Society, 11 (2), 771-786, 2023
P-ISSN: 2338-6932 | E-ISSN: 2597-4874
https://society.fisip.ubb.ac.id

# The Impact of Economic Growth, Foreign Direct Investment, Population, and Energy Consumption on Carbon Dioxide Emissions in Six ASEAN Countries During the Period 2000-2021

**Yohanes Berchman Suhartoko [1], and Monica Gede Dewinta Ekaristi [2,*]**
[1] Department of Applied Economics, Universitas Katolik Indonesia Atma Jaya, Jakarta, 12930, Indonesia
[2] Department of Development Economics, Universitas Katolik Indonesia Atma Jaya, Jakarta, 12930, Indonesia
* Corresponding Author: gede_monicaa@yahoo.com

## ARTICLE INFO

***Publication Info:***
*Research Article*

***How to cite:***
*Suhartoko, Y. B., & Ekaristi, M. G. D. (2023). The Impact of Economic Growth, Foreign Direct Investment, Population, and Energy Consumption on Carbon Dioxide Emissions in Six ASEAN Countries During the Period 2000–2021. Society, 11(2), 771-786.*

***DOI:*** *10.33019/society.v11i2.557*



**Received:** May 17, 2023;
**Accepted:** December 30, 2023;
**Published:** December 31, 2023;

## ABSTRACT

*The increase in CO2 emissions has led to a rise in global temperatures. The rising CO2 emissions in ASEAN need further examination concerning the variables influencing this increase. This study aims to test and obtain empirical evidence on the determinants of CO2 emissions in six ASEAN countries (Indonesia, Malaysia, the Philippines, Singapore, Thailand, and Vietnam) during the period 2000–2021. The factors considered in this study include Economic Growth (GGDP), Foreign Direct Investment (FDI), Total Population (POP), Fossil Energy Consumption (EF), and Renewable Energy Consumption (GET). This research employs panel data regression using both time series and cross-sectional data. The Chow and Hausman tests were conducted to determine the appropriate model, and the fixed-effect model was selected as the best fit. This research demonstrates that GET has an insignificant relationship with CO2 emissions, whereas GGDP, FDI, POP, and EF have significant relationships with CO2 emissions. In conclusion, considering all the independent variables in this study that affect CO2 emissions, future efforts should focus on finding ways to control these variables to reduce CO2 emissions.*

***Keywords:*** *Carbon Emissions; Foreign Direct Investment; Fossil Fuel Consumption; GDP Growth; Panel Data; Population; Renewable Energy Consumption Growth*

## 1. Introduction

In economic terms, traditional development refers to a situation where a sustainable per capita income growth rate is achieved, allowing a country to increase its output faster than its population growth. Economic development is intricately linked to efficiently allocating scarce productive and natural resources, promoting sustainable growth over time. Given this interdependence, the attainment of economic development in a country is also challenged by economic, social, political, and institutional mechanisms, both in the public and private sectors (Todaro & Smith, 2015). Economic development is closely related to economic growth because economic development can stimulate economic growth, and conversely, economic growth can facilitate economic development (Apriliana, 2021). To support high economic growth rates, the government and society can enhance their productivity to generate additional output supporting economic growth. However, high productivity levels in society have environmental consequences, such as waste generation due to human activities. Environmental degradation is a form of environmental damage that indicates a decline in environmental quality and is often associated with increased economic activities that do not consider environmental impacts. Addressing the decline in environmental quality is a top priority for ASEAN countries, including Brunei, Myanmar, Singapore, Thailand, the Philippines, Laos, Vietnam, Cambodia, Indonesia, and Malaysia (Santi & Sasana, 2021).

One significant form of environmental degradation resulting from irresponsible economic activities is the emission of greenhouse gases (GHGs). GHGs include gases such as methane (CH4), nitrous oxide (N2O), and carbon dioxide (CO2). Within these categories of gases, there are also fluorinated gases (HFCs, PFCs, and SF6). Among these GHGs, carbon dioxide (CO2) significantly impacts global warming, contributing to approximately 75% of the total (Hariani et al., 2022). The increase in CO2 emissions leads to climate change, which affects life on a global scale, causing alterations in terrestrial and marine environments (Akbar, 2019). Rising levels of CO2 emissions can also damage the ozone layer, leading to increased global temperatures.

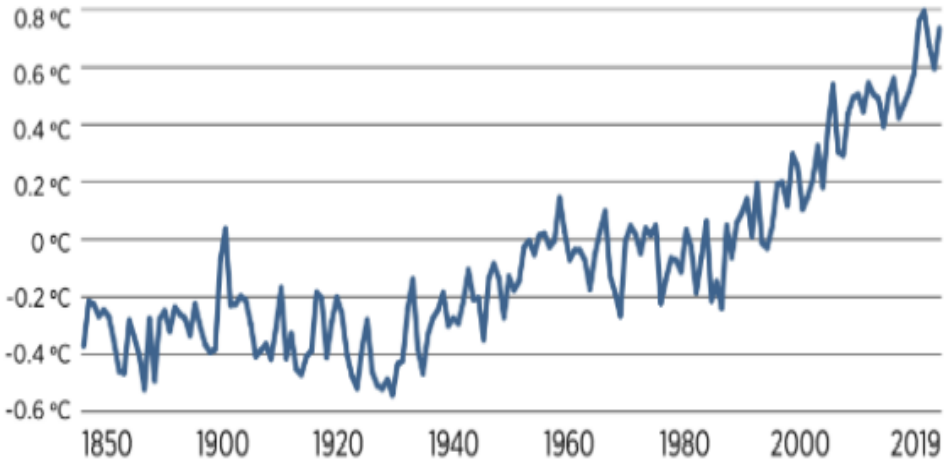


**Figure 1. Earth Temperature from 1880 to 2022**
Source: (Katadata Insight Center, 2022)

In **Figure 1**, it can be observed that the average surface temperature of the Earth increased by approximately 1.1 degrees Celsius from the late 1800s to 2020. This rise in Earth's average surface temperature has led to heatwaves, reducing human capacity to work and diminishing productivity. According to Our World in Data data, Asia accounted for a total CO2 emission of


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457 billion tons, or 29% of global cumulative emissions, in 2017. The six ASEAN countries contributed 31.9 billion tons, or 2.1% of Asia's emissions (Ritchie et al., 2020). Below is a graph depicting CO2 emissions in these six ASEAN countries: Indonesia, Malaysia, the Philippines, Singapore, Thailand, and Vietnam.

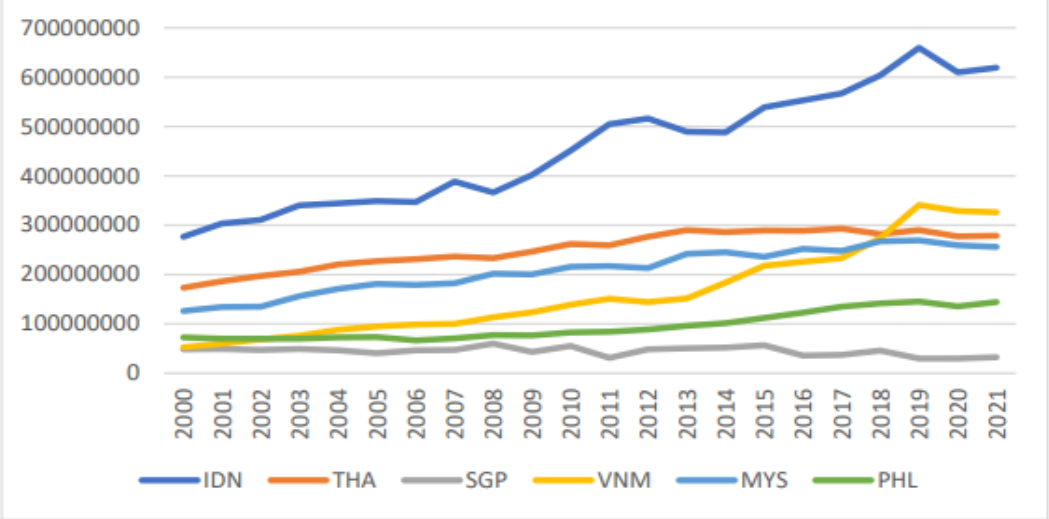


**Figure 2. CO2 Emissions in 6 ASEAN Countries**
Source: (Ritchie et al., 2020)

**Figure 2** illustrates fluctuating CO2 emissions in each ASEAN country from 2000 to 2021. During this period, noticeable variations in CO2 emissions are evident, with Indonesia registering the highest emissions, followed by Thailand, Malaysia, Vietnam, the Philippines, and Singapore. These fluctuations underscore the complexities of environmental sustainability within the region. The global landscape, particularly within the ASEAN member states, is characterized by elevated CO2 emissions, highlighting the underlying driving forces behind this phenomenon. One prominent contributor to the rising CO2 emissions is the intensified reliance on fossil energy to support societal activities and enhance productivity. Fossil energy accounts for approximately 70% of the world's energy demand, with Southeast Asia contributing approximately 8% to global energy growth. Given these circumstances, there is a pressing need for a gradual transition toward alternative energy sources to replace non-renewable or fossil energy, thereby mitigating environmental impact.

Dietz & Rosa, architects of the Impact, Population, Affluence, and Technology (IPAT) model, posit that the surge in CO2 emissions is driven by diverse anthropogenic factors, including population size, economic activities, technological advancements, political and economic institutions, as well as prevailing attitudes and beliefs (Dietz & Rosa, 1997). Both population growth and economic development are pivotal variables influencing CO2 emissions. Additionally, the influence of Foreign Direct Investment (FDI) on CO2 emissions is acknowledged, with the Pollution Haven Hypothesis and the Pollution Halo Hypothesis offering contrasting perspectives on the intricate relationship between FDI and environmental pollution.

In conclusion, the multifaceted factors contributing to CO2 emissions, as elucidated by these various frameworks and observations, underscore the complexity of addressing environmental challenges. The imperative for transitioning to sustainable energy sources and understanding the intricate interplay of population dynamics, economic development, and


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foreign investment becomes increasingly apparent in pursuing a more environmentally resilient and balanced future.

Based on the previous exposition and research, this study aims to analyze the influence of economic growth, foreign direct investment, population size, and energy consumption on CO2 emissions in the six ASEAN member countries from 2000 to 2021. This research combines economic and energy variables to examine their relationship with carbon dioxide emissions and identify policies that can effectively reduce them. 2000–2021 was chosen as it marks a significant increase in carbon dioxide emissions.

## 2. Hypothesis Development

### 2.1. The Relationship between Economic Growth and CO2 Emissions

Economic growth is closely related to environmental conditions, a relationship often explained by the Environmental Kuznets Curve (EKC) theory. Kuznets introduced the concept of economic growth as a key factor in long-term income distribution changes. Kuznets' hypothesis suggests that income inequality initially increases with economic growth, but after reaching a certain point, it decreases as economic development continues (Kuznets, 1955). The EKC hypothesis extends this idea to environmental degradation, proposing that as economic growth increases, environmental degradation initially worsens but eventually declines as further growth occurs.

Below is an image illustrating the EKC theory.

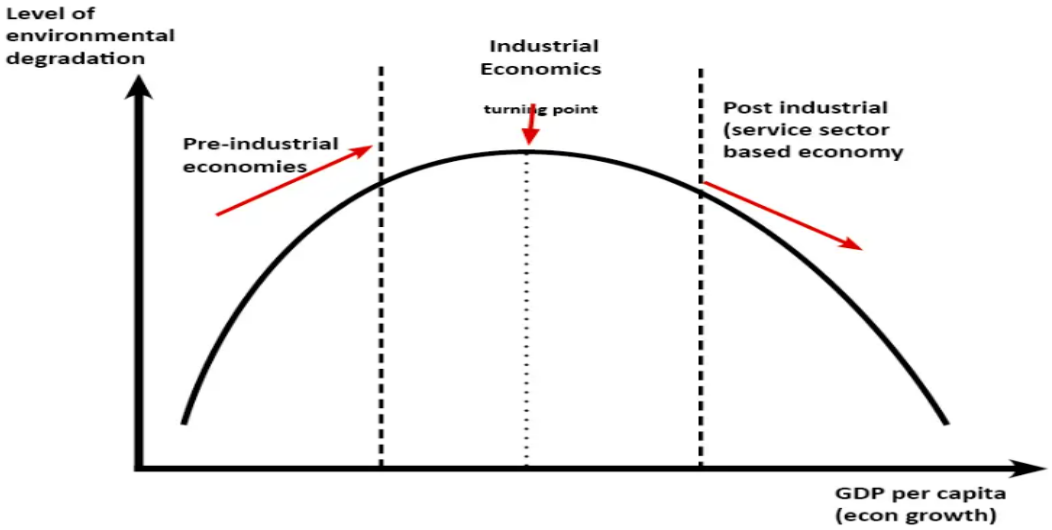


**Figure 3. Environmental Kuznets Curve**
Source: (Panayotou, 1993)

**Figure 3** depicts the relationship between changes in economic structure and economic growth, dividing the EKC into three stages: the pre-industrial economy, the industrial economy, and the post-industrial economy. In the first stage, economic growth transitions from the agricultural sector to the industrial sector, leading to significant environmental degradation due to the shift from rural to urban settings and from agriculture to industry (Panayotou, 1993). This trend continues in the second stage, where investments further drive economic transformation. In the third stage, the economy shifts from the industrial sector to the service sector, accompanied by a reduced air pollution as income grows.


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At lower income levels, countries transition from agriculture to industry, causing an increase in pollution intensity due to higher production and consumption, greater natural resource utilization, and increased pollution emissions. Conversely, at higher income levels, economic development is dominated by the post-industrial or service-based economy. In this stage, environmental awareness rises, environmental expenditures increase, efficient technologies are adopted, and the demand for environmentally friendly goods and services grows (Alam et al., 2016). As a result, the industrial sector becomes cleaner, societal values shift towards environmental preservation, and regulations become more effective (Dasgupta et al., 2002).

Hariani et al. stated that economic growth positively and significantly impacts CO2 emissions, meaning that as economic growth increases, CO2 emissions also rise significantly (Hariani et al., 2022). This finding aligns with Kizilkaya, who also found economic growth's positive and significant impact on CO2 emissions. However, some researchers disagree (Kizilkaya, 2017). For example, Santi & Sasana argued that economic growth has a negative and insignificant impact on CO2 emissions, suggesting that as economic activities increase, people become more environmentally conscious and engage in activities that do not contribute to increased CO2 emissions (Santi & Sasana, 2021).

This research posits that increasing economic growth will significantly increase CO2 emissions in six ASEAN countries. Therefore, the proposed hypothesis is as follows:

**H1**: Economic growth has a significant positive effect on CO2 emissions in six ASEAN countries.

### 2.2. The Relationship between Foreign Direct Investment and CO2 Emissions

Foreign Direct Investment (FDI) influences environmental pollution, with two key hypotheses describing the relationship between FDI and environmental pollution: the Pollution Haven Hypothesis and the Pollution Halo Hypothesis.

#### 2.2.1. Pollution Haven Hypothesis

The Pollution Haven Hypothesis suggests that companies seeking investment opportunities explore developing countries due to their lower taxes and less stringent CO2 emission regulations. Khastar et al. explain that, under this hypothesis, foreign companies might exploit the strict environmental regulations in their home countries by relocating environmentally harmful industries to developing nations through FDI, leading to increased emissions in the recipient countries (Khastar et al., 2020).

The hypothesis argues that in a liberalized trade environment, industries migrate from wealthy countries with stringent environmental regulations to less affluent nations with lax standards, making them attractive for investment. Conversely, industries with environmentally friendly practices tend to remain in developed countries with stricter regulations. The Pollution Haven Hypothesis highlights the adverse environmental impact of this dynamic, particularly in developing countries that, while offering cheap labor and abundant resources, may lack stringent environmental laws.

Thus, an influx of companies seeking investment could potentially lead to environmental degradation in the host country. This hypothesis emphasizes the complex relationship between economic considerations, environmental regulations, and global investment patterns, underscoring the need for balanced policies that consider economic development and environmental sustainability.


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### 2.2.2. Pollution Halo Hypothesis

In contrast to the Pollution Haven Hypothesis, the Pollution Halo Hypothesis, posited by Copeland & Taylor, suggests that FDI can mitigate environmental pollution in host countries (Copeland & Taylor, 2004). This hypothesis contends that foreign investments enhance energy efficiency, technology diffusion, and improved management practices, collectively fostering a cleaner and more sustainable environment in the recipient nation (Aisah, 2019).

Unlike the Pollution Haven Hypothesis, which focuses on the environmental benefits in the home country due to increased productivity, energy efficiency, and better management, the Pollution Halo Hypothesis emphasizes the positive environmental outcomes within the host country. It suggests that FDI acts as a conduit for technology transfer and the development of advanced management skills, leading to more efficient production processes, reduced energy consumption per output unit, and a significant decrease in greenhouse gas emissions (Zarsky, 1999).

Thus, the Pollution Halo Hypothesis offers an optimistic view of the potential environmental benefits of FDI, highlighting the importance of technology transfer and skill development in fostering sustainable practices in host countries.

Mert & Bölük found that FDI significantly reduces CO2 emissions in countries adhering to the Kyoto Protocol, supporting the Pollution Halo Hypothesis (Mert & Bölük, 2016). However, Santi & Sasana argued that while FDI positively impacts CO2 emissions, it is not statistically significant, suggesting that increased investments may exacerbate the environmental burden and reduce environmental quality, aligning with the Pollution Haven Hypothesis (Santi & Sasana, 2021).

This research argues that increasing FDI will significantly reduce CO2 emissions in six ASEAN countries. Therefore, the proposed hypothesis is as follows:

**H2**: Foreign Direct Investment significantly negatively affects CO2 emissions in six ASEAN countries.

### 2.3. The Relationship between Population and CO2 Emissions

Population growth, whether due to immigration or a higher birth rate, impacts natural resources and social infrastructure, posing challenges to a nation's sustainability. Significant population expansion adversely affects land availability for agriculture and increases pressure on resources such as food, energy, water, social services, and infrastructure. As population growth continues, demand for goods and services escalates, leading to resource depletion and increased environmental pollution (Suparmoko, 1997). In The Lancet in 1994, Colin Butler noted that overpopulation has economic consequences due to resource use. In 2017, more than 50 Nobel laureates surveyed by Times Higher Education identified human overpopulation and environmental degradation as the two greatest threats facing humanity.

Hariani et al. found that the total population positively and significantly impacts CO2 emissions in 10 ASEAN countries, arguing that an increase in population leads to more energy consumption, including electricity and fuel usage, resulting in higher CO2 emissions (Hariani et al., 2022). In contrast, Abdouli et al. suggested that population density has a negative and significant relationship with CO2 emissions, arguing that higher population density makes people more aware of the environmental impact of their activities, leading to reduced CO2 emissions (Abdouli et al., 2018).

This research posits that population growth will significantly increase CO2 emissions in six ASEAN countries. Therefore, the proposed hypothesis is as follows:


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**H3**: Population has a significant positive effect on CO2 emissions in six ASEAN countries.

### 2.4. The Relationship between Fossil Energy Consumption and CO2 Emissions

Fossil energy, generated from the combustion of fossil fuels, is classified as conventional energy due to its finite nature. Continuous use of fossil energy can lead to various environmental issues. Amalia et al. stated that fossil fuels produce carbon emissions when burned, releasing them into the atmosphere (Amalia et al., 2022).

A'nnisa et al. noted that increased fossil energy use can cause environmental problems, especially in large cities, mining, and other sectors heavily reliant on fossil energy (A'nnisa et al., 2020). Using fossil energy has implications for the local environment as it increases CO2 emissions, which can negatively impact public health.

Begum et al. found that per capita fossil energy consumption positively and significantly impacts CO2 emissions, indicating that any increase in per capita energy consumption leads to a corresponding increase in CO2 emissions (Begum et al., 2015). This finding aligns with Santi & Sasana, who stated that fossil energy consumption positively and significantly impacts CO2 emissions in eight ASEAN countries (Santi & Sasana, 2021). Therefore, higher energy consumption results in higher CO2 emissions.

This research argues that increasing fossil energy consumption will significantly increase CO2 emissions in six ASEAN countries. Therefore, the proposed hypothesis is as follows:

**H4**: Fossil energy consumption has a significant positive effect on CO2 emissions in six ASEAN countries.

### 2.5. The Relationship between Renewable Energy Consumption and CO2 Emissions

Renewable energy, derived from natural sources that can be replenished, is considered environmentally friendly and an alternative to fossil fuels. The adoption of renewable energy not only improves environmental conditions but also helps conserve finite fossil energy resources.

Renewable energy sources produce fewer emissions and, in some cases, none. Their widespread use is expected to promote environmentally friendly economic growth (Rahmandani & Dewi, 2023). Renewable energy is crucial in economic development as it enhances energy security by providing reliable, widely available, and environmentally friendly energy, essential for sustainable economic growth. Renewable energy offers social and environmental benefits by reducing carbon emissions released into the environment (Rahmandani & Dewi, 2023).

Zulaicha et al. found that renewable energy consumption has a negative and non-significant impact on CO2 emissions (Zulaicha et al., 2020). Therefore, renewable energy consumption is a positive step toward reducing CO2 emissions, but it may not have a significant impact.

This research posits that increasing renewable energy consumption will significantly decrease CO2 emissions in six ASEAN countries. Therefore, the proposed hypothesis is as follows:

**H5**: Renewable energy consumption significantly negatively affects CO2 emissions in six ASEAN countries.


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## 3. Research Methodology

This research utilizes secondary data, specifically panel data, which integrates time series and cross-sectional dimensions. The time series component spans 21 years, covering 2000 to 2021. The cross-sectional component includes data from six countries: Indonesia, Malaysia, the Philippines, Singapore, Thailand, and Vietnam. The sources of the secondary data used in this study are detailed below.

**Table 1. Dependent and Independent Variables with Their Sources**

| Variable | Unit | Data Source |
|---|---|---|
| **Dependent Variable** | | |
| Carbon Dioxide (CO2) Emissions | Billion tons | (Ritchie et al., 2020) |
| **Independent Variables** | | |
| Economic Growth (GDP) | Percent (%) | (World Bank, 2015) |
| Foreign Direct Investment (FDI) | Net Inflows (US$) | (World Bank, 2015 |
| Total Population (POP) | Persons | (World Bank, 2015 |
| Fossil Energy Consumption (EF) | Terawatt-hour (TWh) | (Ritchie et al., 2020) |
| Renewable Energy Consumption (ET) | Percent (%) | (Ritchie et al., 2020) |

The data analysis method employed in this research is panel data regression. Panel data regression allows analyzing data across both spatial and temporal dimensions. The spatial dimension pertains to a set of cross-sectional observation units in this study are the countries. The temporal dimension pertains to periodic observations of variables over time, represented by the years in this study. Panel data regression is used to increase the statistical power of the analysis, produce realistic R-squared values, and avoid spurious regression results (Enders, 2004). The stationarity of each variable is tested using the Phillips-Perron (PP) test (Phillips & Perron, 1988). The panel regression model estimated in this study is as follows:

$$CO_{2it} = \alpha + \beta_1 GGDP_{1it} + \beta_2 FDI_{2it} + \beta_3 POP_{3it} + \beta_4 EF_{4it} + \beta_5 GET_{5it} + e_{it}$$

Explanation:
$i$ = Country $i$
$t$ = Period $t$
$CO_2$ = Carbon Dioxide Emissions
GGDP = Economic Growth
FDI = Foreign Direct Investment
POP = Population
EF = Fossil Energy Consumption
GET = Growth of Renewable Energy Consumption

## 4. Results and Discussion

### 4.1. Results

#### 4.1.1. Model Selection

In panel data regression, there are three models to consider: the common effect model, the fixed effect model, and the random effect model. We use the Chow test to compare the common effect model with the fixed effect model to determine the best model. If the Chow test


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indicates that the fixed effect model is preferred, we then proceed with the Hausman test to choose between the fixed and random effect models. Conversely, if the Chow test selects the common effect model, a multiple-range test compares it with the random effect model.

**Table 2. Results of Chow Test and Hausman Test**

| Description | Prob. | Model Selected |
|---|---|---|
| Chow Test | 0.0000 | Fixed Effect Model |
| Hausman Test | 0.0000 | Fixed Effect Model |

Based on the results presented in **Table 2**, the Fixed Effect Model (FEM) is determined to be the most appropriate model for this study. The Chow test selects between the common and fixed effect models. The decision is based on the probability value of the cross-section F-test. If the probability value is greater than 0.05, the common effect model is selected; if it is less than 0.05, the fixed effect model is chosen. As shown in **Table 2**, the probability value is 0.0000, which is less than 0.05, indicating that the fixed effect model is selected. The Hausman test compares the fixed effect model with the random effect model. The decision is based on the probability value of the cross-section random term. If the probability value is greater than 0.05, the random effect model is selected; if it is less than 0.05, the fixed effect model is chosen. **Table 2** shows that the probability value is 0.0000, which is less than 0.05, confirming the selection of the fixed effect model.

**Table 3. Results of Panel Data Regression with Fixed Effect Model (FEM)**

| Variable | Coefficient | Std. Error | Prob. |
|---|---|---|---|
| GGDP | 129,328,670.4 | 59,442,006 | 0.0315 |
| FDI | -0.00111019 | 0.000137 | 0.0000 |
| POP | 2.793558 | 0.274610 | 0.0000 |
| EF | 233,495.9 | 14,201.85 | 0.0000 |
| GET | -283,939.87 | 1,317,330 | 0.8297 |

The panel data regression results reveal an R-squared value of 0.984250, indicating that 98% of the variability in the dependent variable is explained by the independent variables collectively. The regression outputs also show a probability F value of 0.000000. Since this value is less than the specified alpha level of 5%, it suggests that the combined influence of all independent variables on the dependent variable is statistically significant.

As observed in **Table 3**, the GGDP, FDI, POP, and EF variables significantly influence CO2 emissions. However, the GET variable does not have a significant impact. The regression equation derived from the Fixed Effect Model is:

$$CO_2 = -236872582.574 + 129328670.4GGDP_{1it} - 0.00111019334377FDI_{2it} + 2.79355842676POP_{3it} + 233495.998482EF_{4it} - 283939.874345GET_{5it} + e_{it}$$

The results of the panel data regression using the Fixed Effect Model indicate variations in data characteristics among countries, as evidenced by the differing constants. Consequently, the regression equation incorporating country-specific effects is as follows:


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$$CO_2 = -236872582.574 + 129328670.4GGDP_{1it} - 0.00111019334377FDI_{2it} + 2.79355842676POP_{3it} + 233495.998482EF_{4it} - 283939.874345GET_{5it} - 13871514_{6i} - 363000000_{7i} + 152000000_{8i} + 150000000_{9i} + 38614297_{10i} + 36308085_{11i} + U_{it}$$

## 4.2. Discussion

### 4.2.1. The Influence of GDP on CO2 Emissions

In descending order between 2000 and 2021, the countries with the highest economic growth were Vietnam, Thailand, the Philippines, Singapore, Malaysia, and Indonesia. **Figure 4** illustrates the economic growth in these six ASEAN countries.

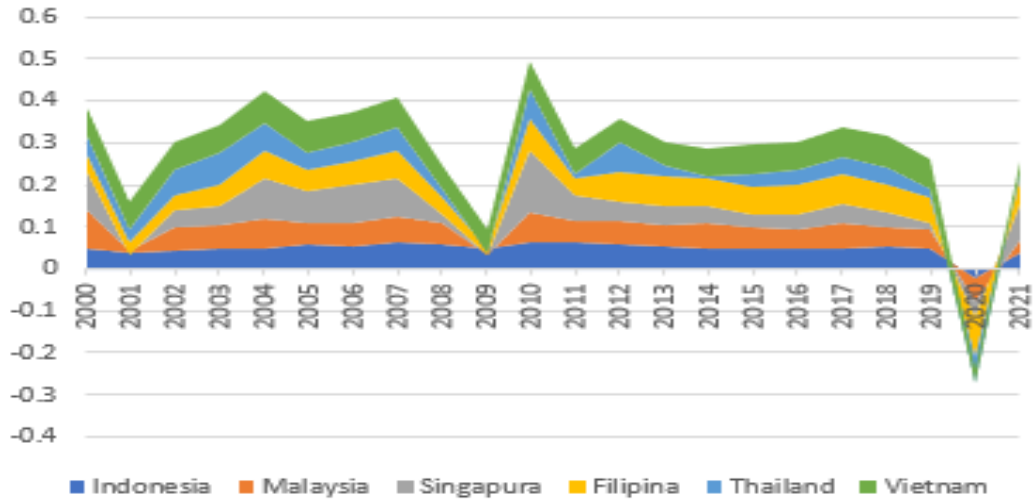


**Figure 4. Real Economic Growth (GDP) in 6 ASEAN Countries**
Source: (World Bank, 2015)

The regression analysis reveals a significant positive correlation between economic growth and carbon dioxide (CO2) emissions. This indicates that there is a corresponding increase in CO2 emissions as economic growth progresses. This finding aligns with the Environmental Kuznets Curve (EKC) hypothesis, which suggests that economic development initially leads to increased environmental degradation. Still, eventually, economic growth will lead to improved environmental conservation efforts and a subsequent decline in environmental impact. The early stages of industrial growth often result in heightened environmental damage, with the expectation that economic advancement will foster better environmental practices over time, leading to reduced emissions. This study's findings are consistent with previous study (Hariani et al., 2022), demonstrating a positive and significant relationship between economic growth and CO2 emissions .

### 4.2.2. The Influence of FDI on CO2 Emissions

From 2000 to 2021, Singapore experienced the largest foreign direct investment (FDI) inflows.


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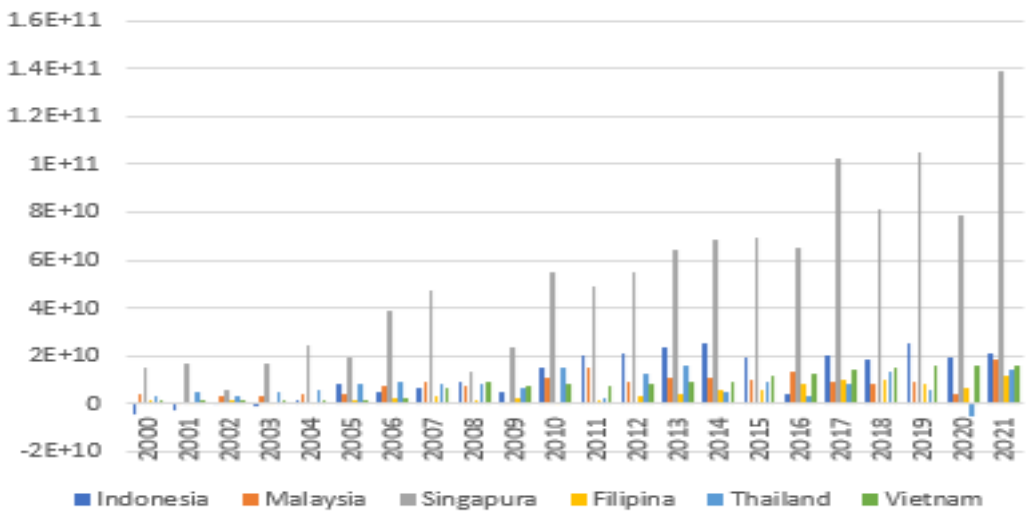


**Figure 5. Foreign Direct Investment (FDI) in 6 ASEAN Countries**
Source: (World Bank, 2015)

The regression results indicate that FDI significantly negatively impacts CO2 emissions. This finding is consistent with previous study (Mert & Bölük, 2016) which found a robust negative relationship between FDI and CO2 emissions. The rationale behind this relationship is that foreign investment often brings technological advancements that improve environmental standards, thereby reducing carbon emissions. This observation supports the Pollution Halo Hypothesis, which suggests that increasing foreign investment decreases CO2 emissions by enhancing manufacturing efficiency through advanced technologies. These findings highlight the positive environmental externalities associated with FDI and the importance of considering economic and environmental impacts in global investment strategies.

### 4.2.3. The Influence of Population on CO2 Emissions

Throughout the research period, Indonesia had the largest population among the six ASEAN countries, ranging from approximately 214 million to 270 million. This was followed by the Philippines (77 million to 113 million people), Vietnam (79 million to 97 million people), Thailand (63 million to 71 million people), Malaysia (22 million to 33 million people), and Singapore (4 million to 5 million people).


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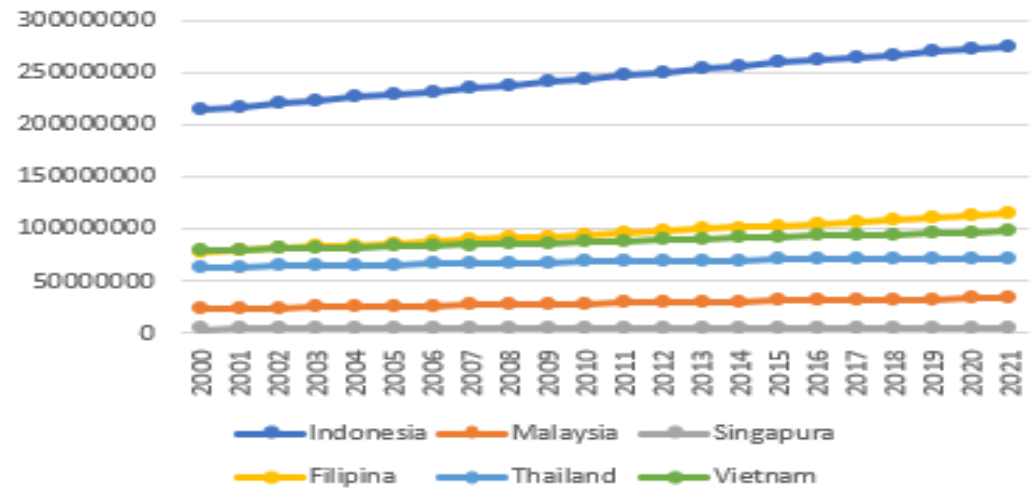


**Figure 6. Population (POP) of the 6 ASEAN Countries**
Source: (World Bank, 2015)

The regression results show a positive and significant relationship between population size and CO2 emissions. This finding aligns with previous study (Hariani et al., 2022), which also found that population density significantly influences CO2 emissions. As the population grows, the demand for goods and services increases, leading to higher production levels and, consequently, greater CO2 emissions. This underscores the complex interplay between population growth and environmental impact, emphasizing the need for sustainable strategies that balance demographic trends with ecological preservation.

### 4.2.4. The Influence of Fossil Energy Consumption on CO2 Emissions

During the research period, Indonesia had the highest consumption of fossil energy, followed by Thailand, Malaysia, Singapore, Vietnam, and the Philippines.

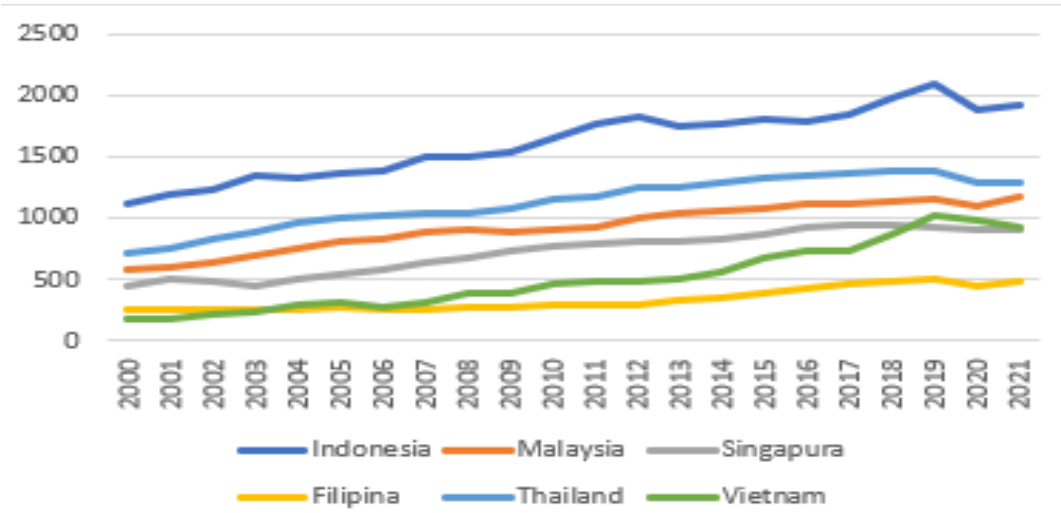


**Figure 7. Fossil Energy Consumption (EF) in 6 ASEAN Countries**
Source: (Ritchie et al., 2020)

The regression results indicate a positive and significant relationship between fossil energy consumption and CO2 emissions. This finding is consistent with Kizilkaya, which found that


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energy consumption significantly impacts CO2 emissions (Kizilkaya, 2017). The positive correlation highlights the carbon-intensive nature of fossil fuels, where increased consumption leads to higher CO2 emissions. Addressing energy consumption patterns is crucial for environmental sustainability, and transitioning to cleaner energy sources is essential for reducing CO2 emissions and mitigating climate change.

### 4.2.5. The Influence of Renewable Energy Consumption on CO2 Emissions

Vietnam had the highest consumption of renewable energy, followed by Indonesia, the Philippines, Malaysia, Thailand, and Singapore.

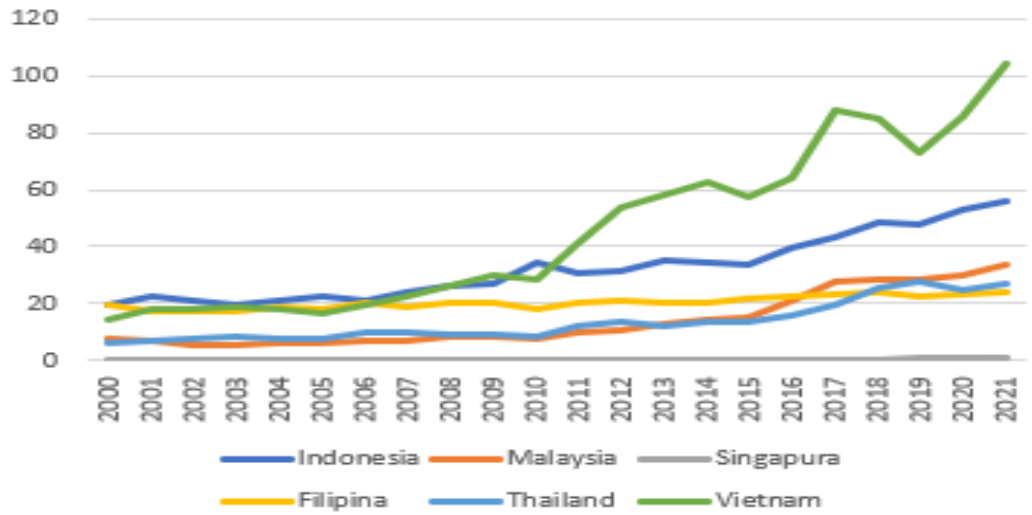


**Figure 8. Renewable Energy Consumption (RE) in 6 ASEAN Countries**
Source: (Ritchie et al., 2020)

The regression results indicate that renewable energy consumption has a negative but statistically non-significant impact on CO2 emissions. This lack of significance may be due to the relatively small proportion of renewable energy compared to conventional sources like coal, oil, and gas. Despite the growing adoption of renewable energy, its impact on reducing global carbon emissions may not be substantial. This observation is consistent with Zulaicha et al., which found that renewable energy consumption is negatively associated with CO2 emissions, but the effect is not statistically significant (Zulaicha et al., 2020). The transition to renewable energy requires substantial investments and time to reduce carbon emissions significantly. Continued commitment and innovative policies are essential to accelerate this transition and reduce CO2 emissions.

## 5. Conclusion

This research investigates the impact of various factors on CO2 emissions across six ASEAN countries: Indonesia, Malaysia, Singapore, the Philippines, Thailand, and Vietnam. The study reveals that Economic Growth, Foreign Direct Investment (FDI), Population, and Fossil Energy Consumption significantly influence CO2 emissions, while Renewable Energy Consumption does not have a statistically significant effect.

The findings highlight the critical need for governments to address environmental challenges related to human and economic activities. Policymakers need to develop and implement proactive strategies to mitigate carbon emissions. Such measures should include


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promoting renewable energy sources, incentivizing environmentally friendly industries, and imposing carbon taxes on industrial activities.

Particularly noteworthy is the study's finding that FDI has a negative impact on CO2 emissions. Governments are encouraged to design policies that increase FDI, especially in sustainable industries, to reduce CO2 emissions further and align economic development with environmental sustainability.

In summary, this research emphasizes the complex interactions between various factors influencing CO2 emissions in the ASEAN region and provides actionable recommendations for policymakers. A comprehensive approach to addressing these environmental issues is crucial for achieving sustainable development and conserving the environment.

## 6. Acknowledgment

The authors thank those willing to cooperate profusely during this research.

## 7. Declaration of Conflicting Interests

The authors have declared no potential conflicts of interest concerning this article's research, authorship, and/or publication.

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**About the Authors**

**1)** **Yohanes Berchman Suhartoko** obtained his Doctoral degree from Universitas Gadjah Mada, Indonesia, in 2013. The author is an Assistant Professor at the Department of Applied Economics, Universitas Katolik Indonesia Atma Jaya, Indonesia.

**2)** **Monica Gede Dewinta Ekaristi** is a student of the Department of Developmet Economics, Universitas Katolik Indonesia Atma Jaya, Indonesia.
E-Mail: gede_monicaa@yahoo.com


https://doi.org/10.33019/society.v11i2.557