ISSN 2964-4291
https://proceeding.unnes.ac.id/index.php/iset

Analysis of Increasing CO2 Emissions and Economic Activity: An Empirical Investigation in 4 ASEAN Countries

Muhammad Adi Adrian[1*], Saifudin Zuhri[2], Sucihatiningsih Dian Wisika Prajanti[1]

[1]Universitas Negeri Semarang, Indonesia

[2]Universitas Islam Negeri (UIN) Salatiga, Indonesia

*Corresponding Author: adiadrian@students.unnes.ac.id

Abstract. The increase in global temperature and climate change that has occurred over the past decade is the result of increased CO2 emissions. Several factors such as gross domestic product, population, deforestation, and energy consumption are considered to be the most influential in increasing CO2 emissions. This paper uses panel data analysis to analyze the relationship between economic growth (GDP), population, deforestation, and energy consumption on increasing CO2 emissions in four ASEAN countries (Indonesia, Malaysia, Thailand, Vietnam) for the period 2001-2021. The research method used is panel data regression with the Fixed Effect Model (FEM). Using FEM, the results show that partially economic growth (GDP) and energy consumption have a positive effect on CO2 emissions. Meanwhile, population and deforestation have no influence on CO2 emissions. But simultaneously has a confidence level of 98.84% where the variation in the percentage change in CO2 emissions in the four countries in ASEAN is explained by the variables of economic growth (GDP), population, deforestation, and energy consumption by 98.84% and the remaining 1.16% is influenced by other variables outside these variables. Finally, the panel data results show that there is a significance of energy consumption and economic growth in the four ASEAN countries that have implications for CO2 emissions.

Keywords: Emission CO2; GDP; Environment; Deforestation; Energi Consumption; Population

INTRODUCTION

The development of the modern era in the past decade has begun to be felt in various countries in the world. The acceleration of this development certainly cannot be separated from the role of globalization which is the entrance to modernization (Asongu et al., 2016). The transition from the Millennial Development Goals (MDGs) to the Sustainable Development Goals (SDGs) has brought a wealth of literature on the relationship between energy, economic growth, population and environmental degradation to the attention of academics and policymakers. Ozturk (2010) states that the relevance of energy as a source of economic prosperity has been substantially explained. However, exploration, exploitation is also necessary for a country to improve individual welfare, optimal use of public commodities, inclusive growth, but must take into account sustainable development and renewable energy development (Akpan & Akpan, 2012).

Forests are one part of the environment that is an important factor for the earth and the survival of humanity. The role of forests and forests in meeting human needs has evolved over the centuries, from previously forests were only used for timber production recently the non-production functions of forests have grown increasingly significant (Ciesielski & Stereńczak, 2018). The benefits produced by forests are long-term and very useful for human survival ranging from improving environmental quality, reducing CO2 emissions economic opportunities, and aesthetic standards (Coletta et al., 2016; Marziliano et al., 2013). In addition, forests are also a gathering place for biodiversity and climate change is influenced by carbon storage which is represented as an ecosystem regulator, with all these reasons, forest protection must consider the nature of politics, customs, social conditions, and economics (Piussi & Farrell, 2000).

From 2001 to 2020, the global forest area shrank by 437 Mha, equivalent to 11% of the forest area in 2000 and increased CO2 emissions by 174 Gt (Global Deforestation Rates & Statistics by Country | GFW, n.d.). The net forest area loss rate has been more than 50% since 1990 (FAO, 2017). The shrinkage of the forest sector is due to the increasing human population and the increasing demand for food and land (Arshad et al., 2020). Forest areas are threatened by climate change, pests, diseases, exploitation, industrialization, and population. The increase in population in a country is closely related to the increase in industrialization based on increasing human needs, the massive industrialization will

certainly affect the creation of economic growth (Liu & Bae, 2018). However, this industrialization process often ignores the environment, causing damage to the natural environment and reducing the quality of human life (Awan et al., 2018).

At the same time, the use of fossil fuels such as coal and petroleum also contributes to environmental degradation and biodiversity reduction, which in turn affects people's health, satisfaction and prosperity (Khan et al., 2021). Therefore, environmental degradation has become a severe threat to the natural habitat of humans and other species on earth (Majeed et al., 2017).

The increase in carbon dioxide (CO2) emissions mainly comes from the burning of fossil fuels that are continuously used as necessities. The emergence of the problem of global climate change began when industrialized countries in the 19th and 20th centuries began using fossil fuels such as oil and coal for fuel consumption (Poku, 2016). The transformation from hydropower to coal with the aim of increasing productivity has in fact led to problems in the future and it is widely seen as a major source of growth performance and climate change (Majeed & Tauqir, 2020). Environmental scientists argue that energy consumption is responsible for carbon dioxide (CO2) emissions, Energy is an important factor in the manufacturing industry both in the production process and in daily use which also requires fuel.

In addition, the manufacturing industry can also increase industrial expansion and increase economic growth. However, high energy use can also lead to increased CO2 emissions which further deteriorate environmental quality (Majeed & Asghar, 2021) and one of the main causes of the creation of Greenhouse Gases (GHG) in the atmosphere and resulting in global warming and climate change. Global warming and climate change can be seen in melting snow and ice, rising sea levels, changing precipitation patterns, rising air and ocean temperatures, deteriorating agricultural and wildlife productivity and reduced labor productivity. Therefore, the threat of global warming and climate change has received more attention among environmentalists in recent decades. As a result, economists and environmentalists have become more aware of the environmental consequences of economic growth, shifting attention from simple economic growth to ecologically (environmentally) friendly economic growth (Alam et al., 2016).

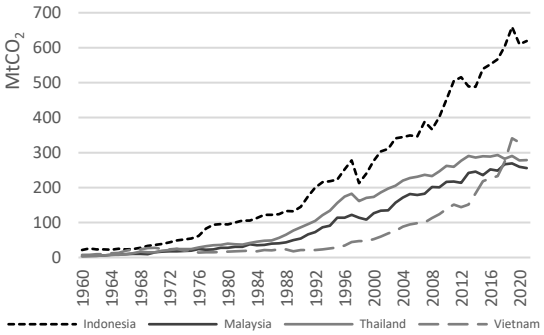

Figure 1. Increased CO2 Emissions
Source: Global Carbon Atlas, 2022

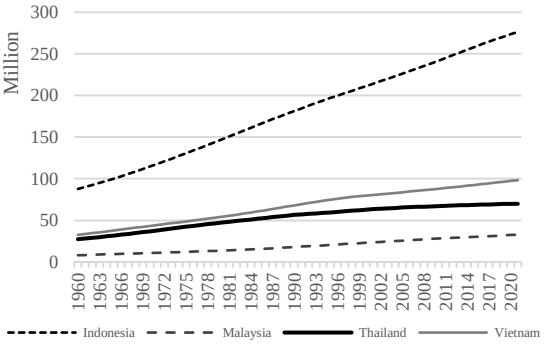

Figure 1. Increased Deforestation
Source: Global Forest Watch, 2022

In general, global CO2 emissions are always focused on developed countries and developing countries in Asia because they together contribute about 80% of global anthropogenic CO2 emissions. For example, the world's top ten emitting countries in 2012, which were all developed and developing countries in Asia, accounted for about two-thirds of global anthropogenic CO2 emissions (Poku, 2016). ASEAN countries such as Indonesia, Malaysia, Thailand, and Vietnam which are developing countries in Asia also have a contribution in the increase of carbon dioxide (CO2) emissions. As involved in Figure 1 during the period from 1960 to 2021 the increase in the amount of CO2 emissions in Indonesia, Malaysia, Thailand, and Vietnam increased significantly. This is in line with the increasing industrialization and increased production activities in the four countries. This is evidenced in the last three decades, where these countries have enjoyed higher economic growth by transforming their economies from primary agricultural sectors to energy-led industrial sectors.

Although these four countries only account for 6 percent of the global population, if you look

at Figure 2, the increase in the population of the four countries is even more significant. From 1960 to 2021, Indonesia's total population increased by 300 percent from 87 million to 276 million. The same thing happened in Malaysia where in 1960 the total population of Malaysia was around 8 million people and in 2021 it became 32 million people, an increase of 400 percent, while the total population of Thailand increased by 250 percent, and Vietnam by 300 percent. A study by Nazir Ur-Rehman (2011) shows that countries with large populations are more responsible for CO2 emissions and that developing countries' CO2 emission levels are higher because they are not required to comply with the Kyoto protocol.

Fossil oil energy use, population, economic growth and deforestation are seen as the biggest contributors to CO2 emissions. Studies conducted by Zeeshan (2020) state that CO2 emissions have a long-term relationship with GDP, population, and deforestation. His research also emphasizes that deforestation and increasing population can worsen environmental pollution. Voumik (2022) said that population has an influence on increasing CO2 emissions, then in his study also stated that energy consumption has a significant impact on the environment which is very detrimental in the country of Bangladesh. Other studies say that there is a correlation between population and increased CO2 emissions (Agung et al., 2017; Alam et al., 2016; Khan et al., 2021; Poku, 2016).

The relationship between deforestation and CO2 emissions according to a study conducted by Raihan (2022) in Malaysia Deforestation has a negative influence on CO2 emissions, which means that a decrease in forest area (deforestation) can have a long-term effect on CO2 emissions. An increase in the amount of energy consumption in a country can cause an increase in CO2 emissions, this is in line with the results of several studies also saying that an increase in energy consumption positively increases the level of CO2 emissions (Asongu et al., 2016; Hussain et al., 2012; Nathaniel & Adeleye, 2021; Olubusoye & Musa, 2020; Wang et al., 2018). Increased economic growth or GDP has an impact on increasing CO2 emissions such as studies conducted by Majeed (2021), Sahzabi (2011), Sohag (2017), and Alam (2016) which say that economic growth (GDP) has a significant and positive effect on CO2 emissions.

Various papers have been written on the theories of economic growth, energy consumption, deforestation and population and their relationship with carbon dioxide (CO2) emissions. As ASEAN is one of the major markets and centers of new industrialization, it potentially has an impact on carbon dioxide (CO2) emissions. Therefore, this study aims to investigate the relationship between CO2 emissions, economic growth, energy consumption, deforestation and total population. This paper uses panel data analysis that combines time series data and cross section data using the Fixed Effect Model (FEM) method to estimate economic growth, energy consumption, deforestation and total population on CO2 emissions in 4 ASEAN countries namely Indonesia, Malaysia, Thailand, and Vietnam from 2001 to 2021.

METHODS

This paper uses quantitative research using secondary data obtained from various sources such as World Bank, Global Carbon Atlas (GCA), Global Forest Watch (GFW) and the US Energy Information and Administration (EIA). This study uses environmental impact as the dependent variable proxied by CO2 emissions in units of metric tons of carbon dioxide (MtCO2). The independent variables used include gross domestic product (GDP) at current prices (in units of US dollars), total population (in people per year), deforestation measured by annual tree cover decline (in units of Kha), and energy consumption (in units of million matric tons of oil equivalent). The data used in this study uses time series data of four countries in ASEAN, namely Indonesia, Malaysia, Thailand, and Vietnam from 2001 to 2021. The analytical method used in this research uses panel data estimated with the Fixed Effect Model (FEM). FEM can show the contribution of Economic Growth (GDP), Total Population, Deforestation and energy consumption to the increase in CO2 emissions in the four ASEAN countries Indonesia, Malaysia, Thailand, and Vietnam.

Panel data is a technique of combining cross section and time series data in panel data, the same cross section unit is surveyed at several times. Estimation using panel data will increase degrees of freedom, reduce collinearity between explanatory variables and improve estimation efficiency. Panel data is often used to determine differences between individuals. In addition, panel data is also used to overcome the limited number of observations, because a larger number

of observations will increase the degree of freedom. The general equation form in panel data is as follows:

$$Y_{i,t} = \alpha_0 + \beta_1 X_{i,t} + \boldsymbol{\varepsilon}_{i,t}$$

In the equation above, Y is the dependent variable, X is the independent variable or explanatory variable, ε is the stochastic disturbance variable, β is the regression parameters. Subscripts denote i observation and t time. The parameter β_{it} is estimated on the basis of available data for variables Y and X. There are K independent variables on X (excluding the constant). Individual characteristics (heterogeneity) are present in β_{it} where β_{it} consists of constant and group specific. The use of panel data can provide many advantages statistically and in economic theory, among others. Panel data estimation can show heterogeneity in each unit; The use of panel data provides more informative data, reduces collinearity between variables, increases degrees of freedom and is more efficient; Panel data is suitable for drawing the dynamics of change; Panel data can be better able to detect and measure impacts; Panel data can be used for studies with more complete models; Panel data can minimize the bias that may be generated in regression. Meanwhile, the econometric model in this study is as follows:

$$CO2_{i,t} = \alpha_0 + \beta_1 GDP_{i,t} + \beta_2 P_{i,t} + \beta_3 DF_{i,t} + \beta_4 EC_{i,t} + \boldsymbol{\varepsilon}_{i,t}$$

This paper uses the natural log of some variables to standardize in units. *ln CO2* is Carbon Dioxide Emission; *ln GDP* is economic growth; *ln P* is population increase; *ln DF* is Deforestation growth, and *ln EC* is energy consumption growth, i is country; t is yearly; β_1, β_2, β_3,... βn is the coefficient parameter of each independent variable, α_0 is intercept; ε_i is error.

RESULTS AND DISCUSSION

The role of the economic activity sector in affecting the environment is partly due to competition in developing countries to become new developed countries. To achieve this, countries often take economic shortcuts by not considering the impacts of these economic activities, such as environmental pollution, exploitation of nature, increased carbon emissions, and socio-economic changes in the community.

Overcoming environmental problems and CO2 emissions, goverments around the world at the Kyoto Summit in 1997 made an agreement on greenhouse gas (GHG) emissions where industrialized countries must reduce national emissions by 5 percent during the period 2008-2012 (Hussain et al., 2012). In addition, the *Sustainable Development Goals* (SDG) agreement also emphasizes that a country's development must be based on environmental sustainability. This should then be a turning point for ASEAN countries such as Indonesia, Malaysia, Thailand and Vietnam. As a developing country, the increase in economic activity must be sustainable by maintaining environmental sustainability in accordance with the agreement contained in the SDGs.

Table 1. Summary Statistic Descriptive

Var	Mean	Std. Dev	Min	Max	Obs
CO2	275.1441	137.0617	59.65400	659.4357	84
GDP	3.64E+11	2.80E+11	3.27E+10	1.19E+12	84
P	1.08E+08	83585385	23709115	2.76E+08	84
DF	509377.5	564974.9	36101.94	2422072	84
EC	98.89854	44.17529	19.29968	205.1861	84

Source: Data Processed, 2022

Table 1 shows the summary descriptive statistics of several indicators affecting the increase in CO2 emissions in the four ASEAN countries of Indonesia, Malaysia, Thailand and Vietnam from 2001 to 2021. First, the increase in CO2 emissions in the period 2001-2021 has an average of 275.1 MtCO2, with a minimum level of 59.7 MtCO2 and a maximum level of 659.4 MtCO2. Second, economic growth proxied by gross domestic product (GDP) in the period 2001-2021 has an average of US$ 364 billion, with a minimum level of US$ 327 billion dollars and a maximum level of US$ 1.19 trillion dollars. Third, the total population in the four countries has an average of around 108 million people, with a minimum level of 23 million people and a

maximum level of 276 million people. Fourth, the increase in deforestation proxied by tree cover reduction in the period 2001-2021 has an average reduction of 509 kha, with a minimum level of 36 kha and a maximum level of 2422 kha. Finally, the energy consumption of the four ASEAN countries namely Indonesia, Malaysia, Thailand and Vietnam has an average energy consumption of 99 (*million metric tons of oil equivalent*), with a minimum level of 19 (*million metric tons of oil equivalent*) and a maximum level of 205 (*million metric tons of oil equivalent*).

Table 2. Correlation

	CO2	GDP	EC	DF	P
CO2	1.0000				
GDP	0.9474	1.0000			
P	0.5459	0.4373	1.0000		
DF	0.7147	0.6476	0.4453	1.0000	
EC	0.9720	0.9549	0.4694	0.5923	1.0000

Source: Data Processed, 2022

The correlation results shown in Table 2 explain the relationship between variables in influencing CO2 emissions. Table 2 shows that economic growth (GDP), total population, deforestation, and energy consumption have a strong positive correlation with CO2 emissions. This is evidenced by energy consumption which has a correlation of 0.97 to CO2 emissions, economic growth (GDP) has a correlation of 0.95 to CO2 emissions, then for deforestation has a correlation with CO2 emissions of 0.71 and for the total population has a correlation of 0.54 to CO2 emissions. Based on the correlation results, it can be interpreted that an increase in energy consumption, economic growth (GDP), deforestation, and total population will follow the trend of increasing CO2 emission levels.

Table 3. CO2 Emissions Estimated with Pooled Least Squared (PLS) Model

Variable	Coefficient	Std. Error	t	Prob
GDP	0.032767	0.037649	0.870326	0.3868
P	0.049908***	0.012795	3.900503	0.0002
DF	0.088896***	0.010635	8.359141	0.0000
EC	0.775893***	0.057210	13.56223	0.0000
Constant	-0.869600	0.762893	-1.139870	0.2578
R2	0.9787	Prob > F		0.0000
R2-Adj	0.9776	F		908.7
N	84	DW		0.6499

Notes: *significant at 10% level, ** significant at 5% level, *** significant at 1% level..
Source: Data Processed, 2022

The appropriate models in panel data include the Common Effect Model (PLS), Fixed Effect Model (FEM) and Random Effect Model. Table 3 explains the results of the Common Effect Model / Pooled Least Squared (PLS) estimation which shows an F probability value of 0.0000 with an F statistical value of 908.7. The R squared value in the PLS estimation is 0.9787. This result states that the variation in the percentage change in CO2 emissions in the four ASEAN countries is explained by the variables of economic growth (GDP), population, deforestation, and energy consumption by 97.87% and the remaining 2.13% is influenced by other variables outside these variables. Then, partially, population, deforestation, and energy consumption have a positive and significant effect on CO2 emissions. Only economic growth (GDP) has no significant effect on CO2 emissions.

Table 4. CO2 Emissions Estimated with Fixed Effect Model (FEM)

Variable	Coefficient	Std. Error	t	Prob
GDP	-0.087476**	0.043312	-2.019662	0.0469
P	0.306492	0.206362	1.485215	0.1416
DF	-0.038635	0.025365	-1.523166	0.1319
EC	1.113625***	0.069133	16.10846	0.0000
Constant	-2.283324	3.291518	-0.693699	0.4900
R2	0.9884	Prob > F		0.0000
R2-Adj	0.9873	Number of Obs		84
F	930.068	Number of Groub		4

Notes: *significant at 10% level, ** significant at 5% level, *** significant at 1% level.
Source: Data Processed, 2022

Then, in the fixed effect model (FEM) model shown in table 4, it shows that according to the F statistic (930.07) and for the F probability of 0.0000. The R Squared value in the FEM estimation is 0.9884. This result states that the variation in the percentage change in CO2 emissions in the four countries in ASEAN is explained by the variables of economic growth (GDP), population, deforestation, and energy consumption by 98.84% and the remaining 1.16% is influenced by other variables outside these variables. Then, partially economic growth (GDP) and energy consumption have a positive and significant effect on CO2 emissions. Only deforestation and population have no significant effect on CO2 emissions.

Table 5. Uji Chow-test

Test	P_{value}	Alpha (α)	Conclution
Chow-test	Prob > F = 0.0000	< 0.05	Reject H_0 : *Fixed Effect Model*

Source: Data Processed, 2022

The next step is to determine the best model between the Pooled Least Squared (PLS) Model and the Fixed Effect Model (FEM), in choosing between PLS or FEM, the Chow Test estimation is required. this test is conducted to compare which model is appropriate to use between PLS and FEM. If the probability test value (Prob.) on the cross-section F is greater than α (Prob > α) then the best model uses PLS. But if the value (Prob < α) then the most appropriate to use the FEM model. The Chow test results in table 5 show the Prob value of 0.0000 < 0.05 is smaller than the α value, this indicates that the Fixed Effect Model (FEM) is the best model rather than the Pooled Least Squared (PLS) model. This paper does not use the Random Effect Model (REM) estimation. This is because the requirement to use REM is that the amount of cross-section data is more than the time series data. Where as in this paper the cross-section data is less than the time series data, namely only 4 countries (Indonesia, Malaysia, Thailand, and Vietnam) while the time series data calculated is 21 from 2001 to 2021 so that the estimation results cannot be done.

Overall, the results show that economic growth and energy consumption in four ASEAN countries affect CO2 emissions. Meanwhile, deforestation and population have no influence on increasing CO2 emissions. The findings of this study are in line with previous studies such as Asongu (2016), Hussain (2012), Fauzi (2017), Majeed (2021), and Alam (2016). However, this study needs to study more deeply the effect of deforestation and population on increasing CO2 emissions because this study shows no effect on CO2 emissions. Illegal logging, forest fires, and other activities that cause deforestation are thought to cause increased CO2 emissions. The reduction of trees can cause the photosynthesis process (absorbing carbon dioxide) of plants to decrease, thus increasing CO2 emissions. In addition to deforestation, the population also causes the need for basic needs to increase and the use of energy also increases. Based on these assumptions, it is necessary to re-examine the effect of deforestation and population on increasing CO2 emissions using more specific indicators.

The results state that Gross Domestic Product (GDP) has a significant result on CO2 emissions. this is evidenced by the probability value (t) = 0.0469 below the test level α = 0.05. The coefficient value on gross domestic product (GDP) means that every one percent increase in Gross Domestic Product in the four countries will be able to reduce the value of CO2 emissions by

0.087% (in metric tons per capita). A negative coefficient means that an increase in the percentage value of a variable will reduce the value of the dependent variable. Empirically, these results are different from some previous studies such as Asongu (2016), Hussain (2012), Fauzi (2017) which say that economic growth can have an adverse effect on environmental damage and increased CO2 emissions.

The massive bilateral relations between ASEAN countries and developed countries in the world facilitate the transfer of environmentally friendly technology. So that in carrying out economic activities minimize environmental damage and air pollution (CO2 emissions). These results are corroborated by Majeed (2020) in his study, saying that economic growth has a heterogeneous effect on some countries. Poor countries tend to rely on traditional technologies that are closely related to pollution and often sacrifice the environment in achieving higher economic growth. As for rich countries, economic growth tends to show a favorable impact on the environment because it respects nature and uses green and environmentally friendly technologies in its economic activities.

Population growth in each country certainly has both positive and negative impacts on a country. The results of this study say that the total population in the four ASEAN countries has no significance to the increase in CO2 emissions. This is evidenced by the probability value (t) = 0.1416 which is greater than the test level α = 0.05. These results are in accordance with research conducted by Alam (2016) that population has no influence on increasing CO2 emissions. The total population has no effect on CO2 emissions because the four ASEAN countries, although having rapid population growth, do not have an impact on increasing economic needs and activities that have an impact on CO2 emissions. In addition, the similar geographical location, which is surrounded by tropical rainforest areas, makes the increase in population not so impactful on increasing CO2 emissions.

Deforestation states similar results to total population where both have no significance on CO2 emissions. This is evidenced by the probability value (t) = 0.1316 which is greater than the test level α = 0.05. This condition is different from previous studies such as Arshad (2020) research which says that deforestation in the long run can worsen environmental pollution and where deforestation has significant results on CO2 emissions stating that a 1 percent decrease in tree cover can have long-term effects in the form of increased CO2 emissions. The insignificance of deforestation on increasing CO2 emissions in the four ASEAN countries is because the level of deforestation fluctuates and tends to decrease. This is also strengthened by public awareness of the importance of protecting the environment or nature as well as by carrying out Reforestation and Afforestation activities.

Energy consumption is a major factor in environmental quality. Increased energy consumption can worsen the air environment as traditional energy sources (fossil oil) emit CO2 in the atmosphere. Energy consumption, which consists mainly of renewable and nuclear energy, improves environmental quality (Majeed & Tauqir, 2020). The results of this study indicate that energy consumption has a very significant effect on CO2 emissions. this is evidenced by the probability value (t) = 0.0000 below the test level α = 0.05. The positive coefficient value on energy consumption means that every one percent increase in energy consumption in the four countries will be able to reduce the value of CO2 emissions by 1.12 percent (in metric tons per capita).

Empirical studies that are in line with the results of research such as those conducted by Majeed (2020) in his study of the effects of Energy Consumption on Carbon Emissions, which then states that energy consumption has positive results on CO2 emissions. Aslan (2022) in his research confirms that oil-importing countries are the biggest emitters of CO2. Studies conducted in Pakistan also state that almost 54 percent of energy consumption in Pakistan depends on oil and gas, which results in more CO2 emissions being created and is the main cause of environmental pollution in Pakistan. To be able to anticipate the increasing CO2 emissions, the use of technology is expected to use environmentally friendly fuels and renewable energy. In addition, the use of fossil oil energy is done by gradually reducing consumption to 0 percent so as to reduce the level of CO2 emissions in the earth's atmosphere. In addition, no less important is the household awareness movement in implementing green development by utilizing space optimally as a place to grow plants that can absorb CO2 emissions. Early introduction of environmental awareness in school-age children is also an effort to protect the environment in the future (Fauzi, 2017).

CONCLUSION

This study aims to determine the effect of economic growth (GDP), population, deforestation, and energy consumption on CO2 emissions in four ASEAN countries namely Indonesia, Malaysia, Thailand, and Vietnam for the period 2001-2021. This paper has examined the relationship between economic growth (GDP), population, deforestation, and energy consumption on CO2 emissions using panel data analysis with the Fixed Effect Model (FEM). As explained in the introduction, over the past few decades CO2 emissions have been increasing every year and are increasingly worrying due to various factors such as economic growth, population, deforestation, and energy consumption.

The results of the FEM panel data model state that partially only economic growth (GDP) and energy consumption have a significant effect on CO2 emissions, while population and deforestation have no significant effect on CO2 emissions. Simultaneously, the results showed a significant result of 0.9884 or 98.84%, which means that the variation in the percentage change in CO2 emissions in the four countries in ASEAN is explained by the variables of economic growth (GDP), population, deforestation, and energy consumption by 98.84% and the remaining 1.16% is influenced by other variables outside these variables.

The results of this study need to be continued by involving different countries in different regions, can also compare between developed countries, developing countries, and poor countries. Adding a longer period will certainly maximize econometric results. In addition, further research is needed on what factors cause population and deforestation to have no effect on CO2 emissions. The results of this study can be used as recommendations or input and consideration for stakeholders in overcoming the problem of CO2 emissions.

REFERENCES

Agung, P., Hartono, D., & Awirya, A. A. (2017). Pengaruh Urbanisasi terhadap Konsumsi energi dan emisi Co2 : Analisis Provinsi di Indonesia Prima. *Jurnal Ekonomi Kuantitatif Terapan*, *10*(2), 9–18.

Akpan, G. E., & Akpan, U. F. (2012). Electricity consumption, carbon emissions and economic growth in Nigeria. *International Journal of Energy Economics and Policy*, *2*(4), 292–306.

Alam, M. M., Murad, M. W., Noman, A. H. M., & Ozturk, I. (2016). Relationships among carbon emissions, economic growth, energy consumption and population growth: Testing Environmental Kuznets Curve hypothesis for Brazil, China, India and Indonesia. *Ecological Indicators*, *70*, 466–479. https://doi.org/10.1016/j.ecolind.2016.06.043

Arshad, Z., Robaina, M., Shahbaz, M., & Veloso, A. B. (2020). The effects of deforestation and urbanization on sustainable growth in Asian countries. *Environmental Science and Pollution Research*, *27*(9), 10065–10086. https://doi.org/10.1007/s11356-019-07507-7

Aslan, A., Ocal, O., Ozsolak, B., & Ozturk, I. (2022). Renewable energy and economic growth relationship under the oil reserve ownership: Evidence from panel VAR approach. *Renewable Energy*, *188*, 402–410. https://doi.org/10.1016/j.renene.2022.02.039

Asongu, S., El Montasser, G., & Toumi, H. (2016). Testing the relationships between energy consumption, CO2 emissions, and economic growth in 24 African countries: a panel ARDL approach. *Environmental Science and Pollution Research*, *23*(7), 6563–6573. https://doi.org/10.1007/s11356-015-5883-7

Awan, U., Kraslawski, A., & Huiskonen, J. (2018). Governing interfirm relationships for social sustainability: The relationship between governance mechanisms, sustainable collaboration, and cultural intelligence. *Sustainability (Switzerland)*, *10*(12). https://doi.org/10.3390/su10124473

Chandra Voumik, L., Rahman, M. H., & Hossain, M. S. (2022). Investigating the subsistence of Environmental Kuznets Curve in the midst of economic development, population, and energy consumption in Bangladesh: imminent of ARDL model. *Heliyon*, *8*(8), e10357. https://doi.org/10.1016/j.heliyon.2022.e10357

Ciesielski, M., & Stereńczak, K. (2018). What do we expect from forests? The European view of public demands. *Journal of Environmental Management*, *209*, 139–151. https://doi.org/10.1016/j.jenvman.2017.12.032

Coletta, V., Lombardi, F., Altieri, V., Bombino, G., Marcianò, C., Menguzzato, G., & Marziliano, P. A. (2016). Environmental

Resources Conservation through Sustainable Forest Management. *Procedia - Social and Behavioral Sciences*, *223*, 758–763. https://doi.org/10.1016/j.sbspro.2016.05.264

FAO, F. and A. O. (2017). Fao 2017. In *Fao 2017* (Vol. 5).

Fauzi, R. (2017). Effects of Energy Consumption, Forest Areas and Economic Growth toward CO2 emissions in 6 (six) ASEAN Member Countries: A Panel Data Analysis Approach. *Ecolab*, *11*(1), 1–52. http://ejournal.forda-mof.org/ejournal-litbang/index.php/JKLH/article/view/3086/2217

Global Deforestation Rates & Statistics by Country | GFW. (n.d.). Retrieved December 23, 2022, from https://www.globalforestwatch.org/

Hussain, M., Javaid, M. I., & Drake, P. R. (2012). An econometric study of carbon dioxide (CO2) emissions, energy consumption, and economic growth of Pakistan. *International Journal of Energy Sector Management*, *6*(4), 518–533. https://doi.org/10.1108/17506221211282019

Khan, I., Hou, F., & Le, H. P. (2021). The impact of natural resources, energy consumption, and population growth on environmental quality: Fresh evidence from the United States of America. *Science of the Total Environment*, *754*, 142222. https://doi.org/10.1016/j.scitotenv.2020.142222

Liu, X., & Bae, J. (2018). Urbanization and industrialization impact of CO2 emissions in China. *Journal of Cleaner Production*, *172*, 178–186. https://doi.org/10.1016/j.jclepro.2017.10.156

Majeed, M. T., & Asghar, N. (2021). Trade, energy consumption, economic growth, and environmental quality: an empirical evidence from D-8 and G-7 countries. *Environmental Science and Pollution Research*, *28*(43), 61302–61316. https://doi.org/10.1007/s11356-021-15066-z

Majeed, M. T., Tariq, ;, & Mumtaz, S. (2017). Happiness and environmental degradation: A global analysis. *Pakistan Journal of Commerce and Social Sciences (PJCSS) Suggested Citation*, *11*(3), 753–772. http://hdl.handle.net/10419/188315

Majeed, M. T., & Tauqir, A. (2020). Effects of urbanization, industrialization, economic growth, energy consumption and financial development on carbon emissions: An extended STIRPAT model for heterogeneous income groups. *Pakistan Journal of Commerce and Social Science*, *14*(3), 652–681.

Marziliano, P. A., Lafortezza, R., Colangelo, G., Davies, C., & Sanesi, G. (2013). Structural diversity and height growth models in urban forest plantations: A case-study in northern Italy. *Urban Forestry and Urban Greening*, *12*(2), 246–254. https://doi.org/10.1016/j.ufug.2013.01.006

Nasir, M., & Ur Rehman, F. (2011). Environmental Kuznets Curve for carbon emissions in Pakistan: An empirical investigation. *Energy Policy*, *39*(3), 1857–1864. https://doi.org/10.1016/j.enpol.2011.01.025

Nathaniel, S. P., & Adeleye, N. (2021). Environmental preservation amidst carbon emissions, energy consumption, and urbanization in selected african countries: Implication for sustainability. *Journal of Cleaner Production*, *285*, 125409. https://doi.org/10.1016/j.jclepro.2020.125409

Olubusoye, O. E., & Musa, D. (2020). Carbon Emissions and Economic Growth in Africa: Are They Related? *Cogent Economics and Finance*, *8*(1). https://doi.org/10.1080/23322039.2020.1850400

Ozturk, I. (2010). A literature survey on energy-growth nexus. *Energy Policy*, *38*(1), 340–349. https://doi.org/10.1016/j.enpol.2009.09.024

Piussi, P., & Farrell, E. P. (2000). Interactions between society and forest ecosystems: Challenges for the near future. *Forest Ecology and Management*, *132*(1), 21–28. https://doi.org/10.1016/S0378-1127(00)00376-5

Poku, F. A. (2016). Carbon Dioxide Emissions, Urbanization and Population: Empirical Evidence in Sub Saharan Africa. *Energy Economics Letters*, *3*(1), 1–16. https://doi.org/10.18488/journal.82/2016.3.1/82.1.1.16

Raihan, A., Begum, R. A., Nizam, M., Said, M., & Pereira, J. J. (2022). Dynamic impacts of energy use, agricultural land expansion, and deforestation on CO2 emissions in Malaysia. *Environmental and Ecological Statistics*, *29*(3), 477–507. https://doi.org/10.1007/s10651-022-00532-9

Sohag, K., Al Mamun, M., Uddin, G. S., & Ahmed,

A. M. (2017). Sectoral output, energy use, and CO2 emission in middle-income countries. *Environmental Science and Pollution Research*, *24*(10), 9754–9764. https://doi.org/10.1007/s11356-017-8599-z

Wang, S., Zeng, J., Huang, Y., Shi, C., & Zhan, P. (2018). The effects of urbanization on CO2 emissions in the Pearl River Delta: A comprehensive assessment and panel data analysis. *Applied Energy*, *228*(June), 1693–1706. https://doi.org/10.1016/j.apenergy.2018.06.155

Yousefi-Sahzabi, A., Sasaki, K., Yousefi, H., & Sugai, Y. (2011). CO2 emission and economic growth of Iran. *Mitigation and Adaptation Strategies for Global Change*, *16*(1), 63–82. https://doi.org/10.1007/s11027-010-9252-z