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Macroeconomic Variables and Its Impact on CO_2 Emissions: An Empirical Study on Selected ASEAN Economic Community (AEC) Countries

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ABSTRACT

Environmental issues are a crucial aspect in promoting sustainable economic growth. Specifically, CO_2 gas emission is an environmental-economic phenomenon that needs to be concerned for all parties to maintain a balance between economic growth and environmental sustainability to realize sustainable economic development. This study aims to analyze the social and economic factors that affect CO_2 gas emissions in selected ASEAN economic community (AEC) member countries. The research used panel data analysis from 2010 to 2019 on selected ASEAN economic community (AEC) member countries: Indonesia, Malaysia, Singapore, Thailand, Laos, Vietnam, Cambodia, Brunei Darussalam, and the Philippines. The research variables consisted of CO_2 gas emissions as the dependent variable and economic growth (GDP), population (POP), energy consumption (EC), external debt (ED), foreign direct investment (FDI), inflation (INF), and exports (X) as independent variables. The results showed that the variables of economic growth (GDP), population (POP), energy consumption, and exports had a positive and significant effect on CO_2 gas emissions. Meanwhile, the variables of foreign debt, foreign direct investment (FDI), and inflation did not affect CO_2 gas emissions in ASEAN economic community (AEC) member countries. This research concludes that it is necessary to carry out an integrated policy to reduce CO_2 gas emissions by implementing sustainable development strategies involving related parties, providing incentives to reduce fossil energy consumption, and replacing it with environmentally friendly new, renewable energy. The novelty of this research is to analyze the social and economic factors affecting CO_2 emissions in ASEAN economic community (AEC).

1. INTRODUCTION

Environmental issues have become a central issue amid policies encouraging development in developing countries, including the ASEAN Economic Community member countries. Therefore, this study aims to analyze the social and economic factors affecting CO_2 gas emissions in the ASEAN Economic Community (AEC) member countries. In addition, environmental issues are central in the context of realizing sustainable economic development [1, 2]. Economic development, in addition to producing goods and services through production and distribution activities, also produces pollutants – one of which is carbon (CO_2) gas emissions – which negatively impact the environment and public health. CO_2 gas emissions are influenced by the rate of economic growth because the higher the economic growth, the higher the economic activity in all economic sectors; thus, the need for energy is also increasing, and the impact will increase the production of pollutants, i.e., CO_2 gas emissions [3, 4]. On the other hand, ASEAN economic community (AEC) member countries play an important role in the constellation of the global economy because they have abundant natural resources and a large population. Hence, there needs to be a structured policy among ASEAN countries in dealing with environmental problems to realize sustainable development in the region [5, 6].

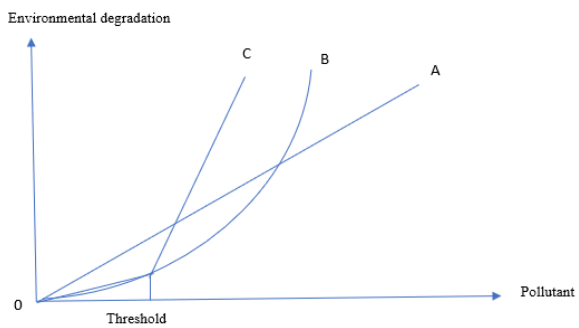
Along with increasing economic development, energy needs are also increasing [6, 7]. The growing population also encourages increased energy needs for households and transportation [8, 9]. This phenomenon impacts increasing CO_2 emissions in selected ASEAN economic community (AEC) member countries. CO_2 gas emissions are also influenced by the entry of foreign investment through multinational companies (MNC) engaged in various economic fields. For this reason, this research explains the social and economic factors influencing CO_2 gas emissions in selected ASEAN economic community (AEC) member countries, so objective information is obtained as material for policymaking to realize sustainable development [3]. An interesting aspect of this article is explaining how the role of development and the economy will always be related to environmental issues, i.e., CO_2 gas emissions. Related to that, the global warming phenomenon that threatens human life's survival on earth gives an important signal of the need to pay attention to environmental aspects in economic development.

2. LITERATURE REVIEW

Environmental issues related to sustainable development processes involve economic and non-economic aspects. Auffhammer and Mansur [5] has examined the relationship

between energy consumption and climate change and its impact on long-term economic growth. The empirical findings explained the need for policies to control energy consumption to maintain environmental stability and degradation. In addition, Gilbert and Graff Zivin [6] researched the implications of taxation policies on people's consumption behavior and economic growth and their impact on carbon gas emissions. His findings indicated the need for appropriate taxation policies and creating an economic balance between the economic benefits and costs of any economic activity impacting the environment. Furthermore, Isaksen [10] studied the behavior of household energy consumption in Norway on CO_2 carbon gas emissions, which showed a significant relationship between people's per capita income and household energy consumption expenditures and the amount of CO_2 carbon emissions in Norway. Moreover, economic development here is a process of increasing people's per capita income, improving people's quality of life, and enhancing public awareness of social, political, and legal aspects of individual and social life [11]. Aside from producing output, economic activity also produces pollutants, which have a negative impact on the environment, both natural and social [10, 12].

In the early stages, the impact of pollutants on the environment is not too big, but its effects are already starting to be felt. However, at a later stage, it will have a significant effect on environmental degradation significantly. This condition results from the inability of the environment to absorb pollutants at a certain threshold [1, 13]. The below curve in Figure 1 explains the relationship between pollution and environmental degradation, where more pollutants increase environmental degradation. Curve A also explains a positive correlation between the number of pollutants and environmental degradation, which is linear. It means that constant changes in the number of pollutants will increase environmental degradation. However, economic development also produces pollution from industrialization and public transportation activities, which have an impact on environmental degradation. Meanwhile, curve B reveals the relationship between the number of pollutants and environmental degradation, which is exponential. It indicates that an increase in the number of pollutants will increase changes in environmental degradation by an increasing magnitude. In this case, the policy of determining the pollution level threshold at a certain amount will encourage an increase in environmental degradation with even greater changes, as shown in curve C. It signifies that when the amount of pollution exceeds the threshold, it will have a more serious impact on environmental degradation [14].



Source: Hanley, Shogren [14]

Figure 1. Environmental degradations

In addition, pollution is an externality phenomenon from an economic activity that can be derived in a mathematical formulation to reach the optimal point as follows [15]:

$$\max_{s,f,x} p_s s + p_f \int - c_s(s,x) - c_f(f,x)$$

$$p_s = \frac{\Delta c_s(\hat{s},\hat{x})}{\Delta c}$$

$$p_f = \frac{\Delta c_f(\hat{f},\hat{x})}{\Delta f}$$

$$0 = \frac{\Delta c_c(\hat{s},\hat{x})}{\Delta x} + \frac{\Delta c_f(\hat{f},\hat{x})}{\Delta x}$$

The number of pollution can be determined where the marginal cost (MC) is equal to 0, namely:

$$\frac{\Delta c_c(s*,x*)}{\Delta x} = 0$$

$$MC_s(s*,x*) = 0$$

$$\frac{\Delta c_c(\hat{s},\hat{x})}{\Delta x} + \frac{\Delta c_f(\hat{f},\hat{x})}{\Delta x} = 0$$

Studies on the implications of economic development on increasing CO_2 gas emissions have been carried out by many experts. By adopting the theoretical framework of the Solow Model on the New Growth Theory to achieve an ideal economic growth (steady-state), the mathematical derivative can be formulated as follows:

$$Y(t) = [(1-\alpha_k)]^{\alpha}[A(t)(1-\alpha_t)L(t)]^{1-\alpha}, \quad 0 < \alpha < 1]$$

The increase in the production of pollutant CO_2 gas emissions due to the economic development process in the long term will affect the quality of the environment and ultimately affect the quality of life. Here, there is a causal relationship between environmental quality and the sustainability of economic development [6, 16]. In the long term, CO_2 gas emissions will also impact the quality of people's lives, thereby reducing health standards and ultimately resulting in the loss of time and funds to restore health from various diseases caused by CO_2 gas emissions. Emissions of CO_2 gas are also influenced by the country's population, where a larger population will encourage an increase in energy needs to meet economic needs in the fields of transportation, services, education, health, and others [17]. In addition, the impact of economic development on the environment, among others, is an increase in the production of CO_2 gas emissions, which affects the degradation of air quality and the social life of the community. In the long term, increased production of CO_2 gas emissions will also affect the sustainability of development because it impacts the quality of people's lives and human resources.

For this reason, environmental issues are crucial in economic development from a global perspective because of the interdependence between individuals, groups, and countries [16, 18]. Globally, increased production of CO_2 emissions will affect the greenhouse effect, cause global

warming, and ultimately affect the economic and social activities of the community [19, 20]. The increase in global temperature can also cause crop failure in some areas due to the drastic changes in weather cycles. Global warming also causes sea levels to rise so that some islands are submerged, and coastal areas experience abrasion symptoms, which cause losses for residents living in coastal areas. In addition, Dell, Jones [9] investigated the impact of climate change on the agricultural sector, health, conflict in society, the trade sector, labor productivity, and economic growth. It was shown that integrated policies are needed for all stakeholders to overcome the negative impacts of climate change. Next, Kolstad and Moore [8] conducted a study on the economic impact of climate change through observations of the weather. Their findings revealed that climate change had a very significant effect on the economy in the agricultural, trade, transportation, and distribution sectors, so it is necessary to anticipate well in economic activities and take serious efforts to control the damaging effects of climate change on the economy.

Therefore, research on the determinants of CO_2 gas emissions is essential to find out the factors causing CO_2 gas emissions so that integrated policies can be formulated to overcome the negative impacts of increasing CO_2 gas emissions. The urgency of macroeconomic variables affecting CO_2 gas emissions in member countries of the ASEAN Economic Community is because the Southeast Asia region is a strategic area that determines the future of the world economy and has abundant natural resources and a large population.

3. RESEARCH METHODS

The research method applied in this research was panel data analysis. The data came from World Bank data from 2010 to 2019, covering selected ASEAN economic community (AEC) member countries: Indonesia, Singapore, Malaysia, Thailand, Laos, Cambodia, Vietnam, Brunei Darussalam, and the Philippines. The research variables were the gross domestic product, CO_2 gas emissions, population (POP), foreign direct investment (FDI), external debt (ED), inflation (INF), energy consumption (EC), and exports (X). For the research estimation model for the determinants of CO_2 gas emissions in selected ASEAN economic community (AEC) member countries, it is formulated as follows:

$$Y=\alpha_o+\alpha_1 X_{1it}+\alpha_2 X_{2it}+\alpha_3 X_{3it}+\alpha_4 X_{4it}+\alpha_2 X_{5it}+\alpha_3 X_{6it}+\alpha_3 X_{7it}+e_{it}$$

where, $Y=CO_2$ gas emissions, X_{1it}=Gross domestic product (GDP) in country-i in year-t, X_{2it}=Total population (POP) in country-i in year-t, X_{3it}=External debt (ED) in country-i in year-t, X_{4it}=Exports (X) in country-i in year-t, X_{5it}=Foreign investment (FDI) in country-i in year-t, X_{6it}=Inflation (INF) in country-i in year-t, X_{7it}= Energy consumption (EC) in country-i in year-t.

Then, the Chow test was carried out to determine whether the estimation method for panel data analysis used fixed-effects or common effects. The formulation of the Chow test hypothesis in this panel data study is in the research [15]: Ho=Common effect model, Ha=Fixed effect model.

The statistical formulation of the Chow test is as follows:

$$F = \frac{SSE1 - SSE2/n - 1}{SSE2/n.t - n - k}$$

where, SSE_1=Sum square error of the common effects model, SSE_2=Sum square error of the fixed effect model, n=Number of cross-section research objects (country), t=Length of time series, k=The number of independent variables.

After that, the Hausman test determined whether to use the fixed-effect model or the random effect model. The formulation of the research hypothesis is as follows: Ho=Random effect model, Ha=Fixed effect model.

The estimation of the research equation is formulated as follows:

$$E(aX+b) = aE(X) + b$$

$$E[(aX)^2] = a^2E(X^2)$$

$$Var(aX+b) = a^2Var(X)$$

$$Var(aX+b) = E[(aX+b) - E(aX+b)]^2$$

$$Var(aX+b) = aE(X) + b$$

$$\begin{aligned} Var(aX+b) &= E[(aX - E(aX)]^2 \\ &= E[aX - aE(X)]^2 \\ &= E[(aX - E(aX)]^2 \\ &= a^2E[aX - aE(X)]^2 \\ &= a^2Var(X) \end{aligned}$$

The regression and correlation of the independent variables to the dependent variable in the panel data analysis were to get an estimate of the regression coefficient results that met the efficient and best criteria at the probability value of α=5%. The research methodology applied in this study was also conducting a literature review of reputable journal articles with the same theme to obtain comprehensive information.

4. RESULTS AND DISCUSSION

Research on the determinants of CO_2 gas emissions in selected ASEAN economic community (AEC) member countries had panel data on selected ASEAN economic community (AEC) member countries between 2015 and 2019. The variables in this study included CO_2 gas emissions as the dependent variable, while population (POP), gross domestic product (GDP), foreign investment (FDI), exports (X), energy consumption (EC), and inflation (INF) as independent variables. In panel data research, the steps were to conduct the Chow test to determine whether the analysis model used a fixed or a random effect model. The next step was to carry out the Hausman test to determine whether to use the fixed-effect model or the common effect model [21]. The Chow and Hausman test results uncovered that the estimation results were not significant, so they could not explain information about the relationship between variables properly. Thus, the next step was to estimate using the corrected standard error model method to get better estimation results. Then, research on the determinants of CO_2 gas emissions in selected ASEAN economic community (AEC) member countries applied panel data analysis corrected standard error model, with estimation results as follows:

Table 1. Regression of CO_2 emissions

Variable	Coefficient	Probability
C	-0.9884	0.664
POP	0.1857	0.310
GDP	0.1746	0.264
X	0.0164	0.001
FDI	0.1251	0.000
ED	0.0035	0.965
EC	0.0278	0.000
INF	-0.1542	0.000
R^2	0.6981	
Wald Chi square	226120.27	
Probability Chi square	0.000	

Source: Data processed, 2021

The empirical findings in the Table 1 above explain that CO_2 gas emissions in selected ASEAN economic community (AEC) member countries were influenced by the variables of foreign direct investment (FDI), exports (X), energy consumption (EC), and inflation (INF). The foreign investment variable (FDI) was the largest contributor to CO_2 gas emissions in ASEAN countries, with a regression coefficient of 0.1251. It means that an increase of 1 billion US dollars will increase CO_2 emissions by 0.1251%. This phenomenon is understandable, considering that foreign investment (FDI) through the manufacturing industry processes various kinds of raw materials into finished goods, causing much pollution, both water, air, and land pollution. As with other developing countries, ASEAN countries are the countries of choice for multinational company (MNC) investors to invest in various manufacturing industry sectors. With a wealth of natural resources, many workers, and political support from the government, ASEAN countries are ideal for investment. Thus, ASEAN countries, such as Vietnam, Cambodia, Laos, Malaysia, Indonesia, Thailand, and the Philippines, are competing to provide incentive facilities, both in the form of taxes and free of import duties, for several types of investment and industry. However, the impact of the large number of foreign companies in ASEAN is the main cause of the high production of CO_2 gas emissions. This empirical finding has also been pointed out by Hanley, Shogren [14] in their study of the phenomenon of economic activity - especially investment - and its impact on environmental change. They explained the need for studies to determine the balance between the benefits and costs of economic activities and their impact on environmental damage.

The export variable (X) was also causing CO_2 gas emissions, with a coefficient value of 0.0164. It indicates that a 1% increase in exports causes CO_2 emissions of 0.0164%. This fact implies that the strategy of ASEAN countries to encourage exports through manufacturing industrial products will have a polluting impact on the. It shows that many ASEAN countries' commodity exports are industrially processed products from raw or semi-finished materials into finished materials. The implication is that the demand for fuel increases, causing CO_2 emissions to increase. This empirical finding is relevant to the research results of Gouel and Laborde [3] regarding the effect of global market changes on climate change caused by CO_2 carbon gas emissions. However, their research was only on agricultural products. CO_2 emissions are triggered by investment and exports through industrialization activities. In addition to creating jobs, foreign investment (FDI) in ASEAN countries through the entry of multinational corporations (MNC) can also encourage economic growth. Nevertheless, the export-oriented industrialization strategy triggers an increase in fossil energy consumption, encouraging CO_2 gas emissions. Multinational corporations (MNC) also enter ASEAN countries due to the relatively lax environmental and industrial waste provisions compared to their home countries. Several types of industry trigger increased CO_2 emissions through land burning to prepare land for oil palm plantations, the results of which are primarily for export [5].

Specifically, Malaysia and Indonesia are the two largest countries exporting crude palm oil (CPO) in the international market. As a result, burning and CO_2 gas emissions become routine yearly to prepare new land for oil palm plantations. Therefore, in the long term, it is necessary to consider industrialization strategies in ASEAN countries to pay more attention to environmental aspects and natural balance for sustainable development [3].

ASEAN countries' energy consumption variable (EC) also significantly impacted CO_2 gas emissions. It can be seen from the magnitude of the regression coefficient value of the energy consumption variable of 0.0278, indicating that an increase in energy consumption of 1 mg will cause CO_2 emissions of 0.0278%. This reality is related to energy consumption for household needs, industry, and transportation, which continues to increase. This empirical finding is in line with the research results of Isaksen [10] on the relationship between household energy consumption, per capita income levels, and CO_2 carbon emissions in Norway. Moreover, as a developing country begins to enter the phase of an industrialized country, the consequences of energy needs will continue to increase. Energy consumption in several ASEAN countries indicates the energy needs of developing countries to support economic activities, both for household and industrial needs. Consequently, the government's electrification policy by building power plant installations and networks to support the increasing demand for electrical energy, both household and industrial, contributes to increasing energy consumption, increasing CO_2 gas emissions. In several ASEAN countries, most power plants are powered by coal, besides geothermal and hydropower. In this regard, the increasing demand for electric power for household and industrial needs has encouraged the use of coal to drive electric turbines, resulting in increased CO_2 gas emissions. Increasingly intensive industrialization to encourage economic growth in ASEAN countries has also triggered an increase in energy consumption, thereby increasing CO_2 gas emissions. In addition, energy consumption has risen due to the need for fuel to support the flow of distribution of goods and services. Human mobility then also increases energy consumption through the land, sea, and air transportation sectors, thereby also encouraging an increase in CO_2 gas emissions. Moreover, the congestion and deteriorating air quality in major cities of ASEAN countries, such as Bangkok, Jakarta, Kuala Lumpur, Manila, and Singapore, demonstrate the immense contribution of energy demand in the transportation sector in contributing to CO_2 gas emissions.

Furthermore, the inflation (INF) variable was one of the contributors to CO_2 gas emissions in ASEAN countries, with a coefficient value of -0.1542. It denotes that an increase in inflation of 1% will reduce CO_2 emissions by -0.1542 %. This economic phenomenon can be understood that the increase in the price of goods and services causes people's purchasing power to decrease, and consumption of goods will also decrease according to the law of demand; thus, it causes economic growth and energy needs to fall so that CO_2 gas

emissions will also decrease. On the other hand, lower inflation will also increase the competitiveness of export products so that the production of export goods will increase and CO_2 gas emissions will increase. Likewise, falling prices will increase people's purchasing power so that demand for goods and services increases, encouraging increased production of goods and services, eventually leading to increased CO_2 emissions. Related to that, the empirical findings of Burakov [4] also explained the relationship between the inflation rate and environmental issues, where price increases were triggered by changes in world oil prices and their effects on economic growth. Here, rising inflation tends to hamper economic growth and, in the end, will inhibit CO_2 carbon emissions [14].

5. CONCLUSION AND RECOMMENDATION

Based on the analysis results of empirical findings on the determinants of CO_2 gas emissions in ASEAN countries, it can be understood that CO_2 gas emissions are influenced by industrial activities and people's economic behavior. The need for carbon fuels increases with the increasing number of people and fuel for industrial, household, and transportation purposes. For this reason, it is necessary to formulate an integrated policy for controlling environmental pollution through a reward and punishment system without hampering the rate of economic growth. Also, the government can provide incentives for every industrial activity that can reduce CO_2 gas emissions and, at the same time, impose sanctions by imposing environmental taxes on every company that produces waste that exceeds the threshold. In addition, policies on using environmentally friendly alternative energy, such as geothermal, solar panels, wind power, and ocean wave energy, will positively impact reducing CO_2 emissions in ASEAN countries. Massive and sustainable socialization policies in the community will also change people's behavior in using energy wisely and gradually switching to environmentally friendly alternative energy. Moreover, ASEAN countries need to build cooperation in research and development (R&D) to find renewable energy technologies and innovations that are relatively safe, inexpensive, and easy to use so that they will be able to reduce the production of CO_2 gas emissions gradually.

This study's results recommended that ASEAN countries increase mitigation to prevent environmental quality degradation due to not environmentally friendly economic development. It is also necessary to be more stringent in granting concessions to foreign companies operating to pay more attention to handling industrial waste and CO_2 gas emissions. In addition, environmental audit policies should be implemented regularly and consistently and provide strict sanctions for companies and households indicated to damage the environment.

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