

Research article

Analysis of Determinants of Foreign Direct Investment, Economic Growth, Energy Consumption, Population, and Forest Area on Greenhouse Gas Emissions in ASEAN Countries

Rizal Dzaki Ferdiansyah¹ Rifki Khoirudin²

¹Faculty of Economics and Business, Universitas Ahmad Dahlan

Corresponding email: rizal2000010096@webmail.uad.ac.id

Abstract: The issue of climate change is currently in the spotlight, especially on a global scale. Climate change refers to long-term changes in weather conditions, including changes in precipitation, temperature, and wind patterns. Based on the pressure from the IPCC (Intergovernmental Panel on Climate Change), the research method used is quantitative adopted with the use of secondary data obtained from Our World in Data. The secondary data used as a reference consists of panel data that combines cross-sectional and time series data. The time series data analyzed spans the period 2012 to 2021, while the cross-sectional data covers the region of ten ASEAN countries to be sampled. FDI has no significant relationship with greenhouse gas (CO₂) emissions. Economic growth has a positive but insignificant relationship with greenhouse gas (CO₂) emissions. Energy consumption has a positive but insignificant influence on greenhouse gas emissions (CO₂). population and forest area have a positive and significant influence on greenhouse gas emissions (CO₂).

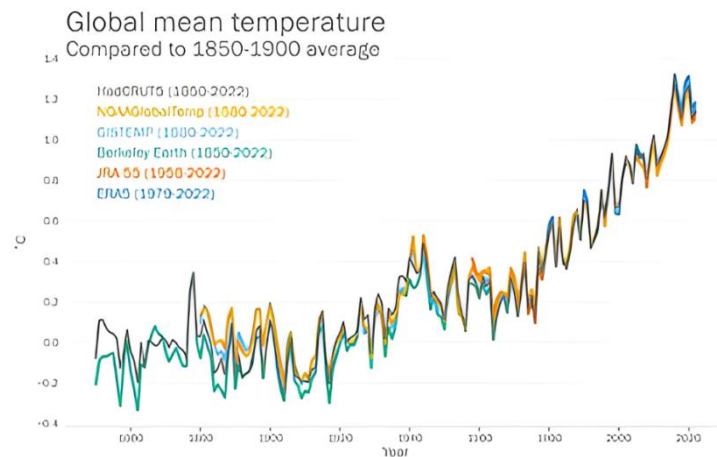
Keywords: greenhouse gas, foreign direct investment, economic growth, energy consumption, population, forest area

INTRODUCTION

The issue of climate change is currently in the spotlight, especially on a global scale. Climate change refers to long-term changes in weather conditions, including changes in precipitation, temperature, and wind patterns. Based on pressure from the IPCC (Intergovernmental Panel on Climate Change), the United Nations has stated that natural conditions such as erratic climate caused by human activities are crucial issues that affect human survival (Hapsari, 2021). Human activities in economic development, especially in the industrial sector, coupled with the use of fossil energy or technology that is not environmentally friendly, are the causes of climate change, this is because industrial activities in the process produce greenhouse gas emissions (carbon dioxide (CO₂), chlorofluorocarbons (CFCs), methane (CH₄), and nitrous oxide (N₂O)) which are in the earth's atmosphere causing solar radiation to be trapped in the atmosphere. High concentrations of CO₂ gas in the atmosphere cause global temperature increases due to the greenhouse effect (Fauzi, 2017).

Increasing greenhouse gas (CO₂) emissions have a direct effect on the quality of the environment, which from time to time there is a significant increase in temperature on the earth's surface. (Sheikh, 2022), states that the signs and impacts of climate

change are becoming increasingly dramatic. The rate of sea level rise has doubled since 1993. This represents an increase in sea level of almost 10 mm since January 2020, which is a new record for this year.



Source: World Meteorology Organization 2022

The global warming trend reflected in the graph in figure above recorded information that in 2014 and 2019 respectively became the hottest years recorded in the history of Earth's temperature since the 1850s. In 2019, there was a temperature increase of 1.1 degrees Celsius above normal conditions. Projections for 2022 show that the global average temperature is now expected to be about 1.15 (1.02-1.28) degrees Celsius above the pre-industrial average (1850-1900). The continued increase in temperature as a result of global warming is not aligned with the world's efforts to achieve the Sustainable Development Goals (SDGs). The SDGs are collective plans or measures to address global issues adopted by the United Nations, including a series of goals to realize sustainable development in all countries by 2030 (Malihah, 2022).

It is important to recognize that human activities, such as the use of fossil fuels and industrial processes, result in the massive release of greenhouse gases into the atmosphere as a major contributor to global climate change. (Bashir et al, 2021), states that energy use is also proven to have a significant positive impact on greenhouse gas emissions in the long term. Which means that energy use and greenhouse gas emissions (CO₂) have a positive correlation, where an increase in energy consumption will go hand in hand with an increase in greenhouse gas emissions (CO₂).

High energy consumption associated with industrial activities such as mining and oil can lead to deforestation through the displacement of land and forests to build infrastructure or expand industrial activities. Deforestation is the cutting down of forests or trees to convert the land to non-forest activities. Deforestation is a global problem due to its significant impact on the environment (Putra et al., 2019).

Deforestation can result in shrinking forest area. Reduced forest area can also increase greenhouse gas (CO₂) emissions due to the potential decrease in the capacity of forests to absorb and process carbon emissions into oxygen. (Fauzi, 2017), concluded that there is a significant negative relationship between forest area and greenhouse gas emissions. The statement implies that when forest area shrinks or decreases, greenhouse gas (CO₂) emissions will increase, which is due to the shrinkage of forest area.

The analysis of energy consumption and forest area is relevant given that the ASEAN region has significant natural resource wealth. Most of the population in the

ASEAN countries depend on forest products for their livelihoods. The heavy dependence and large forest area in Southeast Asia shows that forests play a very important role as the largest export sector comes from forest products, which increases the economic development rate (Nasir et al, 2019).

The fourth assessment report by the Intergovernmental Panel on Climate Change (IPCC) says that Southeast Asia is expected to face serious adverse climate change impacts, especially since much of the region's economic growth depends on agriculture and natural resources. (Widyawati, 2021), stated that the role and efforts of ASEAN member countries in reducing CO₂ emissions are very important to reduce the impact of climate change. This shows that ASEAN countries have a considerable opportunity to become relevant research subjects. (Salim et al, 2024), stated that although global uncertainties and the threat of natural disasters create uncertainty in the region's growth prospects, economic growth in Southeast Asia is considered to be robust, albeit sluggish when compared to the Organisation for Economic Co-operation and Development (OECD) countries. Nonetheless, increased economic growth in the six ASEAN countries has the potential to have a negative impact on the increase in emission of greenhouse gases (Fauzi, 2017).

Fauzi (2017) stated that the positive coefficient of economic growth per capita on CO₂ emissions as a greenhouse gas indicator implies that every 1% increase in economic growth per capita (expressed in US dollars) will contribute to an increase in emissions of about 1.98%. So, in this context, there is a positive influence between the level of economic growth rate per capita, and the level of CO₂ emissions. (Lutfi & Prawoto, 2014), In his research, he explained that living standards refer to the economic welfare of the community, but it cannot be denied that if per capita economic growth increases, CO₂ emissions also tend to increase.

Wibowo & Khoirudin (2022), Explaining a country's economic growth is often measured through Foreign Direct Investment (FDI). FDI and economic growth have a positive relationship, especially in the development of technology and the world of trade (Nasir *et al.*, 2021). FDI is an investment made by a company or individual from abroad, with the aim of controlling or gaining a long-term interest in an operating company (Jufri & Bahri, 2022). FDI can contribute to an increase in greenhouse gas (CO₂) emissions in the destination country. This is because FDI can encourage industrial growth which produces high greenhouse gas (CO₂) emissions. Although FDI can bring economic benefits such as expanding employment and technology sharing. However, the negative impact on the environment needs serious attention (Munir & Ameer, 2020).

(Jufri & Bahri, 2022), stated that foreign direct investment has a positive and significant impact on the level of greenhouse gas (CO₂) emissions. Therefore, there is a need for solutions that allow FDI to still play a role in economic growth without significantly increasing greenhouse gas (CO₂) emissions. A possible approach is to encourage multinational companies to implement environmentally friendly production practices through appropriate policy incentives and regulations (Kurniawan & A'yun, 2022).

The greater interest of foreign investors to allocate capital to a country by creating quality jobs, can play a role in moderating population growth by influencing family decisions regarding the number of children and desired quality of life. When people have adequate access to stable and well-paying jobs, families' economic needs can be better met. This can reduce the economic pressure on families, which in turn can

influence family planning decisions and hence the country's population. (Widyawati, 2021), explained that population has a positive and significant impact on carbon dioxide gas emissions, which is an indicator of greenhouse gas emissions. Which means when the total population increases, greenhouse gas emissions (CO₂) will also increase.

Research on factors such as welfare level, economic growth, energy consumption, population, and forest area on greenhouse gas (CO₂) emissions in the ten ASEAN member countries has important benefits. This analysis can provide insights for designing sustainable development policies, balancing economic progress with environmental preservation. Engaging these aspects also helps identify sustainable solutions in energy management, population growth and forest sustainability. This research provides a valuable guide for decision-makers to advance sustainable development in the ASEAN region.

LITERATURE REVIEW

Foreign Direct Investment and Greenhouse Gas Emissions (CO₂)

The relationship between FDI and increased greenhouse gas (CO₂) emissions has several factors to consider. FDI tends to encourage the growth of more energy-dependent industries and manufacturing activities. This leads to an increase in energy demand which in turn will result in increased levels of greenhouse gas (CO₂) emissions. However, environmentally friendly technologies applied in industrial activities that receive FDI that pay attention to environmental aspects can significantly reduce greenhouse gas (CO₂) emission levels. This finding is in line with research conducted by (Jufri & Bahri, 2022) which states that foreign investment (FDI) has a significant effect on emissions (CO₂), it is necessary to emphasize the importance of foreign investment capacity in sharing technological tools that are more up-to-date and good for the environment and how this has a positive impact on the environment through foreign direct investment. According to research by (Munir & Ameer, 2020), an increase in FDI has a positive and significant impact on CO₂ emissions in the long term, while a decrease in FDI has a negative but insignificant impact on CO₂ emission levels. In this case, FDI affects greenhouse gas (CO₂) emissions.

H1:” Foreign Direct Investment (FDI) affects greenhouse gas emissions (CO₂)”

Economic Growth and Greenhouse Gas Emissions (CO₂)

The higher demand for a product in the market will increase the production rate so that energy consumption and waste generated increase rapidly. This causes environmental pollution, especially global warming caused by greenhouse gases (CO₂). Rapid economic growth has a positive influence on soaring levels of greenhouse gas (CO₂) emissions. (Andjarwati et al, 2020) said that economic growth and (CO₂) emissions have a positive relationship in the short term. Another similar study conducted by (Widyawati, 2021) in her research concluded that economic growth has a positive impact on environmental degradation through increased CO₂ emissions. This indicates that the higher the economic growth, the greater the environmental degradation that occurs.

H2:” Economic growth has a positive effect on greenhouse gas emissions (CO₂)”

Energy Consumption and Greenhouse Gas Emissions (CO₂)

More energy utilization by society and industry can lead to environmental degradation. This can happen when the energy used is fossil energy which contains emissions (CO₂) that reduce environmental quality. Lack of filtering and efforts to reduce the use of CO₂ in industry and the large number of buildings using glass materials, will also increase CO₂ emissions, exacerbating air pollution (A'yun Qurrota & Umaroh, 2023). Rahman et al (2022) stated that the use of fossil fuel energy can accelerate environmental degradation. The relationship between energy consumption and greenhouse gas emissions (CO₂) has a positive influence. Fauzi (2017) in his research stated that the relationship between the coefficient of energy consumption and emissions (CO₂) is positive. A 1% increase in energy consumption leads to a 1.36% increase in CO₂ emissions.

H3:” Energy consumption has a positive effect on greenhouse gas emissions (CO₂)”

Population and Greenhouse Gas Emissions (CO₂)

Population size reflects changes in the number of individuals in an area. As the population increases, so will the use of gas-generating appliances, the use of environmentally hazardous materials, industrial activities, and the possibility of clearing land for settlement. Therefore, population growth in an area can lead to environmental degradation (Ayu et al., 2021). (Widyawati, 2021) in her research, population growth has a positive and significant impact on carbon dioxide gas emissions. The increasing population, which in daily activities with energy use, will contribute to an increase in carbon dioxide emissions. This finding is in line with the study conducted by (Andjarwati et al, 2020), which states that the population growth rate has a positive impact on emissions (CO₂) in the long term.

H4:” population has a positive effect on greenhouse gas emissions (CO₂)”

Forest Area and Greenhouse Gas Emissions (CO₂)

Forest areas have an important role for every living thing, where forests absorb emissions (CO₂) to produce oxygen. With the presence of forests, greenhouse gas (CO₂) emission levels in the atmospheric layer will be absorbed effectively, thereby reducing the impact of global warming. Conversely, deforestation and logging negatively affect greenhouse gas (CO₂) emission levels. The narrower the forest area, the less greenhouse gases are absorbed. The reduced ability of forests to absorb greenhouse gas (CO₂) emissions leads to various disasters such as rising earth temperatures, weather changes, and intense storms. (Fauzi, 2017) in his research, the area of forest area with emissions (CO₂) has a negative coefficient. Thus, stopping the rate of deforestation and maintaining forest area has a positive impact on reducing greenhouse gas (CO₂) emissions. These findings are also supported by (Begum et al, 2020) who stated that the area of forest area with emissions (CO₂) has a negative coefficient. A decrease in forest area causes an increase in greenhouse gas emissions (CO₂).

H5:” Forest area has a negative effect on greenhouse gas emissions (CO₂)”

METHOD

In the current study, the quantitative research method is adopted with a focus on using secondary data obtained from Our World in Data for more comprehensive analysis and interpretation of results. The secondary data used as a reference consists of panel data that combines cross-sectional and time series data. The time series data

analyzed spans the period 2012 to 2021, while the cross-sectional data covers the region of ten ASEAN countries to be sampled. A quantitative approach is taken to examine hypothesized relationships and explore the cause-and-effect relationship between independent variables (FDI, economic growth, energy consumption, population, and forest area) and the dependent variable (greenhouse gas (CO₂) emissions). Structurally, the panel data regression analysis equation model formula is as follows:

$$Y_{it} = \beta_0 + \beta_1 X1_{it} + \beta_2 X2_{it} + \beta_3 X3_{it} + \beta_4 X4_{it} + \beta_5 X5_{it} + \varepsilon_{it}$$

Y : Greenhouse Gas Emissions (CO₂)

X1 : Foreign Direct Investment (FDI)

X2 : Economic Growth

X3 : Energy Consumption

X4 : Population

X5 : Forest Area

β_0 : Constant

$\beta_{1,2,3,4,5}$: Regression Coefficient

i : 10 ASEAN Countries Region

t : During the Time Period 2012-2021

ε : Error Term

Description:

RESULTS

Model testing will be done in two ways. First, conduct a Chow test to determine which common effect model (CEM) or fixed effect model (FEM) will be selected by looking at the results of the probability value of F worth 0.0000 and smaller than 0.05 (0.0000 < 0.05). Signaling that the results of the Chow test selected the fixed effect model (FEM). Then the second stage of model testing is the Hausman test to ensure the random effect model (REM) or the fixed effect model (FEM).

Table Chow and Hausman Test

Test Type	Alpha	Prob F	Selected Model
<i>Chow test</i>	0,05	0,0000	FEM

<i>Hausman test</i>	0,05	0,0000	FEM
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Source: Data processing results,2024

Based on the Hausman test conducted, the results show that the probability value of F is 0.0000 and smaller than 0.05 ($0.0000 < 0.05$) indicating that the selected model is fixed effect (FEM). Based on the two tests that have been carried out, it is not recommended to conduct the Lagrange Multiplier test because the results of the Chow and Hausman tests indicate that the selected model is fixed effect.

Table Multicollinearity Test

Independent Variable	VIF	1/VIF
X4	2,39	0,418974
X5	2,24	0,446539
X1	2,09	0,478305
X2	1,20	0,830626
X3	1,03	0,967171
Mean VIF		1,79

Source: Data processing results,2024

From the multicollinearity test results, it can be seen that all VIF values for the independent variables are below 10. This indicates that there is no significant multicollinearity in the regression model. For the Mean VIF value is 1.79. This indicates that there is no high multicollinearity in the regression model.

Table Heteroscedasticity Test

chi2 (1)	0,06
Prob > chi2	0,8112

Source: Data processing results,2024

Based on the results of the heteroscedasticity test, the chi-square value (1) is 0.06 and the Prob> chi2 value is 0.8112. Since the chi-square value is smaller than the critical value of chi-square with a degree of freedom of 1 at a significance level of 5% and the probability value is greater than the 5% significance level, it can be concluded that there is no heteroscedasticity in the regression model.

Table Determination Test

Number of obs	100
F (5, 85)	19,43
R-sq overall	0,5665

Source: Data processing results,2024

Based on the determination test results, the F value of 19.43 is much higher than the critical value of F at the 5% significance level, so it can be concluded that the overall regression model is statistically significant. The R-sq value of 0.5665 indicates that 56.65% of the variation in the dependent variable can be explained by the independent variable. Thus, this high R-sq value indicates that the regression model has the ability to explain the relationship between the independent variable and the dependent variable quite well.

Table Simultaneous Test

Prob > F	α	Description
0,0000	0,05	Significant

Source: Data processing results,2024

From the simultaneous test results, the probability value $> F$ is 0.00. This figure is lower than the alpha (α) value of 0.05. Therefore, there is enough evidence to reject the null hypothesis stating that all independent variables have no significant effect on the dependent variable. Thus, together, all independent variables have a significant effect on the dependent variable.

Table Partial Test

Variable	Coef.	Std. Err.	t	P> t
Constant (C)	-86,6028	15,56786	-5,56	0,000
X1	-0,0046625	0,0143909	-0,32	0,747
X2	0,0012101	0,0076542	0,16	0,875
X3	0,0209574	0,0259387	0,81	0,421
X4	6,275954	0,8969526	7,00	0,000
X5	-0,0523336	0,0206837	-2,53	0,013

R-sq overall	0,5665
Prob > F	0,0000
Number of obs	100

Source: Data processing results,2024

The regression equation from the results of the data analysis that has been carried out can be formulated as follows:

$$Y_{it} = -86,6028_0 + -0,0046625_1X1_{it} + 0,0012101_2X2_{it} + 0,0209574_3X3_{it} + 6,275954_4X4_{it} - 0,0523336_5X5_{it} + \varepsilon_{it}$$

Foreign Direct Investment (FDI)

Based on the t-test results table above which uses the Fixed Effect (FEM) model. It was found that the FDI regression coefficient was -0.0046625 and insignificant at a significance level of $0.747 > 0.05$. This indicates that the hypothesis H0 is accepted. Thus, the results show that there is no significant relationship between FDI and greenhouse gas (CO2) emissions in ten ASEAN countries from 2012 to 2021.

Economic Growth

The regression coefficient of economic growth is 0.0012101 and does not have a sufficient significance level at $0.875 > 0.05$. Thus, these results indicate the acceptance of the H0 hypothesis. The results of this analysis indicate that there is no significant relationship between economic growth and the dependent variable based on the results of the statistical analysis that has been carried out. Thus, it can be concluded that economic growth has a positive but insignificant effect on greenhouse gas (CO2) emissions in ten ASEAN countries from 2012 to 2021.

Energy Consumption

According to the regression coefficient of energy consumption of 0.0209574, energy consumption is not significant at a significance level of $0.421 > 0.05$. Thus, the result indicates accepting H0. This means that there is no significant relationship between energy consumption and the dependent variable. Thus, it can be concluded that energy consumption has a positive but insignificant effect on greenhouse gas (CO2) emissions in ten ASEAN countries from 2012 to 2021.

Population

The population regression coefficient is 6.275954, the population is significant at a significance level of $0.000 < 0.05$, the coefficient is considered significant. Thus, the result indicates that H4 is accepted. This indicates that there is a significant influence between the population and the dependent variable. Thus, it can be concluded that population has a significant positive effect on greenhouse gas (CO2) emissions in ten ASEAN countries from 2012 to 2021.

Forest Area

The regression coefficient of forest area is -0.0523336, the forest area is significant at a significance level of $0.013 < 0.05$. Thus, these results indicate that H5 is accepted. This indicates that there is a significant relationship between forest area and the dependent variable. Thus, in the context of the regression analysis conducted, forest

area has a negative and significant effect on greenhouse gas (CO₂) emissions in ten ASEAN countries from 2012 to 2021.

DISCUSSION

From the results of statistical analysis testing conducted, it shows that Foreign Direct Investment (FDI) does not have a significant relationship with greenhouse gas emissions (CO₂). Therefore, increasing FDI does not have a significant impact on greenhouse gas (CO₂) emissions. This result rejects the initial assumption that FDI has a significant positive effect on greenhouse gas (CO₂) emissions. Despite the initial assumption that FDI can increase greenhouse gas (CO₂) emissions through industrial and production activities, other factors such as energy efficiency, technology, and environmental policies have a significant influence on greenhouse gas (CO₂) emissions. Economic growth has a positive but insignificant relationship with greenhouse gas (CO₂) emissions. This result rejects the initial assumption that economic growth has a significant positive effect on greenhouse gas (CO₂) emissions. Economic growth is often associated with greenhouse gas (CO₂) issues resulting from increased production. However, the relationship between economic growth and greenhouse gas (CO₂) emissions is not always in line. Energy consumption has a positive but insignificant effect on greenhouse gas (CO₂) emissions. This rejects the initial assumption that energy consumption has a significant positive effect on greenhouse gas (CO₂) emissions. Thus, it can be concluded that the increase in greenhouse gas (CO₂) emissions in ASEAN countries is not only caused by energy consumption factors. The results of statistical analysis show that population and forest area have a positive and significant influence on greenhouse gas (CO₂) emissions. Rapid population growth can lead to increased human activities that contribute to greenhouse gas emissions. More people mean more need for energy, transportation, and natural resource utilization, all of which can worsen the impact on the environment. In addition, forest area has a major impact on the amount of greenhouse gas (CO₂) emissions. Forests play a vital role in absorbing carbon dioxide and reducing greenhouse gas emissions. If the forest area decreases, the capacity of the forest to absorb greenhouse gas (CO₂) emissions will also decrease.

CONCLUSION

Based on regression analysis on ten ASEAN countries, it is found that the variables of Foreign Direct Investment (FDI), economic growth, and energy consumption do not have a significant relationship with greenhouse gas (CO₂) emissions. While the population variable has a significant positive relationship. The regression test results show that an increase of 1 population will increase greenhouse gas emissions by 6.28%. The variable forest area shows a significant negative relationship. The regression test results show that a decrease in forest area by 1% will result in an increase in greenhouse gas emissions by 0.05%.

Implication

Theoretical Implications

The findings can enrich the existing literature on factors affecting greenhouse gas emissions in developing countries, particularly in the ASEAN region. By

identifying key determinants, this study provides a stronger theoretical basis for understanding the complex interactions between economic growth, energy consumption, population and environmental factors. It also helps clarify how foreign investment can affect greenhouse gas emissions, both directly through investment in energy sectors and indirectly through changes in economic structure and energy consumption.

Practical Implications

In practice, these findings can help policymakers and practitioners in ASEAN countries to design more effective strategies to reduce greenhouse gas emissions. For example, if it is found that energy consumption is a major contributor to emissions, then efforts to improve energy efficiency and develop renewable energy sources should be prioritized. Likewise, if foreign investment is shown to have a significant impact, then policies that encourage green investment and environmentally friendly technologies should be prioritized. In addition, efforts to conserve forests and increase forest areas should also be integrated into climate change mitigation strategies.

Policy Implications

The findings have important implications for policy formation at the national and regional levels. ASEAN member states can use the results of this study to develop more targeted and integrated policies to reduce greenhouse gas emissions. For example, fiscal policies and incentives to encourage green investment, strict regulations on industrial emissions, and programs to improve energy efficiency. In addition, sustainable forest management policies and forest area protection should also be strengthened as part of climate change mitigation strategies.

Limitation and Future Direction

Future research could focus on more detailed sub-sectoral analysis, for example looking at the impact of foreign investment and economic growth in the industrial, transportation or agricultural sectors on greenhouse gas emissions. Each sector has different characteristics and contributions to emissions, so a more specific understanding can help design more targeted policies. Conduct longitudinal studies involving time-series data for longer periods to look at long-term trends and lag effects of the determinants being analyzed.

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