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The Effect of Gross Domestic Product, Energy Consumption and Forest Area on Carbon Dioxide Emissions in ASEAN-5

Isni Syafhira Adha [1], Azwardi [2]

[1,2] Faculty of Economics, Universitas Sriwijaya, Indonesia

Abstract. *Due to human activity-related carbon dioxide emissions, the earth's temperature has increased, resulting in climate change and global warming. The anomaly of climate change, which raises the global average temperature, has shown that environmental damage is genuine. In five ASEAN nations—Indonesia, Thailand, Malaysia, Singapore, and the Philippines—between 2001 and 2020, this study will examine the impact of GDP, energy use, and forest area on carbon dioxide emissions. This study's methodology combined quantitative descriptive analysis with panel data regression analysis. The findings indicate that forest area and gross domestic product have a negative and considerable impact on carbon dioxide emissions. Consequently, carbon dioxide emissions are positively and significantly impacted by energy usage.*

Keywords: Carbon Diocide Emission, Gross Domestic Product, Energy Consumption, Forest Area

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1. Introduction

Economic development and technological advances are currently a big challenge for all countries in the world. Often the state ignores the consequences of the massive use of energy from the industrial sector which can lead to an increase in carbon dioxide emissions. Worldwide, both in developing and industrialized nations, environmental deterioration is a significant issue that is currently a danger to economic development [1]. Environmental degradation continues to occur and reduces environmental quality. The impact of this environmental degradation is very large on climate change and global warming.

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Economics is all about sacrifice, and the world has sacrificed preserving nature for global progress. According to environmental experts, climate and temperature changes in the last 60 years are very risky for human survival [2]. Emissions of carbon dioxide gas released as a result of human activities warm the earth's temperature causing climate change and global warming. The main cause of this increase in temperature is the negative externality of human economic activities in the form of environmental degradation. More than 150,000 people die every year due to the negative effects of environmental degradation [3]. Economic activities that are not responsible for increasing greenhouse gas emissions are considered to be one of the main causes of environmental degradation where carbon dioxide emissions are a relevant cause of extreme climate change and global warming [4]. Figure 1.1 is absolute proof that environmental damage is real and there is an anomaly of climate change that causes the world's average temperature to rise.

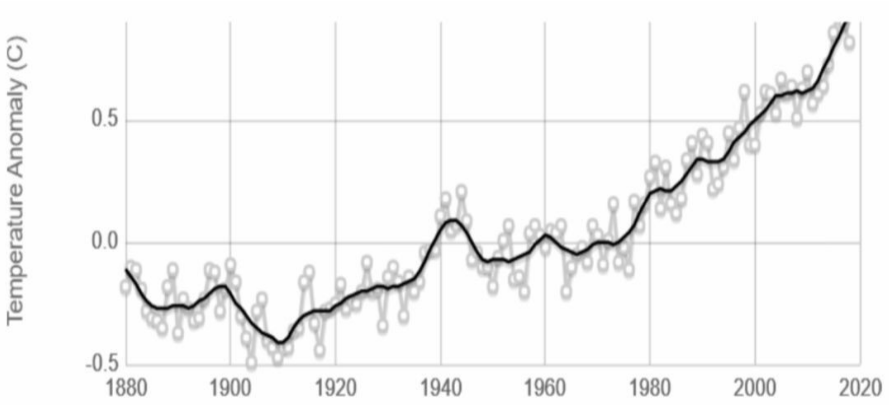

Fig. 1: Temperature Anomalies 1880-2020 (Source: Climate NASA)

The majority of CO2 emissions from human activities are caused by the use of unfriendly technologies that burn fossil fuels and clear forests [5]. Developing nations frequently employ technology that is not ecologically friendly. Consumption of fossil fuels will result in a rise in the concentration of greenhouse gases, the majority of which are CO2 (56% of global warming), CH4 (18% of global warming), and N2O (6% of global warming) [6]. Indeed, there is a close relationship between the use of non-renewable energy and the development of economic activity. But actually, this can be controlled by using environmentally friendly technology.

According to The OECD, ASEAN countries in 2030 are expected to contribute globally to the increasing rate of carbon dioxide emissions [7]. Based on data from Our World In Data, CO_2 emissions continue to increase every year in ASEAN countries which shows an indication that sustainable environmental degradation continues to occur. The industrialized economies of Southeast Asia are highly dependent on energy and have high energy consumption [8]. The following is a graph illustrating the carbon dioxide emissions of 5 countries in ASEAN Indonesia, Thailand, Malaysia, Singapore, and the Philippines.

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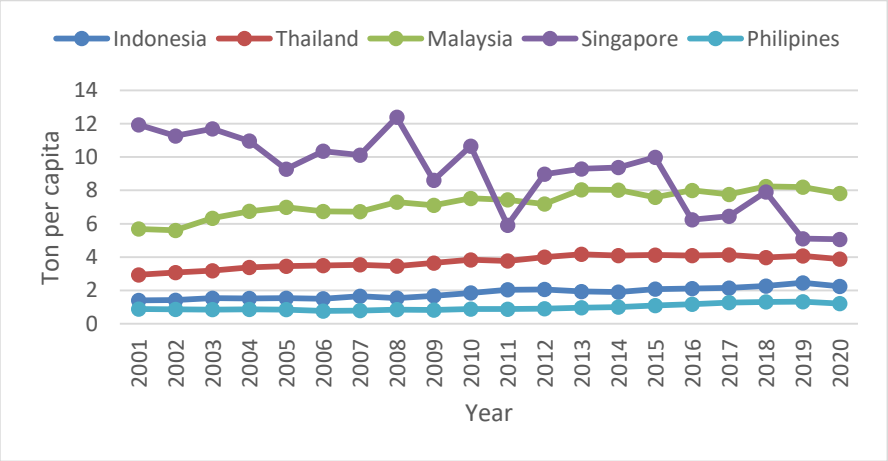

Fig. 2: Carbon Dioxide Emissions Per Capita of 5 ASEAN Countries 2001-2020

Based on Figure 2, Singapore's CO_2 emissions per capita are the highest and tend to fluctuate compared to 4 other countries in ASEAN. Despite the high number of CO_2 emissions, Singapore is the only ASEAN-5 country that has been able to reduce CO_2 emissions from 11,94 tons per capita in 2001 and in 2020 to 5,06 tons per capita. This means that in a span of 20 years, Singapore has succeeded in reducing CO_2 emissions per capita by 42.3%. Then followed by Malaysia, Thailand, and Indonesia which showed a slow increasing movement. Based on the data in Figure 2, the Philippines is the country with the lowest CO_2 emissions in ASEAN-5. In 2001 the Philippines produced CO_2 emissions of 0.88 tons per capita then in 2020 it will be 1,21 tons per capita. This means that the increase in the Philippines CO_2 emissions in a span of 20 years is 13.7%.

After looking at Figure 2 of the carbon dioxide emission levels of the 5 ASEAN countries, the question arises as to how the other variables that affect CO_2 emissions, such as economic growth, energy consumption, population, and forest area of these countries, emit CO_2 in such a way. Rapid economic growth is an important phenomenon experienced by the world in the last two centuries[9]. In the development of economic growth, in addition to the availability of natural resources, capital accumulation, and technological developments, the population has always been used as a determinant of economic growth. Solow has outlined how a nation's overall output of products and services is affected by its capital stock, population, and technical advancements [10].

Based on the description above, this study aims to analyze the variables that can affect carbon dioxide emissions which can accelerate the pace of global warming, namely Gross Domestic Product, Energy Consumption, and Forest Area in ASEAN-5.

2. Literature Review

2.1. Environment Kuznet Curves (EKC)

The EKC hypothesis began with the development of Grossman and Kreuger in 1995 on Kuznet's theory in 1991 which discussed the inverted U-curve. According to this theory due to heavy exploitation of

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resources to support the level of elements of production to produce significant output, environmental damage will be at a high level in the early stages of development when a country starts to build its economy or in the early stages of economic growth. However, due to the low economic level, the public and government knowledge about the value of environmental quality for human survival is relatively small [2].

A country will exploit its resources on a large scale to spur economic growth in the initial phase of development. After being exploited extensively, this nation will eventually reach a critical point where environmental degradation will no longer keep pace with economic growth. This is known as the Turning Point. The economy continues to grow after the turning point, and the level of environmental damage is reduced. Communities and governments are starting to appreciate the value of the environment and are starting to prioritize clean economic operations and environmentally friendly practices.

An inverted U-curve illustrates the EKC hypothesis According to this EKC theory, for a country to reach the final stage, it must go through three different economic structures: an agrarian economy, an industrial economy, and a service-based economy. According to this hypothesis, when a country's income is still relatively low, the country pays less attention to environmental problems and focuses more on production which can lead to an increase in income. Therefore the level of pollution will increase first followed by income growth and then will decrease over time [11].

2.2. Externality

Externality is a problem that causes market failure in efficiently allocating factors of production. The consumption or production of one party that has an impact on another party without compensation from the one who caused it is known as an externality. Externalities can be positive or negative. When there are negative externalities, the production costs estimated by the entrepreneur are less than the social costs borne by the community. When there are positive externalities, production costs are higher than social costs, which results in fewer goods being produced than society considers efficient [12]. In short, negative externalities impose costs on other parties while positive externalities provide benefits for other parties [13].

The existence of externalities increases the government's allocative role in the economy. There are many ways to deal with unfavorable diseconomies of externality in this situation. The government first charges polluters with tax collections. The premise of this policy is that everyone has the right to a clean environment. In addition to tax collection, subsidizing by the government, providing pollution rights through auctions or regulations and policies for companies to overcome externalities to the environment by imposing penalties for violators of the rules [12].

3. Research Methods

The dependent variable in this study is carbon dioxide (CO2) emissions, while the independent variables are gross domestic product (GDP), energy consumption (EC), and forest area (FOREST). The five ASEAN nations of Indonesia, Thailand, Malaysia, Singapore, and the Philippines will be the subjects of this study from 2001 through 2020. Panel data regression methods are applied to the panel data. The study's regression models include:

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$$CO_{2it} = \beta_0 + \beta_1 GDP_{it} + \beta_2 EC_{it} + \beta_3 FOREST_{it} + \varepsilon_{it}$$

which is: CO_2= Carbon dioxide emissions per capita (tons); GDP= GDP per capita (US$); EC= Energy consumption per capita (Mwh); FOREST= Forest area per capita (million ha);β_0= Constant; $\beta_1, \beta_2, \beta_3$= Regression Coefficient; i= 5 countries in the ASEAN region; t= Time series, period 2001-2020; ε= term error.

Three different testing techniques—the Common Effect Model (CEM), Fixed Effect Model (FEM), and Random Effect Model (FEM)—were used in this investigation. The Chow test and Hausmann test were used to choose the best model. The heteroscedasticity test and the multicollinearity test are the classic assumption tests in this work. The normality test is not required for panel data research, so the autocorrelation test is only used for studies with time series data. Then proceed with the F statistical test and t test. The F test was carried out to statistically prove the effect of the independent variables on the dependent variable together. The t-test was conducted to prove whether the independent variables affect the dependent variable individually.

4. Results and Discussion

4.1. Panel Data Estimation Model Selection

Table. 1 Chow Test Result

Redundant Fixed Effect Tests			
Effect Test	**Statistics**	**df**	**Prob.**
Cross-section F	440.811293	(4.92)	0.0000

Table 1's results from the Chow test indicate that the probability value is 0.0000<0.005 with a 5% alpha level. As a result, the Fixed Effect Model (FEM) test by Chow indicates that it is superior to the Common Effect Model (CEM).

Table. 2 Hausman Test Result

Correlated Random Effect - Hausman Test			
Test Summary	**Chi-Sq. Statistics**	**Chi-Sq. df**	**Prob.**
Random cross-sections	95.065025	3	0.0000

Based on Table 2's results for the Hausman test, it can be seen that 0.00000.05 represents the probability value in a random cross-section. In light of the Hausman Fixed Effect Model (FEM) test's conclusion that this model is superior to the Random Effect Model.

4.2. Panel Data Estimation Model Selection

The findings of panel data estimate using the Fixed Effect Model (FEM) are displayed in the table below based on the model specification test in the study:

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Table. 3 Regression Estimation Results with the Fixed Effect Model

Variables	coefficient	Prob.
C	7.106517	0.0000
GDP?	-0.000134	0.0000
EC?	0.063732	0.0203
FOREST?	-11.93820	0.0000
R-squared	0.992196	

The regression equation can be written as follows based on the estimation results of the Fixed Effect Model in Table 3:

$$CO_{2it} = -7.106517 - 0.000134GDP_{it} + 0.063732EC_{it} - 11.93820FOREST_{it} + \varepsilon_{it}$$

According to the equation above, if the constants of Economic Growth, Energy Consumption, and Forest Area in Indonesia, Thailand, Malaysia, Singapore, and the Philippines in 2001-2020 are constant, it will affect Carbon Dioxide Emissions by 7.106517 units. The GDP coefficient was then determined to be -0.000134, indicating that a 1 US dollar rise in the GDP per capita in Indonesia, Thailand, Malaysia, Singapore, and the Philippines between 2001 and 2020 will result in a 0.000134 ton reduction in carbon dioxide emissions per capita.

The Energy Consumption variable has a positive coefficient with a value of 0.063732 meaning that if there is an increase in Energy Consumption in Indonesia, Thailand, Malaysia, Singapore, and the Philippines in 2001-2020 by 1 MWh per capita, it will increase Carbon Dioxide Emissions by 0.063732 tons per capita. Then the coefficient value of the variable Area of Forest Area has a negative sign with a value of -11.93820 meaning that if there is an increase in the area of forest area in Indonesia, Thailand, Malaysia, Singapore, and the Philippines in 2001-2020 by 1 million ha, it will reduce Carbon Dioxide Emissions by 11.93820 tons per capita.

The variables Economic Growth, Energy Consumption, and Forest Area in Indonesia, Thailand, Malaysia, Singapore, and the Philippines between 2001 and 2020 can account for 98.98% of the variable Carbon Dioxide Emission, according to the coefficient of determination or R-squared value of 0.989874, while the remaining 1.02% is explained by other variables not included in this study or outside the regression model

Table. 4 Intercept Fixed Effect Model Results

Country	Coefficient
_ENG--C	-0.552514
_THA--C	-0.368462
_MLY--C	7.305802
_SNG--C	-1.224478
_PHL--C	-5.160348

Table 4 explains the results of the data regression in the 5 ASEAN countries, Indonesia has an intercept value of 0.552514, which means that the average amount of carbon dioxide emissions in Indonesia is

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0.552514 tons per capita if the GDP, energy consumption and forest area variables are considered zero. The same is true for 4 other countries, namely Thailand, Malaysia, Singapore, and the Philippines which have intercept values of 0.368462, 7.305802, 1.224478, and 5.160348 respectively. This means that if the variables of gross domestic product, energy consumption, and forest area are considered zero then the average carbon dioxide emission of each country is equal to the intercept value.

Because Indonesia has the highest population density compared to other nations, there is a larger demand for goods, which leads to higher energy consumption and economic expansion while depleting natural resources, in this instance forest land. However, some researchers think that the intercept does not always have meaning. Negative or positive values in the intercept are not a problem and can be ignored [14].

4.3. Classic Assumption Test

Table. 5 Heteroscedasticity Test Results

Variables	coefficient	Prob.
C	0.045814	0.9289
GDP	6.66E-06	0.7567
EC	0.006919	0.6817
FOREST	0.163580	0.8792

Based on Table 5, the probability value of all research variables is > 0.05. Gross Domestic Product has a probability value of 0.7567 > 0.05, energy consumption has a probability value of 0.6817 > 0.05, and forest area has a probability value of 0.8792 > 0.05. Therefore, the conclusion is that the model in this study does not have heteroscedasticity problems.

Table. 6 Multicollinearity Test Results

	GDP	EC	FOREST
GDP	1.000000	0.969777	-0.468916
EC	0.969777	1.000000	-0.447151
FOREST	-0.468916	-0.447151	1.000000

Table 6 explains that the correlation value of the Gross Domestic Product, energy consumption, and forest area variables on average shows <0.9. So the conclusion is that this model does not have multicollinearity problems.

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4.4. Hypothesis Testing

Table. 7 F Test Results

• F-statistics	Prob (F-statistic)
1284,753	0.000000

Based on Table 7 the value of the F-statistic is 1284.753 with a probability value of 0.0000. This study uses α = 0.05, then df1 (k-1 = 4-1 = 3) and df2 (nk = 100-4 = 96) so it can be seen that the value of the F-table is 2.699. Then the F-statistic > F-table (1284.753 > 2.699) and the probability value of the F-statistic is 0.0000 <0.05. Based on the criteria, H_o is rejected and H_a is accepted. This means that there is a jointly significant effect of Gross Domestic Product, energy consumption, and forest area on carbon dioxide emissions in 5 countries in the ASEAN region in 2001-2020.

Table. 8 t-Test Results

Variables	coefficient	std. Error	t-Statisctic	Prob.
GDP?	-0.000134	3.14E-05	-4.268999	0.0000
EC?	0.063732	0.026983	2.361977	0.0203
FOREST?	-11.93820	0.772104	-15.46191	0.0000

It is known that the df in this study is 96 with a significance level of 5% (α = 0.05). Based on the hypothesis, this study uses a directed correlational hypothesis, so hypothesis testing uses one-tailed so that the t-table value is 1.661. Following are the results of the analysis based on Table 8.

- The Gross Domestic Product (GDP) variables individually had a significant and negative impact on carbon dioxide emissions in Indonesia, Thailand, Malaysia, Singapore, and the Philippines in 2001-2020. This negative relationship can be seen from the value of the GDP coefficient which obtains a value of -0.000134. The probability of the t-count value is 0.0000 <0.05 indicating that GDP has a significant effect on carbon dioxide emissions. Then in the column t-statistics GDP shows the number -4.268999. This means that t-count > t-table (-4.268999> 1.661) then H_o is rejected and H_a is accepted.
- Individual Energy Consumption Variables (EC) have a significant influence and have a positive direction on carbon dioxide emissions in Indonesia, Thailand, Malaysia, Singapore, and the Philippines from 2001-2020. This positive relationship can be seen from the value of the EC coefficient which obtains a value of 0.063732. The probability of the t-count value is 0.0203 <0.05 indicating that energy consumption has a significant effect on carbon dioxide emissions. Then the EC t-statistics column shows the number 2.361977. This means that t-count > t-table (2.361977 > 1.661) then H_o is rejected and H_a is accepted.
- The Forest Area Variable (FOREST) individually has a significant influence and has a negative direction on carbon dioxide emissions in Indonesia, Thailand, Malaysia, Singapore, and the Philippines from 2001-2020. This negative relationship can be seen from the coefficient value of the forest area which obtains a value of -11.93820. The probability of the t-count value is 0.0000 <0.05 indicating that the area of forest has a significant effect on carbon dioxide emissions. Then the

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FOREST t-statistics column shows the number -15.46191. This means that t-count > t-table (-15.46191 > 1.66105) then H_o is rejected and H_a is accepted.

4.5. Discussion

- **The Effect of Gross Domestic Product on Carbon Dioxide Emissions**

Based on the probability value and coefficient value of the panel data estimation using the Fixed Effect Model in this study, it can be concluded that GDP partially has a significant and negatively related effect on carbon dioxide emissions in five ASEAN countries, namely Indonesia, Thailand, Malaysia, Singapore, and the Philippines from 2001 to 2020. The GDP variable's coefficient value is -0.000134, which means that for every 1 US$ increase in GDP per capita, carbon dioxide emissions will fall by 0.000134 tons per person, and vice versa if GDP per capita declines by 1 US dollar. With this coefficient value, it can be stated that the research hypothesis which states a positive relationship between GDP and carbon dioxide emissions is rejected.

The findings in this study are in line with research conducted by [7] which states that economic growth can reduce carbon dioxide emissions in ASEAN countries. According to the research, this happens as a result of a nation's ability to minimize carbon dioxide emissions due to environmental awareness and various sustainable development strategies that have an impact on environmental quality and can reduce carbon dioxide emissions. Research [15] stated that these findings support the EKC hypothesis that occurred in the South Asia region from 1985-2018, which means that in the early stages of development, environmental pollution increased along with economic growth, but after the threshold point, environmental degradation began to decrease along with increased economic growth. However, the finding that economic growth has a negative effect on carbon dioxide emissions is different from the findings in research conducted by [6][16]which states that economic growth as measured by GDP has a significant and positive effect

- **The Effect of Energy Consumption on Carbon Dioxide Emissions**

According to the probability value and the coefficient value, energy consumption in five ASEAN nations Indonesia, Thailand, Malaysia, Singapore, and the Philippines has a large and positive impact on carbon dioxide emissions between 2001 to 2020.. The coefficient value of the energy consumption variable is 0.063732 meaning that for every increase in consumption of fossil energy which includes natural gas, oil, and coal by 1 MWh per capita, carbon dioxide emissions will increase by 0.063732 tons per capita and vice versa if fossil energy consumption decreases of 1 MWh per capita, carbon dioxide emissions will decrease by 0.063732 tons per capita. With this coefficient value, it can be stated that the research hypothesis which states a positive relationship between energy consumption and carbon dioxide emissions is accepted.

The research conducted by [3] also reached similar conclusions, namely that energy use has a considerable and bad impact on carbon dioxide emissions increase. According to the study climate finance, local, national, or international funding may come from alternative funding sources, public or private to support the needs of the global transition to a low-carbon economy. This will drive the large investment in renewable energy, which is needed to drastically reduce CO2 emissions. Then in research [17] The usage of non-renewable energy results in environmental deterioration. Research [15] states that a significant dependence on the use of fossil fuels is destroying the environment in South Asia. The

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empirical findings imply that in order to combat the problem of environmental degradation, governments must support and promote renewable energy sources.

- **The Effect of Forest Area on Carbon Dioxide Emissions**

  Based on the probability and coefficient values, forest area partially has a significant and negative

  Based on probability and coefficient values, forest area has a large and good impact on reducing carbon dioxide emissions in Indonesia, Thailand, Malaysia, Singapore, and the Philippines, five ASEAN nations, between 2001 and 2020. The coefficient value of the variable area of the forest area is-11.93820 meaning that for every increase in forest area by 1 million ha, carbon dioxide emissions will decrease by11.93820 tonnes per capita and conversely, if the forest area decreases by 1 million ha, carbon dioxide emissions will increase by11.93820 tonnes per capita. So the area of forest is one of the solutions to reduce carbon dioxide emissions in ASEAN. With this coefficient value, it can be stated that the research hypothesis which states a negative relationship between forest area and carbon dioxide emissions is accepted. The coefficient value of forest area in the estimation results is the value that has the greatest influence on carbon dioxide emissions compared to other variables in this study.

  According to research by [18][2][6], the amount of forest is large and can reduce carbon dioxide emissions, which is in line with the conclusions of this study. However, in contrast to the results of research by [19]who examined the EKC curve in 208 countries from 1990-2018. His research states that natural resources including forests can cause an increase in carbon dioxide emissions in most of the countries analyzed.

5. Conclusion

Negative externalities from human activities in the form of environmental pollution are increasingly worrying. The increase in the earth's temperature caused by greenhouse gases must be addressed immediately with human awareness and support from the government. This study discusses the variables that can affect carbon dioxide emissions, namely Gross Domestic Product (GDP), energy consumption, and forest area in 5 ASEAN countries, namely Indonesia, Thailand, Malaysia, Singapore, and the Philippines in 2001-2020. Based on the results of the study it can be concluded as follows.

1. Based on research findings and the EKC hypothesis, the Kuznet Curves Environment Hypothesis occurred in Indonesia, Thailand, Malaysia, Singapore, and the Philippines between 2001 and 2020. These 5 countries have now transitioned to an industrial economic structure and are beginning to practice environmental responsibility
2. Gross Domestic Product (GDP) and Forest Area had a negative and significant effect on carbon dioxide emissions in ASEAN-5, namely Indonesia, Thailand, Malaysia, Singapore, and the Philippines from 2001-2020. In the meantime, between 2001 to 2020 carbon dioxide emissions in the ASEAN-5 countries of Indonesia, Thailand, Malaysia, Singapore, and the Philippines are positively and significantly impacted by energy use. With a negative relationship between GDP and forest area, The public should be made aware of the necessity of conserving the forest ecosystem and the hazards of greenhouse gases, and it is hoped that the government will be able to establish more effective regulations to minimize carbon dioxide emissions. The government and the community can jointly protect forest areas, use environmentally friendly energy, prevent deforestation.

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