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Carbon Dioxide (CO2) Emission, Energy Consumption and Economic Growth: Evidence from Selected Southeast Asia Countries

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ABSTRACT

Southeast Asia countries have experienced rapid economic growth within the past decades with a significant increase in energy dependency and carbon dioxide (CO_2) emissions. Continuous development in the urban area has stimulated a rise in energy consumption in many Southeast Asia countries, which resulted in an improvement of citizen's lifestyles and living standards due to increasing income and population. Understanding the relationship between economic growth, energy consumption, and carbon dioxide emissions help economies in formulating energy policies, enhancing energy security and developing a sustainable energy resource. Therefore, this study focuses on the economic growth, energy consumption and carbon dioxide emissions evolved in Southeast Asia by using Environment Kuznets Curve theory. This paper could be useful and beneficial for the Southeast Asia countries to form appropriate environmental policies to maintain the balance of energy demand and supply and to deal with environmental quality issues.

1. Introduction

Today, there is an immense effect due to the rapid development of economic industrialization, particularly on environmental issues. According to the Global Climate Change Report by NASA, human activities such as clearing of land for the agriculture sector and massive production in the industrial sector have changed the natural greenhouse gases and increased global warming. Global warming has always been a topic of discussion among world leaders. Up to now, carbon dioxide (CO_2) emissions have been identified as one of the main contributors to global warming. From 1990 to 2015, the total global warming effect

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added by humans to the Earth's atmosphere increased by 37 per cent and the effect associated with carbon dioxide emissions per se have increased by 42 per cent (EPA, 2017).

Inline to improve citizen's living standards, economic activities and industry development cannot be avoided, and this situation might cause environmental pollution and the increase of carbon dioxide emissions. According to Wahid, Aziz and Mustapha (2013), carbon dioxide emissions released through many industrial activities and the use of energy such as fossil fuels. In general, carbon dioxide emissions have a positive relationship with energy-use, which indirectly affect economic growth (Abbasi et al., 2020). This is supported by Thao (2015) and Aye and Edoja (2017) where the authors stated that the high use of energy consumption in a country's economic activity has positively influenced economic output, although it simultaneously causes an increase of carbon dioxide emissions. For some countries in Southeast Asia, such as Malaysia and Singapore, carbon dioxide emission has become a significant problem affecting the deterioration of environment to a country. There are several factors related to carbon dioxide emissions, where energy consumption has become the leading factor, followed by economic development. For a highly developed country in Asia such as Singapore and several developing countries such as China and Malaysia, their main economic activities that contribute to carbon dioxide emissions is through primary energy consumption (use of electricity) by industry and commercial activities such as manufacturing and trade.

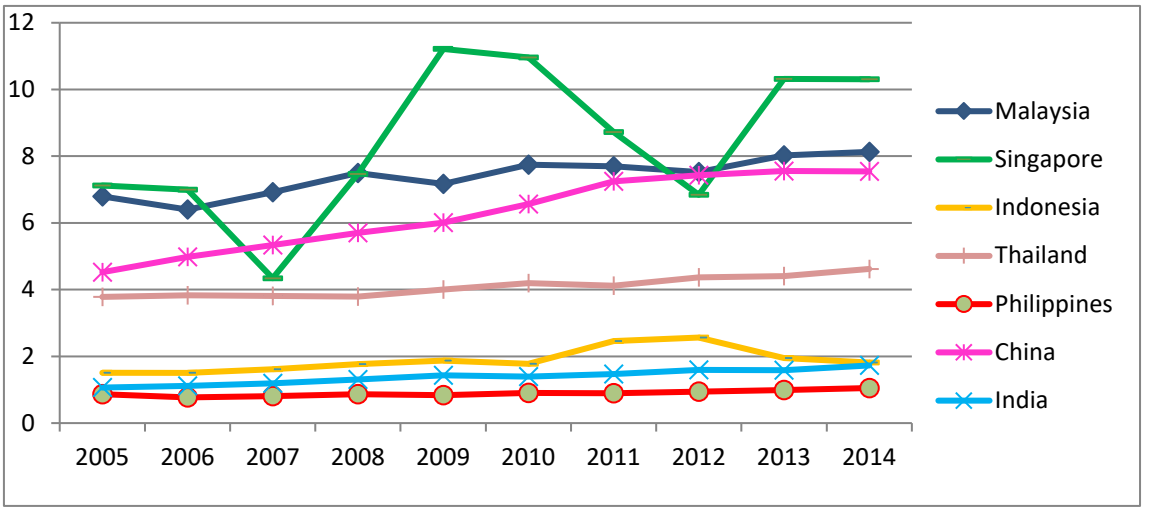

Fig 1. Carbon Dioxide Emissions in Metric Tons per Capita in Asian Countries (2005-2014)

Fig. 1 above exhibit the carbon dioxide emissions in selected Asian countries from 2005-2014. As we can see, there is an increasing trend of carbon dioxide emissions in Singapore, which was the highest, followed by Malaysia, China and Thailand, respectively. Emerging market countries such as Indonesia, India and the Philippines showed an increasing carbon dioxide emission, although the lowest among other and developing countries. Southeast Asia Energy Outlook (2015) reported that growth in Southeast Asia demand for energy consumption is higher compared to the world average. Higher fossil fuel use and carbon dioxide emission will raise the issue of climate change and high pollution. Carbon dioxide emission in Southeast Asia reported to be increased by 5.1% annually as a result of higher energy consumption, and it will be nearly double by 2040 due to increase in the energy mix of fossil and coal (Zhu et al., 2016). Vo, Vo & Le (2019) found that as the economy in many ASEAN countries grows at an early stage, it significantly leads to an increase in the level of carbon dioxide emissions. However, the impact is reversed when the economic growth reaches a certain level at a later stage. Rapid economic growth may involve a higher energy consumption where more burning of fossil fuel is needed. As a result, more carbon dioxide

emissions are produced in the Southeast Asia region, and these will cause serious environmental issues (Zhang & Cheng, 2009).

The primary motivation of this paper is to identify the relationship between carbon dioxide emissions, economic growth, and energy consumption in selected Southeast Asia countries, namely Malaysia, Singapore, Indonesia, Thailand, and the Philippines. This paper contributes to the literature by analyzing the sensitivity of carbon dioxide emissions with energy consumption and economic growth in selected five Southeast Asia countries. Second, this paper also studies the relationship of carbon dioxide emissions with energy intensity, and population size to understand its impact on socio-economic development. Besides, this paper emphasizes and recommends the policy implications of the linkages between carbon dioxide emissions, economic growth and energy consumption for Malaysia, Singapore, Indonesia, Thailand and the Philippines in dealing with environmental quality issues.

In the next section, we present a related literature review. Section 3 details the empirical method that we employ in analyzing the data. The results of our analysis are presented and discussed in section 4. The final section is the conclusion and policy implication.

2. Literature Review

Meadows et al. (1972) argued that there is a negative effect of the environment on economic growth. Later, Grossman and Krueger (1991, 1995) developed the concept of the Environmental Kuznets Curve (EKC) by applying Kuznets (1955) original theory of an inverted U-shaped pattern between economic development and income inequality to the relationship between economic development and environmental quality. The EKC proposed that an inverted U-shape also exists for different pollutants where higher income levels tend to generate less environmental degradation. Besides, EKC suggests that rapid economic development could contribute to higher carbon dioxide emissions and economic growth at an early stage; however, further leading to a decrease in carbon dioxide emissions. This is because of the introduction of green and clean technology and the shift to a service-based economy rather than industry-based economy activities (Galeotti, 2007).

Economic growth is determined by the improvement of technology advancement, knowledge and training skills of workers in labour supply (Sirwar & Haq, 2017; Sanidas, 2014). As the standard of living is rising, energy consumption will proliferate together with economic growth. Therefore, economic growth can influence a higher amount of energy consumption (due to fossil fuel), carbon dioxide emissions and other environmental pollution. Previous studies in Asian countries done by Ismail, Mahmud and Abdul Rahman (2017), Lean and Smyth (2009), and Shaari, Abdul Razak and Hasan Basri (2017) found that energy consumption was related to economic growth and it can cause an increase in carbon dioxide emissions. For example, Lean and Smyth (2009) indicate that there is a significant relationship between energy consumption, carbon dioxide emissions and economic growth among Asian countries over the period 1980-2006. The authors also mentioned a connection between carbon dioxide emissions to electricity use in the short run.

Chen, Kuo and Chen (2007), Ismail et al. (2017), Vafaeirad, Mohammadiha and Goodarzy (2015) and Yoo (2006) have investigated the relationship between energy consumption and economic growth among the Asian countries. For example, a study was done by Yoo (2006) in Indonesia, Malaysia, Singapore, and Thailand suggested that there is bi-directional long-run causality between energy consumption and economic growth in Malaysia and Singapore. However, Indonesia and Thailand show uni-directional short-run causality from economic growth to energy consumption. The same result was supported by Chen et al. (2007). The author also found that bi-directional long-run causality exists between energy consumption and economic growth, and uni-directional short-run causality exists between economic growth and energy consumption. Similarly, Ismail et al. (2017) also suggested that there is an existence of a bi-directional relationship between energy consumption and economic growth in Asian countries.

Another case study in Asian countries which was done by Jalil and Mahmud (2009) also has proven that there is an effect running through economic growth to carbon dioxide emissions. The result indicates that carbon dioxide emissions are mainly determined by income and energy consumption in the long run. Otherwise, in Indonesia, there was no relationship between energy consumption, economic growth and carbon dioxide emissions except the effect that runs from an urban population to energy consumption (Jafari et al., 2012). Ang (2007) has concluded in his study that environmental pollution and energy consumption are positively related in the long run, and there is a strong effect between economic growth and energy consumption in the short run and long run in Malaysia. Similarly, Azlina and Nik Hashim (2012) found that there is a uni-directional causality effect between environmental pollution, economic growth and energy consumption in Malaysia.

Naminse and Zhuang (2017) and Emir and Bekun (2018) proposed that there is a significant negative relationship between carbon dioxide emissions and energy intensity in the short-run and also a significant positive relationship in the long-run. This is supported by Roca & Alcantara (2001), where the authors suggest that energy intensity changes have a positive impact on carbon dioxide emissions changes. Moreover, the authors also revealed that the relative changes in the energy intensity are much higher than the changes in the carbonization index. Nevertheless, Sun (1999) argued that there might be a decrease in the intensity of carbon dioxide emissions when a maximum for the energy intensity had been reached.

Sikdar and Mukhopadhyay (2016) indicate that the distribution of the human population due to rapid development in economic activities such as industrial, production and mining have become a significant factor in influencing carbon dioxide emissions. The higher population may reduce carbon dioxide emissions due to commuting; however, it can also increase carbon dioxide emissions due to the relocation of economic activities (Yeh and Liao, 2016). Similarly, an increase in population density may release higher carbon dioxide emissions from public commuting (Gaigné, Riou & Thisse, 2012). A study done by Lee and Lee (2014) has demonstrated that an increase in population, especially in the urban area, can cause a reduction in carbon dioxide emissions due to residential energy consumption.

From the literature review, several conclusions can be made. First, most studies investigate the relationship between carbon dioxide emissions and energy consumption with economic growth (Gross Domestic Product). Most of the studies focus on the effect of carbon emissions on economic growth where the primary variable used was Gross Domestic Product as to be applied as the dependent variable in either single or cross-country studies. For example, studies were done by Fakhri, Hassen and Wassim (2015), Omri, Nguyen and Rauld (2014), Leitao (2014) and Franklin and Ruth (2012). However, this study will adopt carbon dioxide emissions as the dependent variable and analyze the effect of economic growth on carbon emissions. Second, existing studies which have examined the relationship between carbon dioxide emissions, energy consumption, economic growth, energy intensity, and population within one model is scarce. Thus, it is pertinent to study how sensitive is carbon dioxide emissions, energy consumption, economic growth, energy intensity, and population in selected five Southeast Asia countries.

3. Methodology

Based on World Bank Development Indicators, the availability of all data for the selected Southeast Asia countries start from 1995 until 2014. Therefore, this study utilizes annually data from 1995 to 2014 for all variables. Carbon emissions metric tons per capita data measures the overall selected Southeast Asia countries; Malaysia, Singapore, Indonesia, Thailand and the Philippines. These selected five countries are the original founding members of ASEAN in 1967 and remain the most influential members of Southeast Asia in the 21st century (Lean and Smyth, 2009). Besides that, these five Southeast Asia countries are the major Asian economies which involved in the implementation of the ASEAN Agreement on Transboundary Haze Pollution (Haze Agreement) that focus on the environment-related issues such as carbon emission and pollution through strategic ASEAN Community Blueprint 2025. Four selected independent variables

were used in the analysis, namely energy consumption, Gross Domestic Product, population and energy intensity. All data used for the analysis were also sourced from the World Bank Development Indicators. The summary of variables, sources and measurement units are shown in Table 1 below.

Table 1. Variables, Sources and Measurement Units

Variables	Sources	Measurement unit
Carbon emissions (CO_2)	World Bank	Metric tons per capita
Energy consumption (ECO)	World Bank	Percentage (%)
Gross Domestic Product (GDP)	World Bank	Real GDP growth rate (%)
Population (POP)	World Bank	Total number
Energy intensity (ENI)	World Bank	Btu units

This study is using pooled mean group (PMG) regression, a technique to estimate non-stationary dynamic panels in which the parameters are heterogeneous across groups. Following Pesaran, Shin, and Smith (1997 and 1999), PMG relies on a combination of pooling and averaging of coefficients. Given the inconsistency problem in estimating traditional panel models, Pesaran et al. (1999) proposed the pooled mean group (PMG) model to overcome the limitation. Unlike the static panel models, the PMG model is an intermediate estimator that allows for heterogeneity of the intercept, short-run coefficients and the error variance while imposing a cross-country homogeneity restrictions only on the long-run coefficients irrespective of whether the included series are *I*(0), *I*(1) or of mixed order integration. Also, the PMG is estimated using a maximum likelihood (ML) estimator where the error correction term (ECT) is expected to be negative and statistically significant negative if the model exhibits a usual return to long-run equilibrium. However, the primary interest of the PMG model estimation is the speed of adjustment (error correction term) and the coefficient of the long-run estimates.

Detailed discussion on the relationship between carbon dioxide and macroeconomic determinants are explained in the basic form of the model as in Equation (1);

$$Y=\beta_0 +\beta_1 X_1 +\beta_2 X_2 \ldots\ldots +\beta_k X_k+ \varepsilon \quad (1)$$

where Y is the carbon dioxide emissions and X_1 through X_k represent the macroeconomic determinants such as energy consumption, Gross Domestic Product, population and energy intensity. Meanwhile, β_j refers to the weight or coefficient for each of the X's. Basu and Thibodeau (1998) proposed that a semi-log functional form can correct for the heteroscedasticity problem between the coefficients and the residuals. Therefore, the final log functional form for cross-country carbon dioxide model can be estimated using Equation (2);

$$LCO_{2it} =\beta_0 + \beta_1 LECO_{it} + \beta_2 LGDP_{it}+ \beta_3 LGDP^2{}_{it} + \beta_4 LPOP_{it}+ \beta_5 LENI_{it}+ \varepsilon_{it} \quad (2)$$

where LCO stands for carbon emissions, $LECO$ is energy consumption, $LGDP$ is Gross Domestic Product, $LPOP$ is population and $LENI$ is energy intensity. The epsilon ε means error term, whereas *i* represents selected Southeast Asia country and *t* denotes the sample period of the study. Therefore, i = 1, 2, 3, …, 5 for the selected Southeast Asia countries while t = 1, 2, 3, …, 20 is for the number of years to be covered. Following Umar and Nayan (2019), the unrestricted PMG model specification is shown in Equation (3):

$$LCO_{it}=\sum_{n=1}^{r} = \theta_{ij} LCO_{i,\, j\text{-}e} + \sum_{n=1}^{s} \gamma_{ij}\, C_{i,\, g\text{-}1} + \delta_i + \varepsilon_{it} \quad (3)$$

where LCO is the dependent variable representing carbon dioxide emissions, $C_{I,g-1}$is the vector of explanatory variables (energy consumption, Gross Domestic Product, population, and energy intensity) for country i. The subscript, t = 1, 2, 3, …, T for time t and i = 1, 2, 3, …, N, for selected Southeast Asia countries in the sample. The symbol δ_i represents country-specific effects, while λ_i denotes fixed effect parameterization. The equation can be rewritten as VECM model as in Equation (4):

$$\Delta LCO_{it} = \gamma i \left(LCO_{it} = LCO_{\ i,t-1} - \partial'_i C_{i,g-e} + \delta_i\, \varepsilon_{it}\right) + \sum_{n=1}^{r-1} = \theta_{ij} \Delta \rho_{i,g-e} + \sum_{n=1}^{s-1} \gamma_{ij}\, \Delta C_{i,\,g\text{-}e} + \varepsilon_{it} \quad (4)$$

where γ_i is the error correction term (ECT) coefficient, and δ_i represents the long-run parameters. The primary interest is the speed of adjustment and the coefficient of long-run estimates. The model is estimated using pooled maximum likelihood estimation to compute the average long-run estimates and group-specific short-run coefficients. The coefficient of γ_i is expected to be negative and statistically significant if the model exhibits a usual return to long-run equilibrium (Umar and Nayan, 2019). The estimates of PMG parameters are consistent and asymptotically normally distributed for both stationary and non-stationary regressors (Pesaran et al., 1999).

Based on the above discussion, the suggested hypotheses and expected signs of energy consumption, Gross Domestic Product (GDP), population and energy intensity variables are shown in Table 2 below.

Table 2. Expected signs of the coefficients of variables

Variables	Expected Sign
Energy consumption (ECO)	Positive
Gross Domestic Product (GDP)	Positive
Population (POP)	Positive
Energy intensity (ENI)	Positive

4. Results and Discussions

The main objective of this study is to identify the relationship between carbon dioxide emissions, Gross Domestic Product (GDP) and energy consumption in selected Southeast Asia countries namely Malaysia, Singapore, Indonesia, Thailand and Philippines. Therefore, the estimation result of this study is as in Table 3 below.

Table 3. Estimation Results

Variable	Coefficient	St. Error	T-Stat	P-Value
Constant	-6.2851***	2.8354	-2.2166	0.0289
Energy consumption (ECO)	-2.5140	2.3126	-1.0870	0.2796
Gross Domestic Product (GDP)	0.1038***	0.0418	2.4793	0.0148
Population growth (POP)	2.7768***	0.4198	6.6142	0.0000
Energy intensity (ENT)	0.2931***	0.1009	2.9047	0.0045
Error Correction term	-0.1990***	0.0834	-2.3855	0.0189
Number of observations		140		
Number of groups		5		
Log-Likelihood		75.89		

Note: *, **, *** denote significant at 10%, 5% and 1% respectively

Based on the results in Table 3, the error-correction term was negative and significant, which indicates that the speed of adjustment towards long-run equilibrium. The coefficient of error-correction term 0.1990 suggests that the speed of adjustment from the short run to long-run equilibrium is about 19.9 per cent. Half of the disequilibrium will occur in about three ¾ years. It shows that although the significant value of the coefficient is small, it may take a very long time for the disequilibrium to be reduced by 50 per cent.

Interestingly, based on the estimation result, the coefficient of energy consumption (ECO) is insignificant. This indicates that any increase in primary economic activities in selected Southeast Asia countries which relates to energy consumption such as mining and agricultural activities are not directly causing high carbon dioxide emission. Also, it shows that the use of energy resources such as electricity in production and industrial activities is not causing much environmental pollution. The possible explanation for this result might be because of the environmental conservation, and energy-saving policy has been implemented in many Southeast Asian countries to avoid persistent pollution. For example, in Thailand, the government has developed several regulatory and energy efficiency frameworks towards Energy Efficiency Action Plan 2011–2030 (EEAP) and Energy Efficiency Development Plan 2011–2030 to achieve country less dependent on oil and gas energy as well as to reduce its greenhouse gas emissions. The government has considering increases the use of alternative energy sources such as solar, wind, biomass, and mini-hydropower from 12 per cent currently to 25 per cent by 2021.

Besides Thailand, Malaysia also has been continuing its effort to support holistic energy sustainable development in combating climate change due to greenhouse gas emission through the National Energy Efficiency Action Plan. This action plan presents a framework on promoting an efficient energy consumption in several sectors such as industrial without impacting the rise of carbon emission level or increase the air pollution level. Apart from that, in line with the Green Technology Master Plan 2017-2030, Malaysia government through Green Technology Corporation has expended effort in promoting a Low Carbon Cities Framework (LCCF) to guide and assess the development of industrial cities by implementing green technology to strengthen its environment for green growth goal. This result is consistent with a study done by Chebbi and Boujelbene (2008), where energy consumption and carbon dioxide emission provide some pieces of evidence of insignificant relationship due to the introduction of renewable energy.

Coefficient of Gross Domestic Product (GDP) is positive and statistically significant. It shows that an increase in per capita GDP leads to an increase in the growth rate of carbon dioxide and carbon dioxide emissions. Results show that the GDP variable raises the turning point of an EKC substantially. Association of Southeast Asian Nation reported that carbon emissions caused by the high energy consumption which originated from the industry sector such as manufacturing and trading industrial metals. The report highlights the direct impact of the manufacturing and trading industry as it is the essential cause of the country's economic growth. For example, in the Philippines, as the trade levels are growing and trading volume is increasing, GDP variable contributes to the carbon dioxide emissions. Besides that, although Indonesia has recorded as among Asia countries with the lower amount of fossil carbon dioxide emissions, however, in recent years, Indonesia has to face a rapid economic growth that causes expansion in the industrial sectors. Many large-scale constructions and productions in Indonesia have increased energy consumption to progress forward with economic growth. Thus, this situation is expected to enhance carbon emission level in Indonesia. This result is consistent with Lu (2017) where the author suggested that for the Southeast Asia economy sample such as Indonesia, Malaysia, the Philippines, Thailand, a 1 per cent increase in GDP will increase greenhouse gas emissions by 0.22 per cent.

Besides that, the coefficient of the population (POP) is also positive and significant. This indicates that a country with a high population rate shows a steady rate of growth in carbon dioxide emissions. As the country’s population grows, the need for energy consumption also increases. The size of the population, coupled with a rise in economic growth and higher income per capita, will create demand for multiple choices of products. Therefore, this could lead to a large scale of energy consumption in production and manufacturing activities which will affect an increase in environmental pollution as well as carbon dioxide

emissions. United Nation (2011) predicts that in 2050, Southeast Asia countries are expected to increase in population by 30% due to rapid growth in industrialization and urbanization which will influence high demand in energy consumption and this will cause the carbon dioxide emissions rate are expected to grow significantly in the future (Chontanawat, 2018).

An example is Indonesia, having a population of 46.3 per cent in the Southeast Asia region, accounts for almost 30 per cent of carbon dioxide emissions in this region. It shows that Indonesia experienced the highest carbon dioxide emissions growth, given its most significant number of populations. Moreover, other Southeast Asia countries such as Malaysia, Thailand, Singapore and Philippines show the highest rate in carbon dioxide emissions growth as they experienced growth in population rate over the past few decades. Similarly, Borhan et al. (2012) and Chontanawat (2018) stated that countries with high rates of population growth show stable rates of increase in carbon dioxide emissions and will cause more significant pollution to be released.

Lastly, the coefficient of energy intensity (ENI) shows positive and significant. This result indicates that level of carbon dioxide emissions could be increased with a rise in energy intensity, which remains fundamental in meeting basic needs and achieving the country's economic development goals. In other words, an increase in energy intensity demonstrates the high energy required to produce a given level of output. As the energy intensity has a positive influence on carbon dioxide emissions, it will subsequently affect the environmental quality in the future. For example, Thailand indicates a positive relationship between energy intensity and carbon dioxide emissions where the energy intensity contributed about 18.72 per cent of the increase in carbon dioxide emissions on average from 1990 to 2014. This result is consistent with a study done by Alam et al. (2007) where the authors found that increases in energy intensity growth lead to an increase in the carbon dioxide emissions as the economic development is dependent on the level of energy consumption.

5. Policy Recommendation and Conclusion

Our findings show that energy consumption does not affect carbon dioxide emissions. This indicates that major economic activities that relate to energy consumption are not directly causing high carbon emission or reducing environmental quality. This is because, many Southeast Asia countries have implemented a wide range of green environmental policies such as Energy Efficiency Action Plan 2011–2030, Energy Efficiency Development Plan 2011–2030 and Green Technology Master Plan 2017-2030. Apart from that, several policy recommendations may be proposed to reduce carbon dioxide emissions and improve environmental quality in the Southeast Asia region. First, Southeast Asia countries should develop an energy development program to switch from fossil fuels to adopt alternative or renewable energy resources. The proposed energy development program aims to utilize local environment-friendly energy production and cleaner technologies, which could help to reduce the impact of greenhouse gases and to ensure the use of sustainable energy. Example of alternative or renewable energy resources is biodiesel and biofuel. Several Southeast Asia countries such as Indonesia and Malaysia have taken steps ahead to impose these renewable energy policies. Indonesia, for instance, had implemented a biofuel policy which aims to develop the potential of alternative fuels that can be renewed and maximize economic development throughout the country.

Meanwhile, Malaysian biofuel policy was designed to reduce the impact of carbon dioxide emissions and optimize the use of biofuels in various economic sectors. Second, Southeast Asia countries should further diversify alternative energy sources such as solar energy and biomass energy in order to achieve clean energy goals to enhance economic growth. Third, in order to ensure program execution, Southeast Asia countries should provide fiscal and non-fiscal incentives for manufacturing producers and supplier to use renewable energy in their mass production. Lastly, Southeast Asia countries should focus on the

development of green technologies such as green building and electric vehicle in the short term and long term to reduce dependence on imported energy.

Besides that, our findings also show that Gross Domestic Product (GDP), energy intensity and population are positively affecting the carbon dioxide emissions. The increasing rate of carbon dioxide emissions in most of Southeast Asia countries at the early stage of the industrial revolution is one of the strategies to achieve sustainable economic growth. High carbon dioxide emissions rate recorded might be caused by various governments' policy interventions to boost economic growth such as the protection of manufacturing industry and energy subsidies. Hence, prudent action should be taken by Southeast Asia countries to reduce the level of carbon dioxide emissions such as introducing energy-efficiency project which inclining energy intensity that will improve environmental degradation with an increase of economic growth. Besides that, each Southeast Asia country should impose a restrictive trade openness for low and high carbon dioxide emissions or restrictions of international trade such as tax, tariff and quota among them in order to reduce carbon dioxide emissions rate in this region.

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