980-2012. Rafindadi and Ozturk [21] used Granger Bounds curve tests and ARDL to study the impact of renewable energy consumption on economic growth in Germany, similar to Rahman and Kashem [22] analyzed the relationship between energy consumption, carbon emissions and industrial growth in Bangladesh. Ntanos et al., [23] studied RE and ICT in Europe, aiming to analyze the impact of economic factor to renewable energy consumption of 25 European countries from 2007 to 2016. Saidi and Omri [24] argue that countries need to promote and increase the use of renewable energy in production to avoid economic harm to the environment. Meanwhile, Jebli and Youssef [25] suggest that renewable energy consumption could potentially increase CO_2 emissions, as specific renewable sources, like biomass and waste, can be highly pollution-intensive. Therefore, a fully integrated renewable energy system may decrease carbon emissions effectively [26, 27] also reports that higher renewable energy consumption might boost energy-intensive economic activities. Pata and Samour [28] recommend that OECD countries focus on policies that promote renewable energy use rather than incentivizing the insurance market. Islam et al., [29] reveal a significantly positive influence for renewable energy and a significantly adverse impact for non-renewable energy with respect to sustainable development in ASEAN countries.

Theoretically, the impact of FDI on economic growth in very different ways [30]. Some economic researchers conclude that FDI can have an impact in two different directions [31]. First, some theories refer to the positive

role of FDI in capital accumulation for economic growth. Second, FDI can promote economic growth through spillover effects in technology transfer and training of high-quality human resources. Balasubramanyam et al., [32] conducted a study in the context of 46 developing countries, and the results illustrated that FDI has a positive effect on economic growth. Similarly, Gao [33] found that the level of positive impact of FDI on economic growth is correlated with the level of economic integration. Li and Liu [34] also found that FDI has a positive relationship with economic growth when studying 84 countries during the period 1970-1999. Some studies find a negative effect of FDI on economic growth through the competition effect. According to Aitken and Harrison [35], Konings [36], foreign companies can reduce the productivity of domestic enterprises. These studies agree that multinational companies have some special advantages due to lower marginal costs.

Furthermore, Musila & Yiheyis [37] also used the data of annual time series to explore the impact of trade openness on investment and economic growth in Kenya. Trade policy-induced openness and trade openness were estimated with different effects. Aggregate trade openness was found to have a positive impact on investment and economic growth, however, the latter effect was statistically insignificant. On the other hand, the study also found that trade policy-induced openness had a significant negative impact on investment and economic growth. The Granger test also showed that changes in trade openness tend to affect long-run economic growth through its interaction with physical capital growth in the case of Kenya. Lawal et al. [38] applied the ARDL method to Nigeria and found a negative long-run impact of trade openness on economic growth but a positive short-run impact. Keho [39] established a positive impact of trade openness on economic growth in Coted d'Ivoire over the period 1965 to 2014 using the ARDL autodistributed lag regression model. Malefane and Odhiambo [40] studied the ARDL autodistributed lag regression model to investigate the impact of trade openness on economic growth. According to the long-run empirical results obtained, trade openness has a positive and significant impact on economic growth.

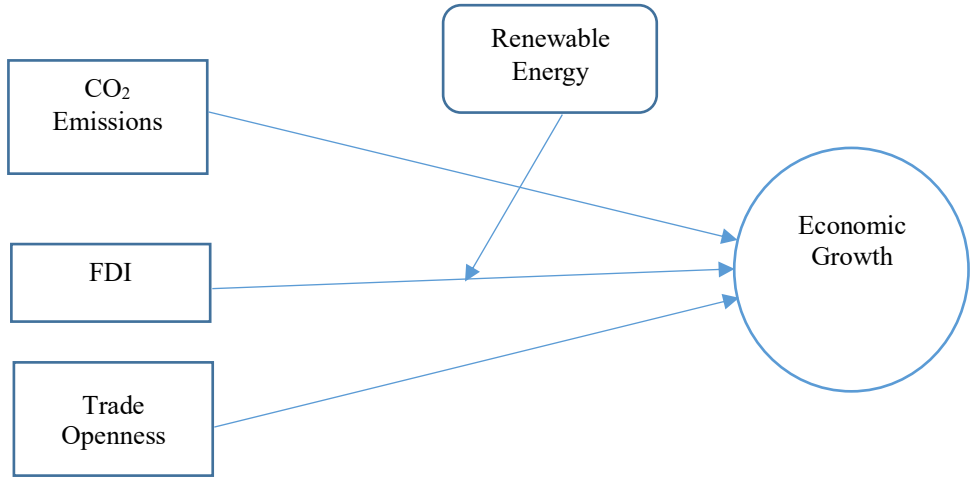


Figure 1. Research model.
Source: Authors.

Many studies have focused on CO_2 emissions for the effects on the economic growth [15, 16, 26] while this relationship is still quite complicated, the using of fossil energy or renewable energy is still controversial; at the same time, the use of renewable energy can

affect to economic growth, just like the using of green energy reduces the negative impact on the environment, at the same time the aggregate data for ASEAN countries to verify this relationship, especially for the moderating role of renewable energy has not been fully concluded, this study hopes to find convincing answers to the above problem. Studies have shown a complex relationship between economic factors, particularly foreign direct investment attraction, trade openness, or the use of renewable energy, and CO_2 emissions on the economic growth. There is still much debate on this issue. Based on these findings, the authors propose the following research model.

The model proposes that economic growth are influenced by trade openness, foreign direct investment net inflows, CO_2 emissions, and the moderating role of renewable energy. It suggests that renewable energy adoption can impact to economic growth through foreign direct investment net inflows in the economies.

3. Methods

Building on previous research [11, 15, 16], this study analyzes data from 10 ASEAN countries spanning 2001 to 2020 and the annual data was sourced 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 primary advantage of the Mixed-effects Maximum Likelihood (MLE) estimation method is its exceptional ability to handle multilevel or repeated-measures data; it automatically partitions variance into between-group and within-group components while providing unbiased estimates even with unbalanced data. This makes it well-suited for the data concerning the selected ASEAN countries. A mixed-effects model is a statistical model containing both fixed effects and random effects. These models are used to analyze data where measurements are repeated over time or where data are clustered, such as in longitudinal studies or ecological data. They are preferred over simpler regression models because they account for the non-independence of observations within subjects or groups, providing more accurate and sensitive analyses. The author proposes the following econometric model:

$GDP_{it} = a + \beta 1.\ CO2_{it} + \beta 2.\ TRADE_{it} + \beta 3.\ FDI_{it} + \beta 4.\ REN_{it} + \beta 5.\ (FDI_{it}.REN_{it}) + u_i$

Where: GRO_{it} stands for the GDP growth (%); CO_2 denotes the total of carbon dioxide emissions (kt); FDI represents foreign direct investment net inflows ($million); TRADE denotes trade openness (%); REN represents renewable energy (%).

4. Results

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

The descriptive statistics show that CO_2, FDI, and TRADE have relatively high standard deviations (139.8459, 8701.933, and 86.43294, respectively), indicating a wide range of values. GRO has a moderate standard deviation (3.724358). The average values of CO_2 (120.758) and TRADE (133.7727) are positive, while the average value of FDI (-3938.728) is negative. Descriptive statistics, such as minimum and maximum values, offer valuable insights into a database's range and distribution of data points. For instance, examining the variable CO_2 reveals a minimum value of 0.99781 in Lao PDR in 2001 and a maximum value of 605.2906 in Indonesia in 2019.

Similarly, FDI net inflows range from -58083.1 in Singapore in 2018 to 23543.53 in Thailand in 2020. Additionally, the variable GRO demonstrated a minimum of -9.51829 in the Philippines in 2020 and a maximum of 14.51975 in Singapore in 2010. Furthermore, TRADE values span from 32.97218 in Indonesia in 2010 to 437.3267 in Singapore in 2008. Finally, the variable REN ranges from 0 in Brunei Darussalam to 85.5 in Myanmar in 2009.

Table 1. Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
GRO	200	5.182678	3.724358	-9.518295	14.51975
CO_2	200	120.758	139.8459	.99781	605.2906
FDI	200	-3938.728	8701.933	-58083.1	23543.53
TRADE	200	133.7727	86.43294	32.97218	437.3267
REN	200	33.555	27.57672	0	85.5
Note: GRO_{it} stands for the GDP growth (%); CO_2 denotes the total of carbon dioxide emissions (kt); FDI represents foreign direct investment net inflows ($million); TRADE denotes trade openness (%); REN represents renewable energy (%).					

Source: Authors.

Table 2. Correlation matrix

	GRO	CO_2	FDI	TRADE	REN
GRO	1.0000				
CO2	-0.1312	1.0000			
FDI	-0.0129	-0.1530	1.0000		
TRADE	0.0354	-0.2521	-0.4430	1.0000	
REN	0.5176	-0.2726	0.2450	-0.4017	1.0000
Note: GRO_{it} stands for the GDP growth (%); CO_2 denotes the total of carbon dioxide emissions (kt); FDI represents foreign direct investment net inflows ($million); TRADE denotes trade openness (%); REN represents renewable energy (%).					

Source: Authors.

The correlation coefficients of the variables are negligible when their values are all less than 0.7, showing that the variables do not have perfect multicollinearity and are suitable for inclusion in the analysis model.

Table 3. The results of the factors impact to economic growth in the moderating role of renewable energy in ASEAN

	Model 1	Model 2
	GRO	GRO
CO_2	0.00392*	0.00239
TRADE	0.0151***	0.0169***
FDI	-0.00000281	0.0000372
REN	0.0946***	0.0883***
c.REN#c.FDI		-0.00000478*
N	200	200
Note: * p<0.05, ** p<0.01, *** p<0.001. *GROit stands for the GDP growth (%); CO_2 denotes the total of carbon dioxide emissions (kt); FDI represents foreign direct investment net inflows ($million); TRADE denotes trade openness (%); REN represents renewable energy (%).*		

Source: Authors.

Regression model results, including a mixed-effects model (Model 1) and mixed regression with moderation (Model 2). Both models show that trade openness and renewable energy have a significant positive impact on GDP growth. In Model 1, CO_2 emissions have a

positive impact on economic growth, indicating that ASEAN countries remain in the early stage of the Kuznets curve—meaning there is a trade-off between the environment and economic growth. The most notable finding is in Model 2, where the negative and significant interaction term (c.REN#c.FDI) reveals that FDI negatively moderates the positive effect of renewable energy on GDP growth. This implies that while renewable energy is beneficial for the economy, the presence of foreign direct investment may slightly diminish this positive effect. Based on the mixed regression results, both trade openness (TRADE) and renewable energy (REN) show a statistically significant positive effect on GDP growth (GRO) across both Model 1 and Model 2. Their coefficients are positive and highly significant ($p<0.001$). Conversely, carbon dioxide emissions (CO2) and foreign direct investment (FDI) do not have a significant direct impact on GDP growth (in Model 2).

The results are presented in Table 3. Renewable energy, Trade openness and Carbon dioxide emissions contributed to increasing the GDP growth, with an average increase in the economic growth of 0.08883 percent when the rate of renewable energy increases by 1 percent, which indicated a similar impact in the previous studies [12, 28].

In Table 3, the results show that the TRADE variable shows statistical significance and positively affects the economic growth in the ASEAN countries; when the Trade openness increases by 1%, GDP growth increase 0.0169 percent (in Model 2). Similar results are documented in the previous studies [11, 29], indicating a positive influence between CO_2 emissions and economic growth in these countries. Meanwhile, CO_2 emissions have positive effect to economic growth. This result shows a trade-off between economic growth and environmental emissions, which means that ASEAN countries must either accept this trade-off or find ways to change with environmentally friendly production activities, towards green growth.

In particular, A key finding is presented in Model 2, where the interaction term between renewable energy and FDI (c.REN#c.FDI) is negative and statistically significant ($p<0.05$), the moderating effect of renewable energy on the relationship between foreign direct investment and economic growth is that the interaction term between REN and FDI carries a negative and statistically significant coefficient ($\beta = -0.00000478$, $p < 0.05$), indicating a slight decline in the marginal impact of renewable energy on economic growth as FDI inflows increase. These results also align with the previous studies [28], but it is different from other studies [24, 25] due to some reasons, such as the scope and object of research.

5. Conclusion

This study further reinforces the important role of trade openness and renewable energy in growth in ASEAN economies, where trade openness is increasing along with the interest of countries in the region in green growth, renewable energy and emissions. It is noteworthy that CO2 emissions continue to be a matter of concern when considering the relationship between environment and growth in these countries. In addition, the moderating role of renewable energy in mitigating the contribution of FDI to economic growth is also an important part of the process of re-evaluating the impact of foreign direct investment issues towards sustainable growth in the future.

Furthermore, the results suggest that promoting renewable energy significantly increases the impact of foreign direct investment inflows on the economic growth in ASEAN, which should pay attention to the investment problems and boost the rate of renewable energy in the economy. Transitioning to renewable energy lessens dependence on finite fossil fuels, stabilizes energy prices, and enhances energy security. As an infinite resource, renewable safeguard the environment and support sustainable development for future generations. Green transformation is an inevitable trend of countries in the world, in which emerging economies in the ASEAN region need to pay

more attention to green growth and sustainable development. Paying more attention to the ecological environment and using renewable energy plays an important role in the green transformation trend towards a sustainable development future for ASEAN countries.

While research has clarified certain aspects of economic growth in relation to CO2 emissions, FDI, trade openness, and renewable energy, further study is needed to incorporate other growth factors—such as human capital and technology-and to expand the geographical scope to Asia or the global level, thereby ensuring a more comprehensive cross-regional perspective.

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