Greenhouse Gas Emissions Determinants Using Empirical Datasets in the Southeast Asian Region

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Abstract

Greenhouse gas (GHG) emissions of the ten-member countries of Association of Southeast Asian Nations (ASEAN) were determined using panel data analysis. The longitudinal data were subjected to sensitivity analysis, multiple correlation, and regression analyses to examine statistical correlation among the identified variables. The findings revealed that the urban population is significantly associated with GHG emissions mostly induced by industrial development. Meanwhile, forest cover and population density among the member countries statistically influenced GHG emissions. Likewise, the urban population showed direct bearing with GHG emission while access to clean fuels, forest cover and population density inversely correlate with GHG emissions. In large part, forest cover influenced the dynamic condition of GHG emissions based on sensitivity analysis. The resulting regression model further confirmed that forest cover essentially contributed to the minimizing effect of GHG emissions. However, the model explained only 37.15% of the deviance in the prediction of total GHG. In conclusion, forest cover programs in the member countries played as the primary determinant of GHG emissions, which are limited to the carrying capacity of the forest lands. Nonetheless, other determinants should not be neglected for they still contribute to the increase of GHG emission level. To reduce the level of GHG emissions, ASEAN governments must formulate policies and programs that favor access to fuels and people awareness on reforestation initiatives. Detrimental human activities related to GHG emissions in the urban area have to be reduced in order to curtail GHG emissions.

***Keywords**:* panel data analysis, GHG emissions, regression model

1. Introduction

Greenhouse gas (GHG) emissions have been expanding due to human activities around the world, thereby causing a generous increase in climatic fixations (Intergovernmental Panel on Climate Change [IPCC], 2013). Each country around the globe exudes greenhouse gases into the air – this means the underlying driver of environmental change is really worldwide in scope. Few nations in the Southeast Asian region generate far more GHG than others, and a few factors, for example, economic activity, a populace, pay level, arrive use and climatic conditions can affect a nation's emanation levels (Randers, 2012). GHG discharges in a greater degree give a more extensive setting for understanding the role of every nation in responding to issues on climate change. There has been growing interest in examining how climate change – as a global phenomenon – and its regional impacts, including the Southeast Asian region, are unfolding.

Swift economic growth in Southeast Asia has succeeded in lifting hundreds of millions out of poverty in recent years (Raitzer *et al.*, 2015). However, the region's growth pattern was not environmentally sustainable. The ASEAN-member countries contribute 4% of worldwide GHG emissions that are energy-related (Fulton *et al.*, 2017). Its CO_2 emissions have increased by nearly 5% annually, making Southeast Asia a fast-growing climate-changing GHG emitter over the previous two decades (Raitzer *et al.*, 2015). If present trends continue, the region will face heightened effects of climate change, including coastal flooding and rising sea levels, enhanced flooding of rivers, water stress, and more repeated and intense cyclones and storms (IPCC, 2014). Temperature and rainfall changes could lead to declines in farm production, labor productivity, and human health; enhanced demand for energy and other resources; and deterioration of coastal ecosystems and biodiversity (Hijioka *et al.*, 2014).

The role of energy revolution advancement in lessening emissions is winding up progressively in the perceived change to a reduced and more sustainable carbon energy (Gallagher *et al.*, 2006). Moreover, it has turned into a noticeable subject in legislative issues and arrangement, with a perceived need to make interest for clean energy through strategy alongside vital interests in research, development, demonstration, and implementation (Grubler and Wilson, 2013). It was pointed out in the study of Jordaan *et al.* (2017) that facilitating ventures financing and climate policy requires cautious thought about the significance of the energy technology revolution in mitigating emission issues.

Forest and trees in the land area make up a vital pointer of environmental condition and in the long run, GHG emissions (Keenan *et al.*, 2015). Henceforth, fighting against deforestation has turned into a matter of worldwide significance for climate change mitigation and ecological preservation (Miyamoto *et al.*, 2014). Deforestation is dependent on different variables including political, demographic, economic, and institutional forces (Geist and Lambin, 2002). Deforestation is a complex process that is forced by a blend of related and fundamental factors which can shift from one regional location to another (Geist and Lambin, 2002; Rudel *et al.*, 2009). The most evident reason for forest loss in Southeast Asia is the change of forest to cash crop farms. Establishing timber plantations and timber abuse including unlawful logging can cause a considerable change of forest canopies and structure (Stibig *et al.*, 2007). Various studies recognize agricultural development as the immediate primary reason for tropical deforestation, especially the production of commercial merchandises (De Fries *et al.*, 2010; Miyamoto *et al.*, 2014). In an investigation led in Malaysia, regression analysis featured the poverty mitigation as the primary factor prompting some conversion in the forest area (Miyamoto *et al.*, 2014). In Southeast Asia, Vietnam has encountered forest changes, while Peninsular Malaysia and Thailand have diminished their degrees of deforestation (Lidula *et al.*, 2007). Empirical investigations demonstrate that the costs of deforestation and agricultural merchandises are positively associated and indicative of underlying connection among these amounts (Angelsen and Kaimowitz, 1999).

There is a common logical understanding that increased concentrations are the outcome of human events around the world. Among these anthropogenic variables, the primary ones are technology, economic activity, population, attitudes and beliefs, and political and economic institutions (Proctor, 1998). These forces, for the most part, are assumed to drive GHG emanations, as well as all anthropogenic environmental change. Changes in pollution levels may likewise be in any event incompletely clarified by a country's stand in the demographic evolution and their overall population assembly. However, only few researches have incorporated this critical viewpoint in the investigation (Ruth and Franklin, 2014). Social researchers, including demographers, have looked to comprehend the relations amid a complete scope of population dynamics (age, population, urbanization, and migration) and environmental alterations (Curran and de Sherbinin, 2010).

Recent studies neglect to give any solid proof on the determinants of GHG emissions. Moreover, panel-based research on demographic profile, forest cover, technological advances, and GHG emission is rare. These are the sources of motivation for this study. A dynamic panel data used in this work could provide a model on the determinants of total GHG emission. This model guarantees that there is a robust theoretical framework for the empirical investigation of this study. Knowing the shortage of multivariate studies on short-run impacts of technological developments and population on emissions, and data impediments, estimating the short-run relationship was engaged. This current study also gauged the robustness of the relationship between demographic profile, forest cover, and technological innovations through access to clean fuel technology versus the total GHG emission for the country panels in the Southeast Asian region.

2. Methodology

2.1 Source of Data and Statistical Method

The data employed in this study covered the ten ASEAN-member countries located in the Southeast Asian region – west of Papua New Guinea, east of India, north of Australia, and south of China and Japan. The ASEAN members include Indonesia, Vietnam, Singapore, Myanmar, Thailand, Malaysia, Brunei, Cambodia, Laos, and the Philippines. The data taken annually for total GHG emissions (% change from year 1990), access to clean fuels and technologies (% of population), forest area (% of land area), population density (people per square meter of land area), and urban population (% of total population) are downloaded from the World Bank’s World Development Indicators (2018).

Variables were standardized and measured in growth form. Data used is for the period 2005-2012 since this period has the complete data needed yet. Total GHG emissions have served to be the response data while the rest of the variables served as the predictor data. Statistical analysis was done using Minitab v17.0. Table 1 shows one of the time-series data used.

The data were analyzed using descriptive statistics. The data collected were transformed using Box-Cox transformation to normalize the data. Rounded value for the parameter, λ was found to be zero which means that the transformation follows the logarithmic model. Regression analysis with analysis of variance (ANOVA) then followed.

Table 1. Total GHG emission indicators in the Southeast Asian Region in the year 2005

ASEAN Member	Total GHG emission (% Change from 1990)	Clean Fuels and Technology (% of Population)	Forest Area (% of Land Area)	Population Density (People per Square Meter of Land Area)	Urban Population (% of Total Population)
Brunei	10,968.96	100.00	73.81	69.29	73.50
Cambodia	101,252.49	7.35	60.79	75.18	19.17
Indonesia	1,171,042.59	18.10	54.02	125.15	45.94
Laos	53,444.81	4.28	73.09	24.93	27.39
Malaysia	246,665.16	96.03	63.58	78.10	66.59
Myanmar	223,012.72	7.46	51.00	74.21	28.93
Philippines	146,433.72	39.29	23.72	289.35	46.60
Singapore	47,597.81	100.00	23.73	6,191.24	100.00
Thailand	364,315.70	70.21	31.51	128.06	37.52
Vietnam	232,509.77	29.23	42.17	271.90	27.28

Source: World Bank's World Development Indicators (2018)

2.2 The Model

The proposed empirical model is in the form of the following:

$$GHGt = f\,(T, F, P, U) \tag{1}$$

Equation 1 states that access to clean fuels and technologies (*T*), forest area (*F*), population density (*P*), and urban population (*U*) can determine total GHG emissions (*GHGt*), potentially. Since this is a panel data analysis, a dynamic panel specification was used where lagged levels of total GHG emissions are taken into consideration by using the Fit Regression Model (FRM) (Smith and Rose, 1995). Equation 1 was written in a panel growth form, below:

$$GHGt = \propto_o + \propto_1 T_{it} + \propto_2 F_{it} + \propto_3 P_{it} + \propto_4 U_{it} + \varepsilon_{it} \tag{2}$$

where:

i = ASEAN-member country
t = a period of time

$GHGt$ = total GHG emissions (% change from the year 1990)
T = access to clean fuels and technologies (% of population)
F = forest area (% of land area)
P = population density (people per square meter of land area)
U = urban population (% of total population)
$\propto_n$ = coefficients for the fit
ε_{it} = term for residuals

2.3 Conceptual Framework

It requires a systematic review in understanding the positive influence of energy technology innovation in reducing GHG emissions in a country to characterize the existing system (Jordaan *et al.*, 2017). Hence, the role of innovation in reducing GHG emissions has shown to be an important issue. Significant effects for health and environment are attainable by providing access to clean household and industrial fuels for the 2.7 billion people that are still dependent on utilizing primitive, traditional biomass and coal stoves. The use of cleaner energy technologies, mainly on stove fuels to reduce climate change has not been sufficiently explored (World Health Organization [WHO], 2007). The WHO (2007) reported that there was a substantial impact on climate change from stoves due to the emission of air pollutants. Using clean cookstoves helped reduce that impact while benefiting good health. In view thereof, access to clean fuel and technologies is expected to have a positive effect on GHG emission.

The degradation of forests in the tropical and subtropical developing countries is discerned to be an essential contributor to global greenhouse gas emissions (Pearson *et al.*, 2017). Forest emission sources were considered to have significant relationships with forest characteristics (Pearson *et al*., 2017). Hence, forest area is expected to bring a positive effect on GHG emissions.

According to IPCC (2007), a dramatic increase in the amount of greenhouse gases in the atmosphere due to human activity over the last century. IPCC (2007) also reported that this increase of greenhouse gases has contributed to an increase of 1.3 Fahrenheit (about -17 degrees Celsius) on the Earth's surface temperature over the past century. On the same report, it was illustrated that the further warming and induce additional changes in the climate system will be experienced brought by the current rates of greenhouse gas accumulation that would very likely be higher than those observed during the 20th century.

Urbanization in the city is developing more rapidly than the national average brought by the migration of workers from rural to urban areas in quest of better opportunities (Itoh, 2009). In effect, when the population becomes more urbanized, there is added pressure on the resources; thus, affecting the environment leading to an increase in GHG emissions (Sharma, 2011). Indeed, there is a negative impact of urbanization on GHG emission as proven by Sharma (2011).

3. Results and Discussion

3.1 ANOVA and Regression Analysis

First, the panel unit root test was performed using ANOVA. This test evaluated the variables identified in the null hypothesis to decide which variables are applicable for the FRM. Among all four panels, namely access to clean fuels and technologies, forest areas, population density, and urban population, the observations indicated that for forest cover and population density, the null hypothesis is rejected (Table 2). These findings mean that forest cover and population density are stationary and therefore, applicable for the FRM without changing them. Stationary variables have constant long-term mean and a constant variance independent of time (Montgomery and Runger, 2003; Vichi, 2012). On the other hand, for the variables, access to clean fuel and technologies and urban population, the null hypothesis is not rejected for these variables are non-stationary. Non-stationary variables may be spurious in that they may indicate a relationship between two variables where one does not exist (Montgomery and Runger, 2003; Vichi, 2012).

Table 2. Analysis of variance for transformed response

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	4	43.7300	10.9320	11.0800	0.0000
T	1	1.8580	1.8580	1.8800	0.1740
F	1	26.1780	26.1780	26.5300	0.0000
P	1	9.8030	9.8031	9.9400	0.0020
U	1	0.4000	0.3997	0.4100	0.5260
Error	75	73.9930	0.9866		
Total	79	117.7240			

FRM was then done to establish the determinants of the total GHG emissions for all panels (Table 3).

Table 3. Model summary for transformed response

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	14.287000	0.444000	32.150	0.000	
T	-0.010160	0.007400	-1.370	0.174	5.990
F	-0.040940	0.007950	-5.150	0.000	1.690
P	-0.000351	0.000111	-3.150	0.002	4.180
U	0.009500	0.015000	0.640	0.526	10.330
S	R-sq	R-sq (adj)	R-sq (pred)		
0.993267	37.15%	33.79%	28.90%		

Substituting coefficients (Table 3) to Equation 2, yields the regression equation as follows:

$$ln\ (GHGt) = -\ 0.01016\ T_{it} - 0.04094\ F_{it} - 0.000351\ P_{it} + 0.0095\ U_{it} + 14.287 \quad (3)$$

or

$$(GHGt) = exp\ (-\ 0.01016\ T_{it} - 0.04094\ F_{it} - 0.000351\ P_{it} + 0.0095\ U_{it} + 14.287) \quad (4)$$

Equation 4 has been established using the fit regression model, which aims to predict total GHG emissions (*GHGt*) in the Southeast Asian Region using the four predictors, *T, F, P,* and *U.* It has been proven statistically that there is not enough evidence to conclude that the model does not fit the data. However, the model explains only 37.15% of the deviance in the prediction of *GHGt.*

Statistical analysis also revealed that the urban population is significantly associated with GHG emissions mostly induced by industrial development (Itoh, 2009). Meanwhile, forest cover and population density among ASEAN-member countries statistically influence GHG emissions (de Sherbinin *et al.*, 2007; Stibig *et al.*, 2007). Likewise, the urban population shows a direct bearing with GHG emission while access to clean fuels, forest cover and population density inversely correlate with GHG emissions (Gallagher *et al.*, 2006; Choomkong *et al.*, 2017). The resulting regression model further confirms that forest cover substantially contributes to the minimizing effect of GHG emissions.

3.2 Sensitivity Analysis

To be able to determine which factor plays an important role on the total GHG emissions of ASEAN-member countries, sensitivity analysis for each was conducted by increasing a single criterion by a constant value of 60%, one at a time. It was found that the critical factor or the major determinant of total GHG emissions is the forest area (84% increase after adjustment).

4. Conclusion and Recommendation

The urban population has a direct relationship with GHG emission, which demands intervention to reduce population growth – family planning for instance. On the other hand, access to clean fuels, forest cover and population density have negative correlation with GHG emissions, which direct to strengthening programs related to these independent variables provided that most, if not all, which constitute the population density, will participate in the GHG emissions mitigation programs. Based on sensitivity analysis using the regression model, which can be regarded as practically significant, forest cover influenced the highest in the dynamic condition of GHG emissions. In conclusion, forest cover programs played as the major determinant of GHG emissions in the ASEAN-member countries, which are limited to the carrying capacity of the forest lands. This means that there is a need to strengthen and effectively implement forest cover programs to obtain a greater reduction of GHG emission. Other determinants should not be neglected as they also contribute to the increase of GHG emission level. Moreover, ASEAN governments have to formulate policies and programs that favor access to fuels and information on reforestation initiatives to lessen GHG emissions. Harmful human activities that contribute to GHG emissions in the urban area must also be taken into account.

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