Carbon Dioxide Emissions and Implications for Environmental Policy: Evidence in Southeast Asia

Anh Tru Nguyen*

Vietnam National University of Agriculture, Vietnam

Abstract

The article attempts to investigate impacts of determinants on per capita carbon dioxide (CO_2) emissions in six developing countries in Southeast Asia between 1985 and 2014 using a panel dataset. We found that electric power per capita, energy use, and gross domestic product have positive influences on per capita CO_2 emissions in Southeast Asia. However, population and renewable energy consumption negatively affect per capita CO_2 emissions in this region. Our results also addressed that per capita CO_2 emissions of Indonesia and Viet Nam are higher than that of other countries in the region. Lastly, policies are recommended to reduce CO_2 emissions and protect the environment in Southeast Asia, including improvement of energy efficiency of countries in the region, implementation of the Project in Clean Energy Investments, reduction of fuel and CO_2 emissions applied to light duty vehicles and high duty vehicles, exploitation of advantages in exporting greenhouse gas emissions, and cooperation among countries in the region in order to reduce emissions.

Keywords: carbon dioxide, emission, environment, Southeast Asia

1. INTRODUCTION

Effects of climate change on economic and social development have always been considered as an urgent issue in all over the world. Carbon dioxide (CO_2) can be seen as a key factor leading to the global warming since it releases more than 50 percent of greenhouse gas in the global [5]. The expansion of demand for energy, especially in the fossil fuel, due to the rapid economic growth has been a result of environmental degradation problems such as pollution [4].

Southeast Asia is one of the most vulnerable regions of the world due to effects of climate change. Livelihood of millions of people is still trapped in extreme poverty and they have to work in climate-sensitive sectors. In recent decades, the growth of CO_2 emissions in this region has been more rapid than in any other area of the world and this can be seen as the key contributor to global warming [1]. According to the 2nd ASEAN Energy Demand Outlook (2009), energy consumption in the Association of Southeast Asian Nations (ASEAN) will rise 3.9 percent annually from 343 MTOE in 2005 to 901 MTOE in 2030 with the rapid growth of transportation sector by 5.1 percent annually, corresponding to an equivalent growth in CO_2 emissions [15]. By 2017, Southeast Asia has been recorded to account for 8 percent of global energy demand growth [19].

*Corresponding author: nguyenanhtru@vnua.edu.vn
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Countries in Southeast Asia must face obstacles from adverse impacts of climate change, including reduction of agricultural productivity, losses of labor productivity, reduction of human health, the increase in energy and other resource demand, collapse of coastal ecosystems, and loss of terrestrial forest cover and biodiversity. By 2010, five countries, namely Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam accounted for about 90 percent of greenhouse gas emissions in Southeast Asia [1]. Due to industrialization process, CO_2 emission in Malaysia has accelerated by 235.6 percent from 1990 to 2005 [39]. Similarly, CO_2 of the Philippines accounted for about 64 percent of the greenhouse gases, which generates global warming, because of a rapid economic growth [25]. Due to a rapid increase in energy consumption and heavy dependence on fossil fuels, greenhouse gas emissions of Viet Nam reached 177 tonnes of CO_2 equivalent in 2005 and it has been predicted to rise tripled by 2030 [32].

There are various previous studies on factors affecting CO_2 emissions in Southeast Asia in recent years. These researches focus on investigating the relationship among CO_2 and other determinants in either the regional level [14,21] or the national level [6,11,25,27,31,39]. However, none of these employs the ordinary least square (OLS), fixed effect (FE), and random effect (RE) models to estimate impacts of determinants on CO_2 emissions in Southeast Asia for the last three decades (1985-2014). Therefore, it is necessary to carry out this research to narrow down the gap of existing studies because we are able to compare outcomes of three models. Further, the FE and RE models are employed to overcome limitations of the OLS model in terms of the OLS assumptions (linear functional relationship, data distribution, resilience to outliers, and independence of observations) and the omission of variables since both observed and unobserved variables can affect the dependent variable. More importantly, based on findings, affordable policies are recommended to the governments of Southeast Asian countries to reduce CO_2 emissions and protect the environment.

The reminder of this paper is structured as follows. Section 2 presents the literature review. Methods are presented in section 3. Section 4 presents results and discussion. Finally, conclusion and policy implications are summarized in section 5.

2. LITERATURE REVIEW

2.1. Definitions and measurement of CO_2 emissions

CO_2 is a chemical compound, which includes two oxygen atoms bonded covalently with a carbon atom. CO_2 is gaseous at the state of standard temperature and pressure and is present in the Earth's atmosphere. The colorless and odorless gas of CO_2 can be produced by various sources such as animals, plants, fungi, and microorganisms. Also, it may be produced from the side effects of burning fossil energy [28]. CO_2 is the most common greenhouse gas (GHG) emitted by human activities, in terms of the quantity released and the total impact on global warming. Apart CO_2, GHG inventories are more accurate if these include all GHGs, such as Methane (CH4), Nitrous Oxide (N2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), Sulfur Hexafluoride (SF6), and Nitrogen Tri-fluoride (NF3) [10].

Carbon dioxide equivalent (CO_2e) is a term to use for describing different greenhouse gases in a common unit. For any quantity and type of greenhouse gas, CO_2e signifies the amount of CO_2 which would have the equivalent global warming impact [10].

2.2. Empirical studies in effects of determinants on CO_2 emissions

There are numerous studies on influences of factors on CO_2 emission all over the world. Alamdarlo (2016) [3] employed the Kuznets theory to investigate relationships among income per capita, water consumption, and CO_2 emissions in Iran from 2001 to 2013. His findings showed that there was an inverted U relationship between per capita income and water consumption and CO_2 emissions and both water consumption and CO_2 emissions in the agricultural sector had a direct correlation with the value of these two variables in the neighboring areas. Likewise, Boamah et al. (2017) [9] examined the relationship between economic growth and CO_2 emission in China by using a time series data for the period of 1970-2014. Their results demonstrated a long-run N-shaped relationship between economic growth and carbon emission, under the estimated cubic environmental Kuznet curve framework. A study by Cole et al. (2017) [12] estimated CO_2 from gaseous fuel in Nigeria between 1994 and 2014 by using a least square method. Their results argued that in order to curb the emission rate of CO_2 from different sources, the government should use free carbon dioxide emission sources of energy such as solar power, wind power, geothermal energy, low-head hydropower, hydrokinetics (wave and tidal power), and nuclear power.

Further, Gokmenoglu and Taspinar (2016) [16] examined relationships among CO_2 emissions, energy consumption, economic growth, and foreign direct investment (FDI) in Turkey for the period 1974-2010. They found that CO_2 emissions converge to their long-run equilibrium level by a 49.2 percent speed of adjustment every year by the contribution of energy consumption, economic growth, and FDI. On the other hand, there are unidirectional causal relationships running from economic growth and energy consumption to FDI and from economic growth to energy consumption. Likewise, Jalil (2014) [22] estimated the determinants of CO_2 emission in 18 countries of the Middle East and North African (MENA) region from 1971 to 2009 by using the Generalized Method of Moments (GMM) technique. The results addressed that gross domestic product per capita, energy consumption based on fossil fuel, FDI, and agricultural production have significant impacts on the growth of carbon emissions in the region. Sun et al. (2016) [30] examined CO_2 emission convergence in the ten largest economies in the world. They found that CO_2 emission is convergence in most countries and it does not depend on their development pattern.

There are a number of existing studies on effects of determinants on CO_2 emissions in Southeast Asia. Islam et al. (2017) [21] examined the influence of energy consumption, economic growth, population, poverty, and forest area on CO_2 emissions in Southeast Asia from 1991 to 2010. Results addressed that energy consumption and economic growth presented positive relationships with CO_2 emission. By contrast, population growth rate had a little influence on CO_2 emission, while poverty and forest area negatively affected CO_2 emission. Putranti and Imansyah (2017) [27] examined CO_2 emission in manufacturing sector of Indonesia for three years (1990, 1995, and 2010). Their results stated that there is a change in the most elastic CO_2 emission of manufacturing sectors which tends from simple and light manufacturing to be a more complex and heavier manufacturing and as a consequence, CO_2 emission significantly increased. Likewise, Zaid et al. (2015) [39] investigated greenhouse gas emissions in Malaysia from 1990 to 2005. They found that CO_2 emissions in Malaysia grew by nearly 236 percent from 1990 to 2005 because of the rapid increase in national energy demand and number of automobiles and industries. Aung et al. (2017) [6] investigated the relationship between economic growth and CO_2 emissions in Myanmar during the period 1970-2014. Results demonstrated that economic growth positively affects CO_2 emissions in Myanmar in both short-run and long-run. However, trade liberalization and financial openness assist to improve the environment quality in this country in the long run. A study by Palanca-Tan et al. (2016) [25] estimated the relationship among CO_2 emissions and macroeconomic variables in the Philippines from 1996 to 2009. They concluded that economic growth and CO_2 emissions have a significant positive relationship. Further, CO_2 emissions are inelastic with respect to energy use in the short run, but its response becomes elastic in the long-run. Poolsawat and

Wongsapai (2018) [26] assessed impacts of household-related factors on CO_2 emissions in Thailand from 1993 to 2015. The results demonstrated that there is positive relationship between CO_2 emissions and household income and number of households. The growth of urbanization has been a main contributor leading to an increase of CO_2 emissions. Lastly, Thanh and Khuong (2017) [31] employed an Autoregressive Distributed Lag (ARDL) model to estimate factors affecting CO_2 emissions in Viet Nam from 1990 to 2011. The results indicated that the economic growth, energy consumption, financial development, and trade openness positively affect CO_2 emissions, while foreign direct investment (FDI) has a negative impact on CO_2 emissions in the short term.

3. METHODS

3.1. Data and sources

A panel dataset for effects of determinants on per capita CO_2 emissions in Southeast Asia is gathered from the database released by the World Bank. Due to limitations in human and financial resources, six developing countries in Southeast Asia, including Indonesia, Malaysia, Myanmar, the Philippines, Thailand, and Viet Nam, are chosen for the study. A panel dataset is collected for the last three decades (1985-2014). Thus, a total of 180 observations are entered for data analysis. The panel data is used for this research because of the following advantages: (1) it benefits in terms of obtaining a large sample, giving more degree of freedom, more information, and less multicollinearity among variables; and (2) it may overcome constraints related to control individual or time heterogeneity faced by the cross-sectional data [8, 18].

3.2. Data analysis

In this study, the ordinary least square (OLS) model, fixed effect (FE) model, and random effect (RE) model are employed to estimate impacts of determinants on per capita CO_2 emissions in Southeast Asia. The OLS model, FE model, and RE model are estimated by the Stata MP 14.2 software.

The OLS model:

$$Y = \alpha_0 + \sum \alpha_i X_i + \sum \gamma_i D_i + \epsilon_i \quad (1)$$

Where: Y denotes CO_2 emissions per capita (the dependent variable); α_0 is the intercept; α_i and γ_i denote parameters to be estimated; X_i represents independent variables such as electric power per capita, energy use, forest area, fossil fuel energy consumption, gross domestic product (GDP), total population, renewable energy consumption, D_i is dummy variables; and ϵ_i presents the error term.

Description of variables in the OLS model is presented in Table 1.

The FE and RE models: The purpose of OLS assumptions (linear functional relationship, data distribution, resilience to outliers, and independence of observations) is to simplify reality in order to respond to manageable questions that will provide insights into cause-effect relationships. However, these assumptions may be violated due to the model either oversimplifies or misrepresents and therefore the OLS model is not appropriate [13]. Estimators of the OLS model are inconsistent if the dependent variable correlates with the error term [23]. Moreover, the main drawback of the OLS regression is the omission of variables since both observed and unobserved variables can affect the dependent variable [7].

Panel estimation techniques are employed to overcome limitations of the OLS model. Specifically, both the FE and RE models are used to estimate impacts of covariates on per capita CO_2

Table 1: *Description of covariates in the OLS model*

Variable definitions	Label	Unit	Expected signs
Dependent variable: Per capita CO_2 emissions	Y	metric tonne	
Covariates:			
Electric power per capita	X_1	kWh	+
Energy use	X_2	kg of oil	+
Forest area	X_3	square km	-
Fossil fuel energy consumption	X_4	%	+
GDP	X_5	US$	+
Total population	X_6	person	+
Renewable energy consumption	X_7	%	-
Indonesia dummy (1=Indonesia and 0=Otherwise)	D_1		+/-
Viet Nam dummy (1=Viet Nam and 0=Otherwise)	D_2		+/-

Note: US$ means United States Dollar

emissions. If we omit variables and these variables are correlated with other explanatory variables in the model, then the FE model presents advantages. Further, this model assists to control for differences in time-invariant and unobservable characteristics which can affect per capita CO_2 emissions. If we have no omitted variables and these variables are uncorrelated with the explanatory variables in the model, then the RE model is useful. In this model, the individual-specific effect is a random variable which is uncorrelated with explanatory variables [29].

The equation for the FE and RE models can be specified as follows:

$$Y_{it} = \alpha_i + \beta A_{it} + \lambda E_{it} + \phi F_{it} + \rho X_{it} + \mu G_{it} + \gamma P_{it} + ZR_{it} + \pi D_{it} + \delta_t + \epsilon_{it} \quad (2)$$

$$(i = 1,, N; t = 1,, T_i)$$

Where: Y_{it} denotes per capita CO_2 emissions (metric tonne); α_i is the fixed effect; β, λ, ϕ, ρ, μ, γ, Z and π are parameters to be estimated; A_{it} is electric power per capita; E_{it} denotes energy use; F_{it} is forest area; X_{it} represents the rate of fossil fuel energy consumption; G_{it} is the GDP (current US$); P_{it} represents total population; R_{it} is the rate of renewable energy consumption; D_{it} denotes dummy variables; $delta_t$ presents the trend rate of change over time t; and $epsilon_{it}$ denotes the error term.

4. RESULTS AND DISCUSSION

4.1. Air pollution in Southeast Asia: An overview

CO_2 emissions in six countries tended to increase during the last 35 years (1980-2014). In which, Indonesia had the strongest increase by about 370,000 kilotonnes (kt) (or 4.9 times) from nearly 95,000 kt in 1980 to nearly 465,000 kt in 2014, followed by Thailand (about 277,000 kt), Malaysia (about 215,000 kt), Viet Nam (150,000 kt), the Philippines (about 69,000 kt), while Myanmar presented the smallest increase by only 16,105 kt (Figure 1).

Malaysia has overcome Indonesia to become the leading country in terms of per capita CO_2 emissions. For instance, by 2014, per capita CO_2 emissions of this country increased by about 3.5 times compared to that in 1985, while the growth of Indonesia accounted for about 2.6 times.

Table 2: *Description of covariates in the FE and RE models*

Variable definitions	Label	Unit	Expected signs
Dependent variable: Per capita CO_2 emissions	Y	metric tonne	
Covariates:			
Electric power per capita	A	kWh	+
Energy use	E	kg of oil	+
Forest area	F	square km	-
Fossil fuel energy consumption	X	%	+
GDP	G	US$	+
Total population	P	person	+
Renewable energy consumption	R	%	-
Indonesia dummy (1=Indonesia and 0=Otherwise)	D_1		+/-
Viet Nam dummy (1=Viet Nam and 0=Otherwise)	D_2		+/-

Myanmar had the lowest per capita CO_2 emissions in the region and in 2014, per capita CO_2 emissions of this country increased by about 2 times relative to that in 1985. These results are not surprise because Malaysia has the lowest number of population in the region and the process of industrialization and urbanization of Myanmar is slower than that of its neighbours (Figure 2).

This change in living standards, in urbanization rates, and in the movement toward economies driven by industry and services has caused GHG emissions from the region to rise rapidly. Such a transformation has also been underpinned by exploitation of natural resources in the region. Emissions growth in the region has been almost as fast as economic growth, with nearly 5 percent annually from 1990 to 2010. The fastest areas of relative emissions growth have been electricity, manufacturing, and transportation, which are sectors associated with the region's structural transformation away from agriculture. However, the largest share of emissions is driven by land use, which accounts for 55 percent of 2010 emissions, and which is growing at the fastest rate in tons of CO_2 equivalent emissions. Most of these emissions originate from deforestation and subsequent land degradation in Indonesia, which account for more than 70 percent of Indonesia's emissions. Outside of Indonesia, land use accounts for a minority of emissions, with energy use driving a majority of emissions in the Philippines, Thailand, and Viet Nam [1].

There are numerous negative impacts of air pollution on economic, social, and environmental aspects in Southeast Asia. For instance, by 2010, Indonesia has become the largest GHG emitter in the region by nearly 2,000 million tonnes of CO_2 equivalent emissions. In which, 1,400 million tonnes of CO_2 emissions came from land-use processes and the rest is generated by industrial and agricultural production. In the same time, Malaysia emitted about 400 million tonnes of GHGs, in which the rate of CO_2 accounted for 79 percent and 15 percent came from methane (CH_4). In the region, this country is the third largest emitter after Indonesia and Thailand, but Malaysia is ranked as the largest emitter per capita [1]. In Viet Nam, the increase in air pollution is a result of the rapid growth of industrialization and urbanization [20]. In this country, air pollution is worsening, which negatively affects public health and the environment. About 667,000 tons of sulfur oxides, 618,000 tons of nitrogen oxides, and 6.8 million tons of carbon monoxide are released annually in Viet Nam [24]. According to the World Health Organization (2005), there is a strong relationship between GDP growth and absolute levels of nitrogen oxides and sulfur oxides emissions [2]. Transport activities can be defined as a key source of air pollution in big cities of Viet Nam, where the air pollution in urban areas caused by traffic is accounted for approximately

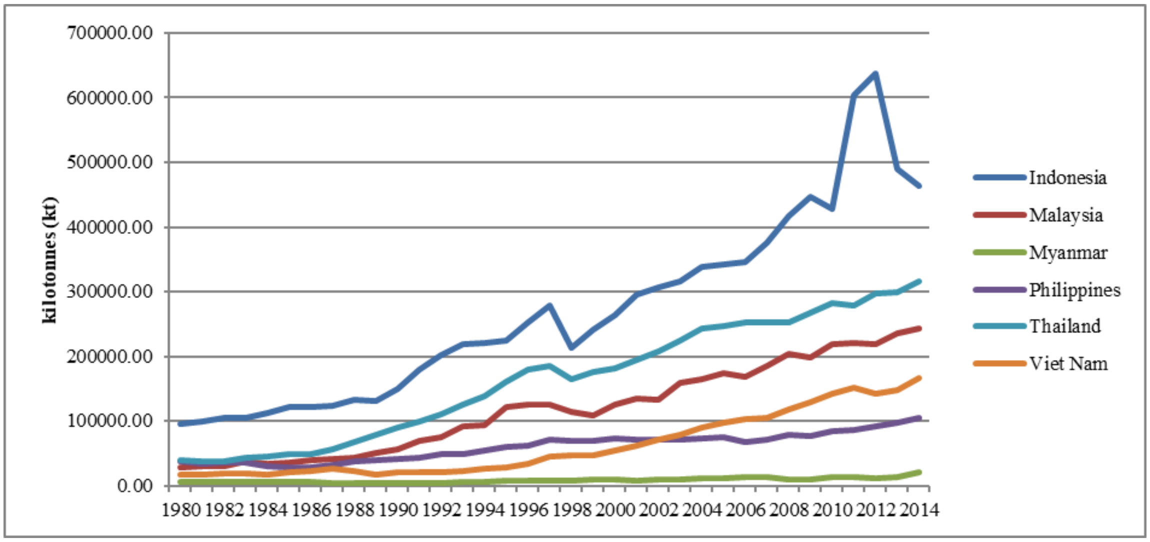

Figure 1: *CO_2 emissions of selected countries in Southeast Asia (1980-2014) [33]*

70 percent. Transport means are dominated by motorcycles and cars and therefore air pollution is arising due to exhausted engines of these vehicles. Transportation activities contribute to nearly 85 percent of carbon monoxide (CO) and 95 percent of volatile organic compounds (VOCs). About 70 percent of sulfur oxide (SO) emission is generated by the industrial activity [17].

4.2. Influences of determinants on per capita CO_2 emissions in Southeast Asia

4.2.1 Characteristics of determinants affecting per capita CO_2 emissions in Southeast Asia

The average per capita CO_2 emissions in Southeast Asia for the period of 1985-2014 accounted for 1.92 metric tonnes. The average electric power per capita and energy use reach about 901 kWh and 840 kg of oil, respectively. Forest area and fossil fuel energy consumption of this region account for about 268,000 square km and nearly 59 percent. The average GDP and total population of six countries reach US$13.4 trillion and 82.6 million, respectively, while the proportion of renewable energy consumption accounts for nearly 35 percent (Table 3).

Table 3: *Characteristics of determinants affecting per capita CO_2 emissions in Southeast Asia*

Variable	Mean	SD	Min	Max
Per capita CO_2 emissions (metric tonne)	1.92	2.01	0.1	8
Electric power per capita (kWh)	901.77	1028.07	38.2	4596.3
Energy use (kg of oil)	840.05	686.93	0	2967.5
Forest area (square km)	268046.1	320238.1	0	1185450
Fossil fuel energy consumption (%)	58.25	24.04	0	96.9
GDP (current US$)	1.34e+11	1.65e+11	0	9.18e+11
Total population (person)	8.26e+07	6.18e+07	1.56e+07	2.55e+08
Renewable energy consumption (%)	34.27	27.63	0	91.1

Source: Author's calculation, 2019
Note: SD means standard deviation

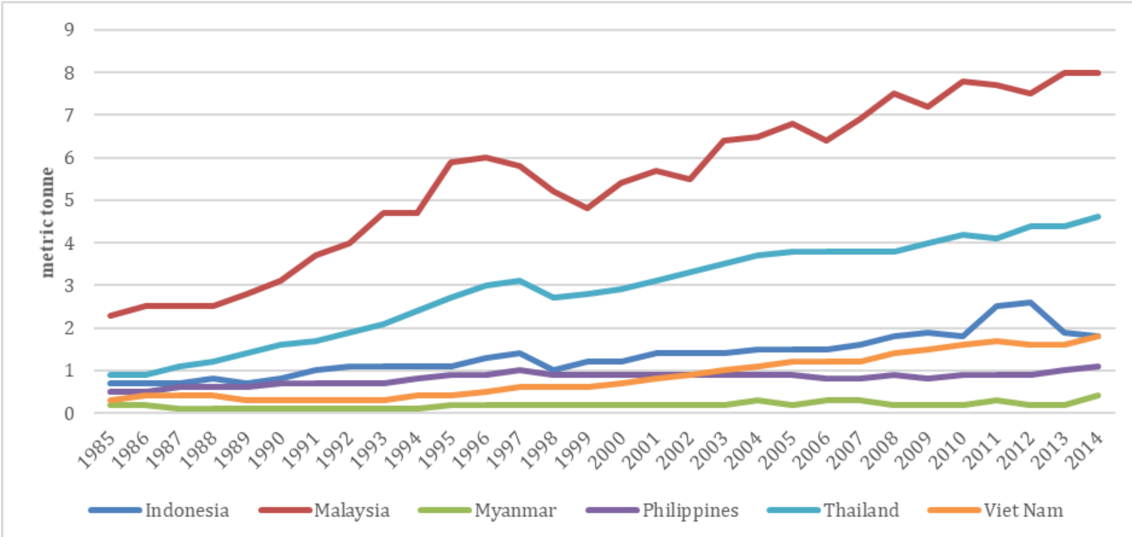

Figure 2: *Per capita CO_2 emissions of selected countries in Southeast Asia (1985-2014) [37]*

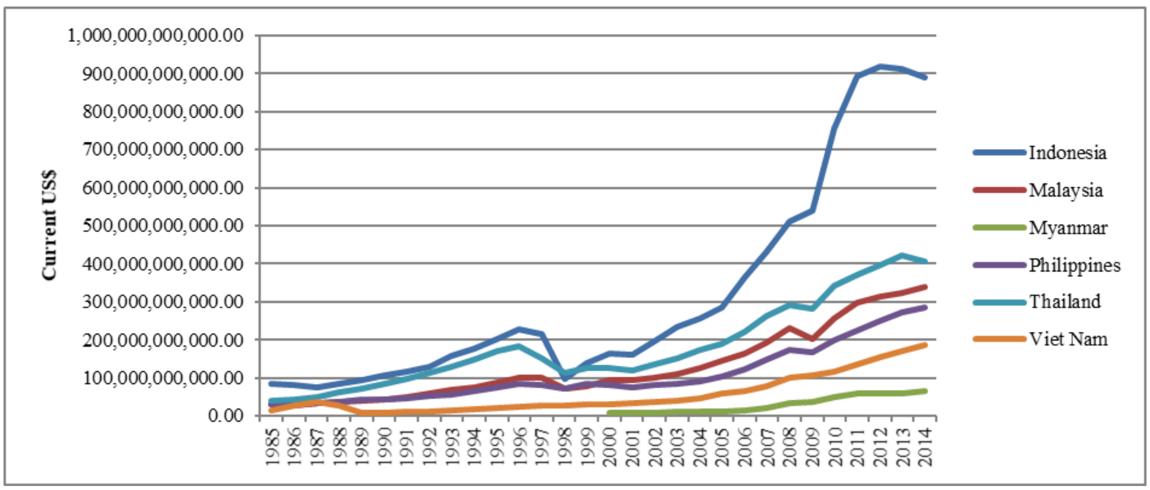

Figure 3: *GDP of selected countries in Southeast Asia (1985-2014) [36]*

GDP of six countries in Southeast Asia increased between 1985 and 2014, especially from 1998 onward. By 2014, Indonesia has become the largest economy in the region with GDP reached nearly US$891 billion, following by Thailand (nearly US$408 billion), Malaysia (nearly US$339 billion), the Philippines (nearly US$285 billion), Viet Nam (nearly US$187 billion), and Myanmar (nearly US$66 billion). In 2014, GDP of Viet Nam grew by more than 13 times compared to that in 1985, while the growth accounted for more than 10 times for Malaysia, Thailand, and Indonesia. In 2014, GDP of Myanmar increased by more than 9 times relative to that of 2000 (Figure 3). The growth of GDP can be interpreted to the rising consumption of energy and fossil fuel in these countries.

Population of six countries in Southeast Asia tended to grow for three decades (1985-2014), especially in Indonesia. For instance, by 2014, population of Indonesia reached nearly 256 million, followed by the Philippines (100 million), Viet Nam (nearly 93 million), Thailand (about 68 million), Myanmar (nearly 52 million), and Malaysia (about 30 million) (Figure 4). The growth of population along with the rising GDP can be seen as major determinants contributing to the increase in energy and fossil fuel consumption in these countries.

Energy use per capita of six countries tended to increase from 1985 to 2014, especially in Malaysia and Thailand. Malaysia had the strongest increase in energy use per capita by more than 1,970 kg of oil from 399 kg in 1985 to nearly 884 kg in 2014, followed by Thailand (1,495 kg), Indonesia (485 kg), Viet Nam (394 kg), Myanmar (77 kg), while the growth of energy use in the Philippines only accounted for 39 kg (Figure 5).

Similar to the pattern of energy use, the rate of fossil energy consumption in six Southeast Asian countries tended to rise for three decades, particularly in Viet Nam and the Philippines. Specifically, Viet Nam and the Philippines had the strongest growth in fossil fuel consumption by more than 40 percent and nearly 27 percent, respectively from 1985 to 2014, followed by Thailand (nearly 25 percent), Myanmar (nearly 20 percent), Indonesia (17 percent), and Malaysia (nearly 10 percent) (Figure 6).

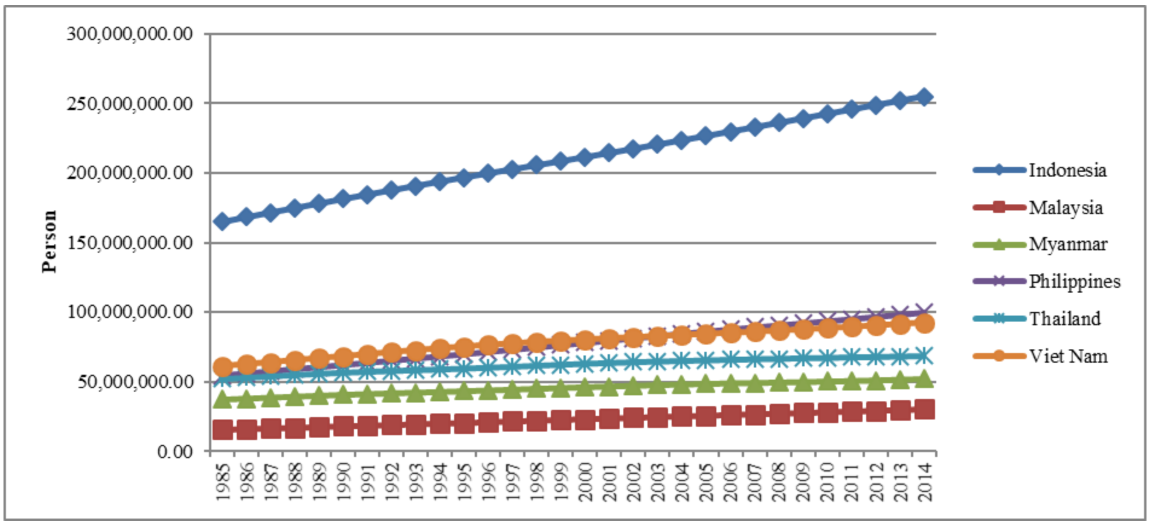

Figure 4: *Population of selected countries in Southeast Asia (1985-2014) [38]*

4.2.2 Impacts of determinants on per capita CO_2 emissions in Southeast Asia

The OLS model, FE model, and RE model are employed to assess impacts of determinants on per capita CO_2 emissions in Southeast Asia for three decades (1985-2014).

F-value and P-value account for 658.85 and 0.000, respectively imply the fitness of the model. Adjusted R-squared is equal to 0.97 reflects that 97 percent of variation in per capita CO_2 emissions can be explained by independent variables in the model (Table 4).

All independent variables are statistically significant, except forest area and fossil fuel energy consumption. Electric power per capita, energy use, and GDP have positive relationship with per capita CO_2 emissions and this implies that the increase in electric power, energy use, and GDP leads to the rise in per capita CO_2 emissions. Specifically, if electric power per capita increases by 1 kWh, then per capita CO_2 emissions rise by 0.7 metric tonnes, ceteris paribus. If energy use increases by 1 kg of oil, then per capita CO_2 emissions increase by 0.09 metric tonnes, ceteris paribus. If GDP rises by 1 US$, then per capita CO_2 emissions increase by 0.006 metric tonnes, ceteris paribus. In contrast, population and renewable energy consumption negatively affect per

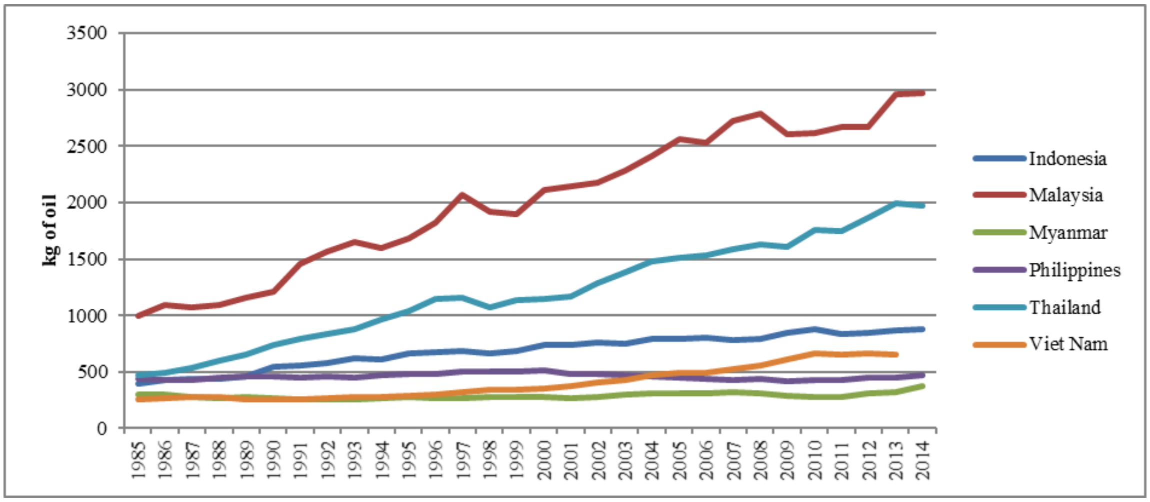

Figure 5: *Energy use per capita of selected countries in Southeast Asia (1985-2014) [34]*

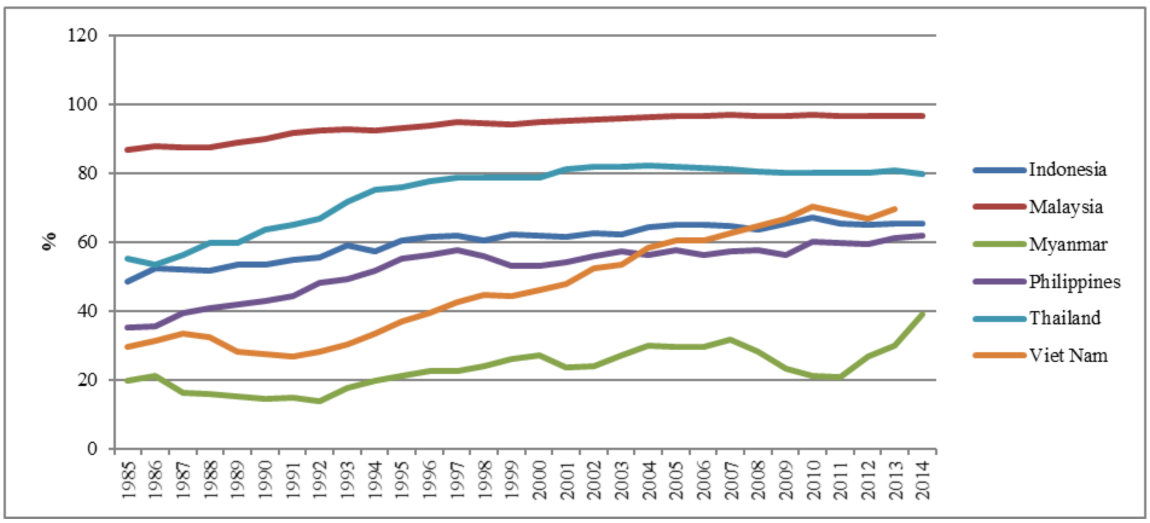

Figure 6: *Fossil fuel energy consumption of selected countries in Southeast Asia (1985-2014) [35]*

capita CO_2 emissions and this suggests that if population and renewable energy consumption increase, then per capita CO_2 emissions decrease. These results are consistent because when population grows, the level of CO_2 emissions per capita decline. Fossil fuel energy such as oil, coal, and natural gas in regions of the world tend to be scared due to over-exploitation and overwhelming consumption for industrialization and urbanization in many countries and these lead to the degradation of the environment, especially in air pollution in recent years. Thus, renewable fuel energy such as solar, wind, tidal, and biological sources, have been used more frequently in order to reduce environmental pollution and avoid dependence on fossil energy sources. Hence, if the rate of renewable energy consumption increases, then per capita CO_2 emissions tend to decrease. Per capita CO_2 emissions of Indonesia and Viet Nam are higher than those of other countries in the region because of the rapid growth of industrialization and urbanization in both countries in the past three decades. Indeed, by 2014, Indonesia is the largest

Table 4: *Regression of the OLS model*

Variable	Coef.	Std. err.	t	P-value
Log_Electric power per capita	0.768***	0.02	25.73	0.000
Log_Energy use	0.090**	0.03	2.28	0.024
Log_Forest area	0.020	0.01	1.43	0.155
Log_Fossil fuel energy consumption	0.016	0.04	0.36	0.719
Log_GDP	0.006**	0.00	2.07	0.040
Log_Total population	-0.263***	0.05	-5.18	0.000
Log_Renewable energy consumption	-0.099**	0.04	-2.23	0.027
Indonesia dummy (1=Indonesia and 0=Otherwise)	0.391***	0.03	9.79	0.000
Viet Nam dummy (1=Viet Nam and 0=Otherwise)	0.115***	0.02	5.68	0.000
Constant	-0.342	0.38	-0.89	0.376
Number of observations	180			
F(9, 170)	658.85			
Prob >F	0.000			
R-squared	0.972			
Adjusted R-squared	0.970			
Root MSE	0.085			

Source: Author's calculation, 2019
Note: *** and ** mean statistical significance at 1% and 5%, respectively

country in terms of economy and population in Southeast Asia, which account for US$891 billion and 255 million, respectively. Viet Nam is the third largest population country in the region with nearly 95 million people in 2017. Hence, the rise in per capita CO_2 emissions is a result of the rapid economic and population growth (Table 4).

F-value and P-value account for 673.46 and 0.000, respectively imply the fitness of the model. Overall R-squared is equal to 0.941 suggests that 94.1 percent of variation in per capita CO_2 emissions can be interpreted by independent variables in the model. U_i presents unobserved heterogeneity. Correlation (u_i, X_b) is equal to -0.065 implies that unobserved heterogeneity has a negative relationship with explanatory variables in the model. Sigma_u is equal to 0.098 and this reflects that the estimate of standard deviation between variables is equal to 0.098. Sigma_e is equal to 0.079 and this implies that the estimate of standard deviation within variables is equal to 0.079. Rho is equal to 0.605 and this suggests that variation of variance due to the error term accounts for 60.5 percent (Table 5).

All independent variables are statistically significant, except forest area and fossil fuel energy consumption. Electric power per capita, energy use, and GDP have positive relationship with per capita CO_2 emissions and this implies that the increase in electric power, energy use, and GDP leads to the rise in per capita CO_2 emissions. Specifically, if electric power per capita increases by 1 kWh, then per capita CO_2 emissions rise by 0.78 metric tonnes, ceteris paribus. If energy use increases by 1 kg of oil, then per capita CO_2 emissions increase by 0.11 metric tonnes, ceteris paribus. If GDP rises by 1 US$, then per capita CO_2 emissions increase by 0.007 metric tonnes, ceteris paribus. However, population and renewable energy consumption have negative relationships with per capita CO_2 emissions and this suggests that if population and renewable energy consumption increase, then per capita CO_2 emissions decrease. For instance, if population grows by a person, then per capita CO_2 emissions drop by 0.19 metric tonnes, ceteris paribus. If renewable energy consumption increases by 1 percent, then per capita CO_2 emissions decline by

Table 5: *Regression of the FE model*

Variable	Coef.	Std. err.	t	P-value
Log_Electric power per capita	0.785***	0.02	26.75	0.000
Log_Energy use	0.117***	0.04	2.87	0.005
Log_Forest area	-0.018	0.03	-0.48	0.633
Log_Fossil fuel energy consumption	-0.036	0.04	-0.77	0.441
Log_GDP	0.007**	0.00	2.32	0.022
Log_Total population	-0.199***	0.05	-3.46	0.001
Log_Renewable energy consumption	-0.123***	0.04	-2.86	0.005
Indonesia dummy (1=Indonesia and 0=Otherwise)	0.383***	0.05	6.77	0.000
Viet Nam dummy (1=Viet Nam and 0=Otherwise)	0.109***	0.01	5.70	0.000
Constant	-0.673	0.54	-1.25	0.215
Number of observations	180			
Number of groups	30			
F(9, 170)	673.46			
Prob >F	0.000			
Correlation (u_i, X_b)	-0.065			
R-squared:				
Within	0.977			
Between	0.659			
Overall	0.941			
Sigma_u	0.098			
Sigma_e	0.079			
Rho	0.605			

Source: Author's calculation, 2019

Note: *** and ** mean statistical significance at 1% and 5%, respectively

0.12 metric tonnes, ceteris paribus. Indonesia and Viet Nam have higher per capita CO_2 emissions compared to other countries in the region (Table 5).

Wald chi2 and P-value account for 5929.69 and 0.000, respectively imply the fitness of the model. Overall R-squared is equal to 0.972 suggests that 97.2 percent of variation in per capita CO_2 emissions can be interpreted by independent variables in the model. U_i presents unobserved heterogeneity. Correlation (u_i, X) is assumed to equal to zero and this implies that there is no relationship between unobserved heterogeneity and explanatory variables in the model. Sigma_u is equal to zero and this reflects that the estimate of standard deviation between variables is equal to zero. Sigma_e is equal to 0.079 and this implies that the estimate of standard deviation within variables is equal to 0.079. Rho is equal to zero and this suggests that there is no variation of variance due to the error term (Table 6).

All independent variables are statistically significant, except forest area and fossil fuel energy consumption. Electric power per capita, energy use, and GDP have positive relationship with per capita CO_2 emissions and this implies that the increase in electric power, energy use, and GDP leads to the rise in per capita CO_2 emissions. For example, if electric power per capita increases by 1 kWh, then per capita CO_2 emissions rise by 0.76 metric tonnes, ceteris paribus. If energy use increases by 1 kg of oil, then per capita CO_2 emissions increase by 0.09 metric tonnes, ceteris paribus. If GDP rises by 1 US$, then per capita CO_2 emissions increase by 0.006 metric tonnes, ceteris paribus. However, population and renewable energy consumption have negative

Table 6: *Generalized least squares (GLS) regression of the RE model*

Variable	Coef.	Std. err.	t	P-value
Log_Electric power per capita	0.786***	0.02	25.73	0.000
Log_Energy use	0.090***	0.03	2.28	0.023
Log_Forest area	0.020	0.01	1.43	0.153
Log_Fossil fuel energy consumption	0.016	0.04	0.36	0.718
Log_GDP	0.006**	0.00	2.07	0.039
Log_Total population	-0.263***	0.05	-5.18	0.000
Log_Renewable energy consumption	-0.099***	0.04	-2.23	0.026
Indonesia dummy (1=Indonesia and 0=Otherwise)	0.391***	0.03	9.79	0.000
Viet Nam dummy (1=Viet Nam and 0=Otherwise)	0.115***	0.02	5.68	0.000
Constant	-0.342	0.38	-0.89	0.374
Number of observations	180			
Number of groups	30			
F(9, 170)	5929.69			
Prob >F	0.000			
Correlation (u_i, X_b)	0 (assumed)			
R-squared:				
Within	0.976			
Between	0.960			
Overall	0.972			
Sigma_u	0			
Sigma_e	0.079			
Rho	0			

Source: Author's calculation, 2019
Note: *** and ** mean statistical significance at 1% and 5%, respectively

relationships with per capita CO_2 emissions and this suggests that if population and renewable energy consumption increase, then per capita CO_2 emissions decrease. For instance, if population grows by a person, then per capita CO_2 emissions drop by 0.26 metric tonnes, ceteris paribus. If renewable energy consumption increases by 1 percent, then per capita CO_2 emissions decline by 0.09 metric tonnes, ceteris paribus. Indonesia and Viet Nam have higher per capita CO_2 emissions compared to other countries in the region by 0.39 and 0.11, ceteris paribus (Table 6).

4.3. Discussion

We found that electric power per capita, energy use, and GDP have positive impacts on per capita CO_2 emissions in Southeast Asia for the last three decades (1985-2014). Our findings are consistent with conclusions of [6, 21, 25, 26, 31] because these studies argued that economic growth and the increasing energy consumption are factors contributing to the rise of CO_2 emissions. During a quarter of a century up to 2014, the average of economic growth of five Southeast Asian countries, including Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam, varied from 4 to 7 percent annually because of transformation in economic structures. Rising GHG emissions in these countries are caused by the change in living standards and a rapid growth of industrialization and urbanizations along with overwhelming exploitation of natural resources in the region. During two decades (1990-2010), emissions growth in the region has been almost equivalent to economic growth by 5 percent annually. Demand for fossil fuel is continuing to rise due to expansion of energy use to facilitate economic growth [1].

Further, our results showed that population and renewable energy consumption have negative relationships with per capita CO_2 emissions. Findings in effects of population on CO_2 emissions are contrast to argument of Poolsawat and Wongsapai (2018) [26] because their research found that there is a positive relationship between the number of households and residential direct CO_2 emissions in Thailand. The difference may be interpreted by the manner of measuring unit of the dependent variable. We calculate CO_2 emission per capita, while their study computes the total CO_2 emissions.

We also found that per capita CO_2 emissions of Indonesia and Viet Nam are higher than that of other countries in the region. By 2014, Indonesia has become the largest economy in the region with GDP reached nearly US$891 billion, while GDP of Viet Nam accounted for nearly US$187 billion. In addition, Indonesia and Viet Nam have been ranked in the first and third position in population, which account for nearly 256 million and nearly 93 million, respectively. In Viet Nam, urban population increased rapidly by nearly 14 million from 19.2 million in 1980 to 33 million in 2014. Fossil fuel energy consumption of this country rose by about 40 percent from nearly 30 percent in 1980 to nearly 70 percent in 2013.

5. CONCLUSION AND POLICY IMPLICATIONS

The article seeks impacts of determinants on per capita CO_2 emissions in six Southeast Asian countries between 1985 and 2014 by employing a panel dataset. We found that electric power per capita, energy use, and GDP have positive influences on per capita CO_2 emissions in Southeast Asia. However, population and renewable energy consumption negatively affect CO_2 emissions per capita in this region. Our results also stated that per capita CO_2 emissions of Indonesia and Viet Nam are higher than that of other countries in the region.

Policies should be recommended in order to reduce CO_2 emissions and protect the environment in Southeast Asia. The initial suggestion is improvement of energy efficiency in countries in the region. Indonesia has intended that 18 percent of primary energy should be conserved between 2011 and 2025 based on the 2010 revision of the National Energy Conservation Master Plan. Malaysia has committed to improve 6 percent of energy efficiency over a decade based upon the draft of Energy Efficiency Action Plan in 2014. In the Program of Energy Efficiency and Conservation, the Philippines has decided to save 10 percent of energy efficiency in all sectors. By 2030, Thailand has committed to reduce energy intensity by 25 percent and also reduce overall energy consumption by 20 percent relative to the business-as-usual (BAU) levels. In the Energy Efficiency and Conservation Programme, Viet Nam has targeted to save from 5 to 8 percent of total national energy consumption during 2012-2015. Moreover, implementation of the Project in Clean Energy Investments in Southeast Asia funded by the Asian Development Bank (ADB) to provide US$4 billion to assist developing countries in the region mitigate GHG emissions. Various activities are carried out in the project, including improvement of efficiency in energy, transport, and urban sectors, and deployment of clean energy sources. Investments of ADB have been focused on themes such as renewable power, development of smart and efficient power grids, energy efficient transport, and development and deployment of advanced energy technology [1]. Reduction of fuel and CO_2 emissions by 16 percent applied to light duty vehicles and up to 26 percent applied to both light duty vehicles and high duty vehicles in Southeast Asia. For instance, Thailand has become the leading country in terms of constructing standards for light duty vehicles and will be applied to other vehicles in the future [15]. Southeast Asian countries can benefit if they exploit advantages in exporting GHG emissions. With the allowances under the 500 parts per million (ppm) and 650 ppm scenarios, the net present value of this region is predicted to increase from 32 percent to 53 percent in the global carbon market during the 2010-2050. Lastly, cooperation among countries in the region should be enforced to reduce emissions by reducing land-use emissions and replacing carbon-intensive fuels with cleaner alternatives [1].

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