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Effect of Economic Growth, Industrialization, Population Growth, and Renewable Energy on CO2 Emissions in the Long and Short Term in ASEAN 5

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ABSTRACT: This study aims to see the dynamic pattern of the relationship between CO2 emissions and economic growth, industrialization, population growth, and renewable energy in the long and short term in ASEAN 5 countries, namely Indonesia, Malaysia, Thailand, Philippines and Singapore. ASEAN is a region of countries that have the potential for natural resources and high economic activity as well as being a strategic area in global trade flows. In addition, the ASEAN region, especially ASEAN 5, has a fairly rapid capacity and socio-economic activity so that its mobility is important to note. The VECM method is used to determine this objective by using panel data sourced from the Worldbank. The results of the analysis show that in the long term, population growth and consumption of renewable energy significantly affect CO2 emissions in the ASEAN 5 region. Meanwhile, in the short term, industrialization and consumption of renewable energy significantly affect CO2 emissions in the ASEAN region 5.

KEYWORDS: CO2 emissions, renewable energy, industrialization, economic growth

I. INTRODUCTION

Global warming and climate change as a result of carbon dioxide (CO2) emissions have become important issues to be discussed in the last few decades. This issue is also at the same time a major global agenda in sustainable economic development. The concept of sustainable development as outlined in the SDG's (Sustainable Development Goal's) concept is currently a global reference in implementing the country's development which includes 17 main goals (Navarrete *et al*. 2020). CO2 emissions related to global warming, climate change and environmental degradation are the main drivers of sustainability problems. Various empirical studies and studies have been carried out related to environmental degradation as a form of problem solving and solutions in formulating a sustainability policy. From a theoretical point of view, this environmental problem was first described by Kuznets (1995) in his study of estimating the change in the relationship between per capita income and environmental quality that moves along an inverted U-curve. Per capita income is reflected in economic growth and environmental quality known as EKC (*Environmental Kuznets Curve*).

In the EKC hypothesis, it is explained that the economic growth of a country will encourage an increase in the concentration of emissions and gas pollution and will experience a turning point after the optimal point where increased development can reduce environmental degradation. One of the contributors to the increase in environmental degradation due to industrialization which is currently increasingly occurring in various countries, especially in the ASEAN region, especially in Indonesia, Malaysia, the Philippines, Thailand and Singapore, which have complex and broader economies of scale. This is the trigger, because industrialization requires large energy consumption in carrying out its production activities with the integration of high technology. Production machines, transportation equipment and others require high energy consumption, the majority of which do not use renewable energy, this causes pollution to increase. This condition further increases the threat to environmental sustainability, so that the responsibility of the government and other policy makers becomes very urgent to mitigate this. Excessive consumption of natural resources that are exploited on a large scale also has a big role in encouraging an increase in CO2 emissions such as exploitation of palm oil which results in a decrease in environmental quality (Hasudungan *et al*. 2020).

Several empirical studies such as that conducted by Chen et al (2020) confirm that the increasing trend of global warming provides a big warning for the Chinese government in facing tremendous pressure to reduce CO2 emissions. Increasing and accelerated economic growth in developing countries will have an impact on environmental degradation (Hanif and Gago-de-Santos 2016). The acceleration of a country's economic growth is marked by an increase in industrialization which will increase energy consumption which in turn results in an increase in CO2 emissions. The study of Wang *et al*. (2015) analyzing more specifically the EKC by including the OLG model that uses population growth with the environment found the results that increasing growth will result in the shape of the EKC being steeper and having a higher peak but not fundamentally changing the relationship between environmental degradation and income. Meanwhile, Alam *et al*. (2016) examined specifically population growth in countries with high population numbers such as Indonesia, India, China and Brazil with environmental impacts. The results found CO2 emissions increased as income and energy consumption increased in the four countries. Meanwhile, population has a significant impact in India and Brazil. In Indonesia and China CO2 emissions decrease as income increases. In India, income and CO2 emissions have a positive relationship so that an increase in income will actually increase CO2 emissions.

The importance of integrating the SDG's concept in economic development for high-activity countries such as Indonesia, Malaysia, Thailand, the Philippines and Singapore. This is necessary for a more relevant analysis of the relationship between CO2 emissions and economic growth. Global dynamics that are rapidly and massively have implications for economic improvement followed by environmental degradation. Based on these problems, this study aims to analyze how the dynamic pattern of the relationship between CO2 emissions with economic growth, industrialization, population growth, and renewable energy in the long and short term in ASEAN countries 5.

2. LITERATURE REVIEW

Sustainable Development (SD) has become a paradigm global development based on environmental development (Mensah 2019). Sustainable development has become a concept that has begun to be accepted globally and has been implemented for a long time. The overall goal of sustainable development is long-term economic and environmental stability that can be achieved through the integration of economic, environmental and social issues during the decision-making process (Gold 2015). Sustainable development has traditionally been defined as development that aims to meet the needs of the present generation without compromising the availability and capabilities of future generations' needs (Jaramillo-nieves and Río 2010).

The concept of sustainable development originated from a world conference, namely the *World Conference Environmental and Development* (WCED) through the Brundtland Commission report which stated that sustainable development is development that meets the needs of the present without compromising the needs of future generations (WCED 1987). Subsequently, after three decades, this concept was formalized and became a major global agenda (Holden *et al*. 2014). In 2015 the 4th quarter of September 25 to be exact, this agenda was formally launched by the United Nations (United Nations) as a new global plan and agenda consisting of 17 core goals of the SDG's agenda (Navarrete *et al*. 2020). Among these goals, around 169 targets were distributed in critical areas that are priorities for humanity and the planet. There are as many as 230 indicators with the overall goal of ensuring that no one is left behind in overcoming development problems in 2030. These SDGs become a complex development priority from all interrelated lines of life. One of the SDG's grand goals is to protect the earth from environmental degradation, including through sustainable consumption and production, managing natural resources in a sustainable manner and taking wise actions for climate change and so on so as to support the preservation of the earth's existence to meet the needs of future generations. forthcoming (Navarette *et al*. 2020).

The SDG's goals since 2015 have become a normative framework for driving global development. The international development community has taken various comprehensive actions to mobilize natural resources in an effort to operationalize the SDG's goals (Kumi *et al*. 2019). In an effort to achieve this SDG's goal, it requires a collaboration of all stakeholders and levels of the world community, including the general public, scientists, practitioners, academics and policy makers to execute these goals. A principle that underlies the SD concept is an acknowledgment of the interdependence of all inhabitants of the earth both socially, economically and environmentally in the dimensions of sustainable development. This principle fosters a higher awareness of the condition and quality of the earth as a planet that must be maintained for its sustainability.

In designing actions for elementary schools, collaboration and discussion are needed that involve policy makers from the regional, national, international scope as well as the private and community sectors because elementary school problems are a complex and integrated problem (Kumi *et al.* 2019). This is so that all problems can be identified properly so that the actions taken are also in accordance with the problems. The main actor in supporting SD is the private sector. This is because the private sector is a contributor to the results of financial resources and innovation in the flow of production to consumption. In

addition, the private sector also plays an important role in encouraging sustainable economic growth and protecting the earth from its activities but also plays a role in eliminating poverty through collaboration with public governments through strategic collaboration (UN Global Compact 2014). The SDG's agenda creates unique opportunities for the private sector by providing: a) a demonstrated results framework supported by government, civil society and business; b) a common language on socio-economic and environmental issues with the potential to improve communication, collaboration and coordination; and directions for future innovation and investment (CISL 2017; Kumi *et al.* 2019).

The SD concept which becomes the global agenda and action plan to achieve sustainable development requires a big and clear commitment related to operations towards the realization of the goal. In addition, the achievement of SD must be supported by all world stakeholders so that in its application it can be realized according to the objectives (Kyn *et al*. 2020). As a step in achieving SD, there are six transformations that aim to help identify priority investments and regulatory challenges, and call on all policy makers to work together to achieve goals. One of these transformations requires the decarbonization of energy and sustainable industry for the purpose of promoting changes in consumption and production patterns so as to maintain environmental quality. This becomes very important related to changes in the structure of the economy through the manufacturing industry sector which plays a core role in this process. Industry is a driving force for the economy because of its capacity to create job opportunities and generate income, but it must be accompanied by an attitude of tolerance with natural resources and climate change that are part of the impact of industrial activities.

From the perspective of technological progress and innovation have an important role to achieve sustainable development, especially in the production process. Industries with high technology can be more environmentally friendly with relatively lower levels of pollution through the integration of the concept of sustainability. For example, in the recycling industry, which carries out activities on used goods that have the potential to pollute the environment so that they can be reprocessed into goods that have a higher and more useful value (UNIDO 2016; Sandin and Peters 2018). The importance of increasing research and development of green energy technology investment to reduce the intensity of energy use (Chakraborty and Mazzanti 2020). This development is to provide a tool for researchers and policy makers to evaluate a country's performance based on how successful the industrial economy is while preserving the environment while promoting the inclusiveness of industrial production (Kynčlová *et al*. 2020). In addition, this development can also build a composite indicator as the best solution for *benchmarking* that analyzes the country's performance in development. It also helps countries track performance progress in implementing SD (Sachs *et al*. 2019). An intuitive solution for building a composite measure of indicators to monitor countries' progress towards sustainable development indicators. The global indicator framework includes indicators spanning three dimensions so that composite measures can be included. This index is called the SDG-9 index and explores the level and pattern of growth of activity in the manufacturing sector and its impact on production processes, workers and the environment (Kynčlová *et al*. 2020).

The SDG's reflect ambitious development goals with a transformative vision accompanied by support from each of the 193 UN member states. Thus, SD provides both opportunities and great challenges for developing countries around the world (Bhattacharya *et al.* 2015). SD also reflects a global consensus about a desirable future for long-term goals. The global economy is experiencing a recovery, the emergence of new social and economic crises that tend to dictate many development policies. This condition makes it difficult for developing countries to carry out good implementation of the SDG's targets. Based on the study of Bhattacharya *et al*. (2016), a series of recommendations can be made to realize the implementation of the SDGs in developing countries. The findings show that implementation at the national level is highly dependent on the proper integration of the global agenda. This happens because there are national and sectoral development figures that exist in each country so that SDG integration can be achieved by comparing planned national development and identifying and reducing gaps that arise. All governments must coordinate actions to implement a comprehensive agenda for the SDGs. Coordination of regional and central leadership is very important as a form of communication to ensure proper participation of all stakeholders. All SDG indicators need to be identified from country to global level and estimates on targets are required.

The successful implementation of SDG targets, targets and indicators requires the role of the public, one of which is the provision of public goods that can occur through public sector policies, so there needs to be clear coordination. Innovation and future-oriented mindset must be a priority so that strong support and motivation are needed in providing public services (Winnie 2015). The provision of these public services requires a skill that aims, among others:

1. Prioritizing targets and indicators, identifying and implementing adequate financial resources for political needs so that the power of leaders in politics can encourage the vision of development because the implementation of SDG's requires factors of personal interest and power relations.

2. Interpreting and contextualizing the targets clearly
3. Addressing problems that contradict the targets, because the successful implementation of the SDG's requires a complex approach at all levels of actors.
4. Overcoming corruption, rent seeking and other public and private sector failures because the implementation of the SDG's targets requires roles from all lines.
5. Promote state legitimacy by building trust and commitment to achieve sustainable development according to the SDG's agenda.

The development and inclusive development agenda implies that all stakeholders must act collaboratively and work together in implementing the SDG targets (Winnie 2015). For this reason, stakeholders with leadership skills are needed who are able to collaborate to encourage all actors to take effective action for good problem solving. Several attempts were made to analyze and examine the significance of the importance of each goal of the SDGs for each country. In addition, the importance of paying attention to possible challenges can be an obstacle faced by the government (Akenroye *et al*. 2018). One of the obstacles that will be faced especially for developing countries is related to funding. SDG goals must be supported from a financial perspective because of their complexity requires large funds to achieve their goals. Investment is a very important instrument to support this problem. According to the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP), which shows that Southeast Asia is a region with a large proportion of developing countries inhabited, it needs to be addressed, including related to investment up to 20% of its total GDP (Akenroye *et al*. 2018).

This research is based on Kuznets hypothesis as reflected in the Environmental Kuznets Curve (EKC). Basically, the EKC aims to look at the relationship between environmental degradation and economic growth. In this study, environmental degradation is proxies by the amount of CO2 emissions that can trigger a decrease in environmental quality. Several cases show that the increase in CO2 emissions is caused by various complex problems and leads to a decrease in environmental quality. In the midst of increasing global dynamics, providing various innovations in achieving the growth and development of a country. In this case, one form of innovation is reflected in industrialization to increase production value added. However, the majority of industrialization from an environmental perspective has a negative impact and contributes to increasing environmental degradation.

In addition, population growth also has a significant impact on increasing CO2 emissions. The increasing population has resulted in greater consumption of energy, both renewable energy and non-renewable energy. The dominant human activity in using energy has a significant impact on increasing energy consumption. However, not many countries are able to create renewable energy as an effort to minimize the use of renewable energy to maintain environmental sustainability. Fossil fuels are one of the non-renewable energies that are widely consumed by humans both for the industrial sector, transportation and other mobile media to encourage human activities. In this case, the emergence of renewable energy as an alternative in minimizing energy use that can trigger an increase in CO2 emissions is very urgent for several countries.

This study uses research objects in ASEAN 5 countries consisting of Indonesia, Malaysia, the Philippines, Thailand and Singapore. This is motivated by the fact that these countries have performed well in the past few decades in expanding their industrialization. In addition, ASEAN is also a country with a fairly large population growth, especially in Indonesia, which is one of the countries with the 5th largest population in the world of 267 million people. According to data released by the World Bank, ASEAN 5 countries on average experienced an increase in CO2 emissions, so this can be an important indication in reducing the increase in CO2 emissions by integrating the SDGs concept to achieve sustainable development in ASEAN 5.

3. METHODOLOGY

Secondary data used in this study with the type of panel data consisting of the 2007-2016 time series for ASEAN 5 countries with data sources from the World Bank. Sampling of five ASEAN 5 countries because these countries have a pattern of economic activity that is large enough to be identified as having an impact on environmental degradation. The emergence of industrialization in the country results in an increase in energy consumption which will have an impact on increasing CO2 emissions.

To answer the problem, the Vector Error Correction Model (VECM) method is used, which is one of the methods of the maximum likelihood method with cointegration testing as one of the pre-estimation tests. This model is a VAR model which usually contains some variable data that is not stationary, but has cointegration in the model (Surjaningsih, et al, 2012). In the VECM model, long-term and short-term relationships can be identified from the research model andcan be concluded a more detailed relationship. In addition, the simultaneous nature of the model and a theory also provides advantages in including

variables in the model without a theoretical background. The VECM model in addition to detecting long-term relationships in the model, can also minimize errors (errors) in the long run (Yin Kuo 2016). The following are the specifications of the research model used:

$$\Delta z_{it} = \Gamma_1 \Delta z_{it-1} + \ldots + \Gamma_{p-1} \Delta z_{it-p+1} + \Pi z_{it-p} + u_{it}$$

$$\Gamma_n = -(I - A_1 - \ldots - A_i), n = 1, \ldots, p-1 \text{ dan } \Pi = -(I - A_1 - \ldots - A_p) = \alpha\beta'$$

It is known that Z is a set of endogenous variables consisting of CO2 (the amount of CO2 emissions by unit kt); GDP Growth (GDP growth by one percent); Pop growt (population growth units percent) Renewable (Renewable energy, units percent) and Industry (Technology manufacturing industry with unit percent) and α indicate the speed of adjustment matrix and β is the coefficient matrix of the long-term.

4. RESULTS AND DISCUSSION

The dynamic pattern of long-term and short-term linkages between CO2 emissions and economic growth, renewable energy, population growth and industrial sector growth is shown by the VECM panel estimation results. In VECM estimation, there is a pre-estimation test to see data stationarity and cointegration. First, the stationarity test to see that each variable used has good stationarity. The data are stationary if the mean and variance are constant over time, followed by the variance between two periods depending only on the distance. Stationary data will move steadily and converge around the average value with a small deviation without a positive or negative trend movement. The unit root test is used to observe whether certain coefficients of the estimated autoregressive model have a value of one or not. . The results of data stationarity are shown in Table 1 as follows:

Table 1. Result of Stationary Test

Variable	Level I(0)	First Integration I(1)	Second Integration I(2)
CO2 Emissions	0.1169	0.0163*	0.0001*
Manufacturing Industry	0.6746	0.9549 0.0076	*
Total urban population	0.0968*	0.0000*	0.0000*
Renewable Energy	0.5578	0.0005*	0.0015*
Economic Growth	0.9874	0.2677	0.0579*

Description: *) Rejects the Zero Hypothesis at =5%

Table 1 shows that at level I(0) only the urban population variable is significant or stationary at =5%, while the other variables are not stationary which means they still contain unit roots. Since all variables are not stationary to the same degree, it is necessary to test the first degree of integration. In the degree of integration test I(1) the industry and economic growth variables do not reject the null hypothesis which means it is not stationary, while the other variables are stationary. Because all variables are not stationary at degree I(1), then the second degree of integration test I(2) is carried out and all variables are stationary at degree I(2).

Furthermore, to see the long-term relationship using the Johansen cointegration test by comparing the *trace statistic* value with the critical value. If the *trace statistic* value has a value greater than the critical value, then the model has a long-term relationship, and vice versa. The number of cointegration relationships in the modeling system uses the criteria of *trace statistics* and *maximum eigenvalue*.

Table 2. Cointegration Test

LR Test	Null	Alternative	*Eigen Value*	*Trace Statistics* or *Max. Eigen Statistics*	*Prob. Value***
Trace Statistics	r = 0	r = 1	0.785822	107.7275	0.0000*
	r <= 1	r = 2	0.706314	61.49904	0.0016*
	r <= 2	r = 3	0.357888	24.74173	0.1709
	r <= 3	r = 4	0.307729	11.45195	0.1852
	r <= 4	r = 5	0.013856	0.418601	0.5176
Maximum Eigen Value	r = 0	r = 1	0.785822	46.22844	0.0011*

	r <= 1	r = 2	0.706314	36.75731	0.0025*
	r <= 2	r = 3	0.357888	13.28978	0.4259
	r <= 3	r 11 =	43507	0.1729	11.
	r <= 4	r = 5	0.013856	0.418601	0.5176

Information: *) rejects the null hypothesis at = 1%

Based on the results of the *Johansen Cointegration test*, the value *trace statistic* and *maximum eigen value* indicate the null hypothesis is rejected at =5% with the number of correlations (*rank*) is two. These results indicate that all variables, namely CO2 emissions, industrialization, urban population, renewable energy and economic growth have long-term relationships. Furthermore, the estimation of the VECM panel in the long term for the research model is shown in Table 3 as follows:

Table 3. Long-term Estimation of the VECM Panel Model in ASEAN 5

Variable	Coefficient	t-count
Manufacturing Industry	12368.62	1.66986
Urban population	0.009571	3.28607*
Renewable Energy	-59706.32	-5.70706*
Economic Growth	289.6950	0.12123

(*) significant at =5%; t table 1.67866 (α=5%; df= 46)

Table 3 above shows that in the long term, population growth and consumption of renewable energy have a significant effect on CO2 emissions in ASEAN 5. This result is confirmed by a t-count value greater than the value of t table at =5%, df.46, which means the null hypothesis is rejected. The increase in population growth affects the increase in CO2 emissions. Population growth that follows a geometrical pattern is followed by an increasingly massive mobility of socio-economic activities and even without recognizing borders between countries can contribute to CO2 emissions due to energy use. Sectoral developments in meeting development needs are followed by behavioral patterns between the goals of achieving growth and sacrificing the environment. One of the significant energy uses in the transportation sector is fossil fuel energy which has the potential to produce CO2 emissions of air pollution. Household energy consumption also occurs in the use of electronic equipment that produces CO2 emissions indirectly. Energy-intensive industrial activities add to a long list of energy problems in the ASEAN Region.

Renewable energy is very important in maintaining the availability of energy in the world such as solar power, wind, water, biological processes and geothermal because its availability will not run out because it is provided by nature in a very long period of time. The long-term estimation results show that the consumption of renewable energy confirms its significant effect as indicated by the t-count value which is greater than the t-table value at =5%, df.46. The pattern of negative relationship shown between CO2 emissions and renewable energy means that an increase in renewable energy consumption will be followed by a decrease in CO2 emissions, and *vice versa*. This pattern is determined by the sustainable management of renewable energy. Renewable energy is an important agenda for governments in the ASEAN Region for the long term through technological innovation and renewable energy development policies.

The development of ASEAN member countries driven by economic growth has driven most of the increased exploitation of natural resources and led to the loss of biodiversity. The loss of biodiversity and degradation of ecosystems has a major impact on people's livelihoods, food security, and well-being in the region. The importance of ecosystems and biodiversity conservation is increasingly recognized in the region with various regulations and measures at the international, regional and national levels to respond to biodiversity loss and ecosystem degradation. Meanwhile, in terms of water supply, it is under pressure due to higher demand while water supply has decreased due to various environmental problems. It is estimated that the demand for water will increase by about a third by 2025 and double during the second half of the 21st century, resulting in increased water stress and water insecurity across the ASEAN region. This problem has also been responded well to various policies such as increasing access to safe drinking water and sanitation facilities, except for Cambodia and Indonesia where about half of the population still lacks access to safe drinking water.

The main threat to water availability and water quality in most of the ASEAN region is poor management, coordination and awareness (ASEAN Secretary 2017). Rapid urban development and poor spatial planning led to encroachment of the built environment into flood prone areas and serious degradation of catchment areas. Climate change increases the level of

uncertainty in water availability and causes an increase in the frequency and intensity of floods and extreme droughts in the region. It also causes changes in river flow regimes, loss of wetlands and floodplains, and salinity intrusion in river deltas due to sea level rise. The low level of wastewater treatment for a growing population, as well as the disposal of private and industrial sewage, pollutes various water sources and greatly reduces the quality of fresh water, leading to increased risks to human health and the environment. Major ecosystems such as coral reefs, mangroves and sea grass beds are threatened by overexploitation and climate change.

Increasing economic growth accompanied by consumption energy increasing also forces the government to innovate as an alternative to using renewable energy. This effort is a form of mitigating the risk of increasing CO2 emissions which will result in decreased environmental quality. It is estimated that by 2034, energy consumption in ASEAN will increase by 4.7%. This is very important to respond to, because in ASEAN alone it has been determined that 23% of renewable energy can be consumed by 2025.

This effort is also inseparable from the support of the private sector in investment to create innovation for energy renewable through various international collaborations such as those carried out by the World Bank, ADB, and the Bank of Japan. One of the efforts made by ADB is outlined in the form of mitigation of investment barriers and intensification of financing for renewable energy generators and distributors. Some of the innovations made by ADB include:

1. Private sector participation where in 2019 around 26% of sector transactions focused on clean energy with a value of $346 million.
2. Reducing greenhouse gas emissions by up to 18.3 million metric tons of carbon dioxide equivalent.
3. More inclusive technology development. ADB is developing a 10 MW wind power plant in Thailand through battery energy storage that allows backup of any energy residues.

The estimation results in the long term also show that industrialization and economic growth do not significantly affect CO2 emissions. This result is confirmed by the t-count value which is smaller than the t-table value at =5%, df.46. In the long term, increased economic growth and industrialization have been supported by energy sustainability through renewable energy. All installed economic capacity has taken into account aspects of energy sustainability towards clean energy. Optimization of innovation and renewable investment is a very important instrument. This supports the hypothesis Environmental Kuznets Curve (EKC) that in the long term an increase in economic growth provides a *turning point* towards decreasing environmental degradation.

Meanwhile, industrialization and long-term economic growth do not significantly affect CO2 emissions. This is indicated by the t-count value which is smaller than the t-table value at =5%, df.46, which means the null hypothesis, is not rejected. In the long term, increased economic growth and industrialization have been supported by energy sustainability through renewable energy. All installed economic capacity has taken into account aspects of energy sustainability towards clean energy. Optimizing innovation and investment in creating renewable energy is a very important instrument and agenda for global development. This supports the hypothesis Environmental Kuznets Curve (EKC) that in the long term an increase in economic growth provides a turning point towards decreasing environmental degradation.

The industrialization that has occurred has not been massively experienced by all regions, especially in the ASEAN 5 region. Some ASEAN regions such as Indonesia, the Philippines and Thailand have not yet carried out the industrialization process on a large scale. The manufacturing sector has only experienced a significant increase in the ASEAN region for several years in line with socio-economic activities supported by the existence of the ASEAN Economic Community (AEC) in early 2016. The existence of this MEA encourages countries to carry out strategies to improve welfare, one of which is manifested in industrialization. in several potential sectors. However, in the long term with the time series of this study with a timeframe of 2010-2016, the impact is not yet optimal in the long term. In addition, the existence of the sector industrial which is being intensified has not significantly affected environmental degradation in a major way. Environmental degradation, which is indicated by the increase in CO2 emissions, is motivated by various other activities, the majority of which use fossil fuel energy, which is dominantly used for the transportation sector. Increasing population mobility results in increased consumption of fossil energy.

Meanwhile, in the short term, the results show that the variables of industrialization and renewable energy significantly affect CO2 emissions. This result is indicated by the t-count value is greater than the t-table value at =5%, df.46. however, other variables, namely population growth and economic growth do not show a significant effect on CO2 emissions. Below are the estimation results in the short term which are shown in Table 4.

Table 4. Short-Term Estimation of the VECM Panel in ASEAN

Variable	Coefficient	t-count
Manufacturing Industry	-12552.98	-3.62736*
Population growth	0.058528	1.01669
Renewable energy	-11667.98	-1.71639*
Economic growth	652.1490	0.45863

(*) significant at =5%; t table 1.67866 (α=5%; df= 46)

The results show that in the short term, when there is an increase in population growth, it may not necessarily affect the increase in CO2 emissions and vice versa. If there is a decrease in population growth, it will not reduce CO2 emissions as much as in ASEAN 5. People who are actors in energy use have a big role in increasing CO2 emissions as a result of consumption of non-renewable energy. A large population like Indonesia will tend to contribute to greater energy use because they have high mobility and activities to meet their daily needs. The largest use of energy, especially fossil energy, is carried out by the transportation and industrial sectors as fuel for transportation mobility and industrial production tools. This is the driving force in creating environmental degradation and decreasing environmental quality through CO2 emissions.

The development of increasingly massive industrialization in all countries accompanied by the acceleration of technology has a significant impact on increasing CO2 emissions. Industrial activities that are dominated by the use of energy consumption and various other resources can lead to an increase in environmental degradation including CO2 emissions that can accelerate global warming and threaten environmental sustainability. The ASEAN countries which are quite dominant and have industrial base sectors are Singapore and Malaysia and automatically have a significant impact on increasing CO2 emissions. Various basic sectors in other countries such as in Indonesia, the agricultural, fishery and plantation sectors have begun to be directed towards industrialization which will also require greater energy consumption to create productivity. This condition further adds to the long list of contributions from the energy user sector which will lead to an increase in environmental degradation. This condition requires attention and policies as a form of solution, effective and efficient in mitigating the problem of environmental degradation.

The short-term estimation results also show that the number of urban residents has no significant effect on CO2 emissions. Urbanization in some countries is not evenly distributed. In some countries, such as Singapore, where the majority of the population resides in urban areas, the dynamics do not have a significant impact on increasing CO2 emissions. In addition, the relatively small population and small area do not require high mobility. In this case, the need for energy for transportation can still be suppressed. In addition, in some areas in developing countries such as Indonesia, Thailand and the Philippines, population agglomerations are still not evenly distributed. Most of them are also in rural areas who work with their respective potential sectors and regional base sectors. This condition is also one that can suppress urbanization or the movement of people to cities.

Therefore, big cities, especially in the ASEAN region, need to immediately look for eco-friendly and low-carbon economic, infrastructure and transportation patterns (ASEA Secretary, 2017). In addition, precise and efficient media is needed to improve monitoring and consistent air quality standards, so that air quality trends can be better observed and followed up. Trans boundary haze pollution due to forest and land fires in the ASEAN region is an ongoing challenge, and has an impact on most of the ASEAN Member States. Up to 90% of Trans boundary haze in ASEAN is linked to peat fires linked to the expansion of large-scale commercial plantations.

Some efforts that may be quite effective and efficient are by implementing environmentally friendly and low-carbon economic, infrastructure, and transportation patterns (ASEAN Secretary 2017). In addition, the right and efficient media is needed to improve monitoring and consistent air quality standards, so that air quality trends can be observed and followed up better and more precisely. A series of strategies formulated (ASEAN Corporation 2020) have shown efforts to overcome the problem of CO2 emissions but still focus on sustainable development with several complex strategies. This goal is carried out through increasing regional and international cooperation to address the problem of climate change and its impact on socio-economic development, health and the environment.

The growth of the ASEAN region which has a heavy dependence on the exploitation of natural resources requires effective and efficient solutions to minimize this. The ASEAN region has a great opportunity to get out of this problem through synergies and collaborative cooperation with countries to create innovative and effective solutions. Especially in the development and development of infrastructure which is currently being intensively happening, a solution policy is needed for

the development of an effective, efficient and environmentally friendly infrastructure model, especially for industrialization which is known to have a high contribution to CO2 emissions. This action is one that encourages the withdrawal of investment that links environmental performance with economic growth (OECD 2013).

Some other concrete actions that have been taken in several regions by adopting and collaborating with other regions include innovation of resource-saving technologies and practices that can reduce costs and increase productivity while reducing environmental stresses (OECD 2013). In addition, bidding for the social safety nets needed to promote entrepreneurship and labor mobility will facilitate the transition to growth green (Bene *et al*. 2014; OECD 2009). This is an important action considering that the ASEAN region with biodiversity that is owned as a sustainable natural resource has experienced many threats because it is estimated that 13% and 42% of species will be lost in Southeast Asia by 2100. And this shows that half of the global biodiversity has been reduced.

Alternatives through the creation of renewable energy which are still minimal are also a separate focus for policy makers in conducting regulations. Renewable energy is very less contributing, especially for sectors that are dominantly used by humans in carrying out their activities such as transportation. Unfavorable regulations are one of the obstacles to the slowdown in the development of new technologies. This is enough to be a reflection and policy revision for policy makers so that in 2018 there was an increasing number of a decarbonization framework developed at the sub-national level. Developing countries continue to increase the spread of renewable energy, and distributed renewable energy helps spread energy access to households in remote areas. In addition, the private sector also plays a key role in promoting the deployment of renewable energy through its procurement and investment decisions. The role of the private sector as a source of investors through renewable energy investments has more than doubled during 2018, and renewable energy has spread in significant numbers around the world.

5. CONCLUSION

In the long term population growth and consumption of renewable energy significantly affect CO2 emissions in the ASEAN 5 region. Meanwhile, industrialization and economic growth do not significantly affect CO2 emissions. In the short term, it was found that industrialization and consumption of renewable energy significantly affect CO2 emissions in the ASEAN region 5. While the variables of population growth and GDP growth did not show a significant effect on CO2 emissions in the ASEAN region 5. The importance of stricter regulations related to industrialization accompanied by impact analysis environment is very important to do considering in the long term industrialization shows a positive coefficient although not significantly to CO2 emissions. In addition, it is necessary to use and improve studies and innovations in creating alternative solutions for renewable energy that need to be improved both in terms of practice and from the institutional side for each relevant stakeholder. This is to achieve maximum synergy to achieve sustainable development without sacrificing any aspect. So that in order to achieve sustainable development, it is hoped that it will not sacrifice other aspects such as economic, social and environmental aspects so that they can go hand in hand.

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