Examining the Relationships between Energy Use, Fossil Fuel Consumption, Carbon Dioxide Emissions, and Economic Growth in Southeast Asia

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Abstract

This article examines the relationships between energy use, fossil fuel consumption, CO_2 emissions, and economic growth in three developing countries in Southeast Asia between 1988 and 2017. We found that the GDP per capita positively affects per capita CO_2 emissions, and that it has a positive relationship with per capita energy use. Additionally, we found that GDP per capita is negatively affected by fossil fuel consumption, whereas it is positively affected by per capita CO_2 emissions. Moreover, results show directional relationships running from per capita CO_2 emissions to GDP per capita, from GDP per capita to per capita energy use, from GDP per capita to fossil fuel consumption, and from GDP per capita to per capita CO_2 emissions. We found cointegration among the variables at the 1% critical value and two levels of cointegration among variables at the 5% critical value. Finally, we recommend policies to boost economic growth, reduce CO_2 emissions, and achieve sustainable development in Southeast Asia.

Keywords: energy use, fossil fuel consumption, carbon dioxide emission, economic growth, Southeast Asia

1. INTRODUCTION

Southeast Asia, where millions of people still live in extreme poverty and have to work in climate-sensitive sectors, is one of the most vulnerable regions in the world to the effects of climate change. The increase in CO_2 emissions in this region has been more rapid than in any other area worldwide in recent decades [1]. By 2017, the growth of energy demand in this region accounted for 8 percent globally [2]. By 2010, five countries-Indonesia, Malaysia, the Philippines, Thailand, and Vietnam-accounted for about 90 percent of greenhouse gas emissions in Southeast Asia [1]. Energy-related CO_2 emissions in the Association of Southeast Asian Nations (ASEAN) region are predicted to increase from 1.26 billion tons in 2014 to 3.14 billion tons in 2040 [3].

Some existing studies have examined the relationships between CO_2 emissions, energy consumption, and economic growth in Southeast Asia in recent years [4–7]. However, none examined the correlation between fossil fuel consumption and these variables. What is the relationship between per capita energy use, fossil fuel consumption, per capita CO_2 emissions, and economic

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growth in Southeast Asia? How do these variables correlate in the short and long run? This study was carried out to fill such gaps in existing studies. Particularly, this article examines the relationships between per capita energy use, fossil fuel consumption, per capita CO_2 emissions, and gross domestic product (GDP) per capita in three developing countries in Southeast Asia between 1988 and 2017 using a vector autoregressive (VAR) model. More importantly, affordable policies are recommended to the governments of these countries to reduce CO_2 emissions and achieve sustainable development.

The remainder of this paper is structured as follows. Section 2 presents the literature review. Section 3 discusses the methods. Section 4 presents results and discussion. Finally, section 5 discusses the conclusions and policy implications.

2. LITERATURE REVIEW

Numerous studies investigated the relationships between CO_2 emissions, energy consumption, and economic growth in the world. Saidi and Hammami (2015) [8] estimated the impact of economic growth and CO_2 emissions on energy consumption in 58 countries from 1990 to 2012. They found that CO_2 emissions are positively affected by energy consumption in the four global panels (all sample countries; Europe and North Asia region; Latin America and the Caribbean region; and the Middle East, North Africa, and Sub-Saharan Africa region), while economic growth has a positive relationship with energy consumption in only the Middle East, North Africa, and Sub-Saharan Africa region. Naminse and Zhuang (2018) [9] investigated the relationship between economic growth, energy intensity, and CO_2 emissions in China over the period 1952-2012, with the results indicating that coal consumption is a major contributor to the increasing CO_2 emissions. In addition, coal consumption has bidirectional relationships with both economic growth and CO_2 emissions. Likewise, Munir and Khan (2014) [10] evaluated the effect of fossil fuel energy consumption on CO_2 emissions in Pakistan between 1980 and 2010, and found that energy consumption negatively affects the CO_2 emissions, with the results supporting the inverted U-shaped environmental Kuznets curve. Industrial value added and trade openness have positive relationships with CO_2 emissions, whereas financial development negatively affects CO_2 emissions. Similarly, Spetan (2016) [11] assessed the causal relationships between renewable energy consumption, CO_2 emissions, labor, capital, and economic growth for Jordan from 1986 to 2012. Results showed a unidirectional causality running from renewable energy consumption to real GDP, a unidirectional causality running from renewable energy consumption to carbon dioxide, unidirectional causality running from real GDP to capital, and bidirectional causality is detected between capital and renewable energy consumption in the short run. Moreover, an increase in the usage of renewable energy can reduce CO_2 emissions.

Some existing studies examined the relationships between CO_2 emissions, energy consumption, and economic growth in Southeast Asia. Magazzino (2014) [4] examined the relationships between economic growth, CO_2 emissions, and energy use in six ASEAN countries between 1971 and 2007. Results showed that economic growth and energy use have a significant and positive relationship, and the error variances in CO_2 emissions are sensible to disturbances in both the GDP and CO_2 equations. Likewise, Nuryartono and Rifai (2017) [5] investigated the causality relationships between economic growth, energy consumption, and CO_2 emissions in four ASEAN countries for the period 1975-2013 using a vector error correction model. Results demonstrated that economic growth and energy consumption in Indonesia and Singapore are not correlated. In contrast, there is a direct causal relationship between two variables in Thailand and Malaysia. There is a directional relationship between economic growth and CO_2 emissions in Indonesia and Thailand, but there is no relationship in Malaysia and Singapore. Bimanatya and Widodo (2017) [6] assessed the relationships between fossil fuel consumption, CO_2 emissions, and economic growth between 1965 and 2012 in Indonesia. They found unidirectional Granger causalities running from coal consumption to economic growth and from economic growth to oil consumption in the short run. However, results showed a unidirectional Granger causality only running from oil consumption to economic growth and CO_2 emissions. Finally, Palanca-Tan et al. (2016) [7] investigated the relationships between CO_2 emissions, economic growth, energy consumption, trade openness, urbanization, and foreign direct investments (FDI) in the Philippines. They found that economic growth and CO_2 emissions have a significant positive linear relationship; CO_2 emissions are inelastic with respect to energy use in the short run, with its response becoming elastic in the long run; and CO_2 emissions have a positive elasticity with respect to FDI.

3. METHODS

3.1. Data and sources

A panel dataset for the relationship between per capita energy use, fossil fuel consumption, per capita CO_2 emissions and GDP per capita in three Southeast Asian countries is gathered from the World Development Indicators released by the World Bank. Specifically, a panel dataset is collected for the last three decades (1988-2017). Thus, a total of 90 observations is 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 multi-collinearity among variables; and (2) it may overcome constraints related to control individual or time heterogeneity faced by the cross-sectional data [12].

3.2. Data analysis

The VAR model is used to examine the relationship between per capita energy use, fossil fuel consumption, per capita CO_2 emissions, and GDP per capita in the Philippines, Thailand, and Vietnam between 1988 and 2017. The VAR model is chosen for this study because it interprets the endogenous variables solely by their own history, apart from deterministic regressors, thus incorporating non-statistical a priori information [13]. In addition, the VAR model is a popular method in economics and other sciences, because of its simplicity and flexibility for processing multivariate time series data [14].

The specification of a VAR model can be defined as follows [13]:

$$Y_{t} = A_1 Y_{t\text{-}1} + \cdots + A_p Y_{t\text{-}p} + \epsilon_t \tag{1}$$

where Y_t denotes a set of K endogenous variables such as per capita energy use, fossil fuel consumption, per capita CO_2 emissions, and GDP per capita; A_i represents (K x K) coefficient matrices for i = 1,· · ·, p; and ϵ_t is a K-dimensional process with $E(\epsilon_t) = 0$.

An important characteristic of the VAR model is stability, thus generating stationary time series with time invariant means, variances, and covariance structure, given sufficient starting values. The stability of an empirical VAR model can be analyzed by considering the companion form and computing the eigenvalues of the coefficient matrix. A VAR model may be specified as follows [13]:

$$\epsilon_t = A\epsilon_{t\text{-}1} + V_t \tag{2}$$

where ϵ_t denotes the dimension of the stacked vector, A is the dimension of the matrix (K_p x K_p), and V_t represents (KP x 1).

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

Variable definitions	Unit
Per capita energy use	kg of oil
Fossil fuel consumption	%
Per capita CO_2 emissions	metric tonne
GDP per capita	US$

In this study, the procedure of a VAR model includes six steps: (1) performing the unit root test, (2) determining lag length, (3) estimating the VAR model, (4) testing the Granger causality, (5) checking the stability of eigenvalues, and (6) implementing the Johansen test for cointegration. The VAR model is estimated by the Stata MP 14.2 software. Table 1 lists the covariates of the VAR model.

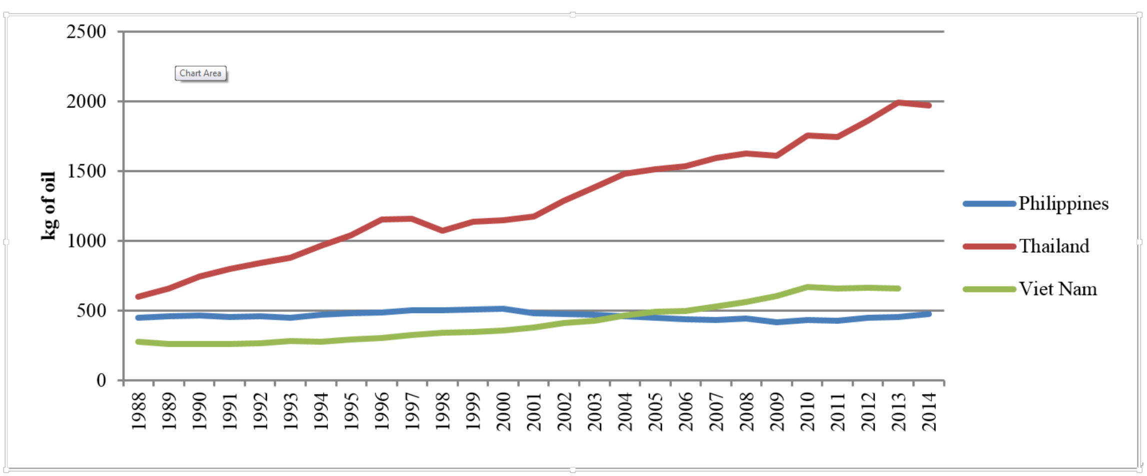
4. RESULTS AND DISCUSSION

4.1. Energy use, fossil fuel consumption, carbon dioxide emissions and economic growth in Southeast Asia: An overview

Per capita energy consumption of Thailand significantly increased over the period 1988-2014. By 2014, its per capita energy consumption increased by a factor of 3.3 compared to 1988. Per capita energy consumption of Vietnam grew by a factor of 2.3 from 273 kg of oil/capita in 1988 to 655 kg of oil/capita in 2013. However, per capita energy consumption of the Philippines nearly remained stable at under 500 kg of oil in the same period (Figure 1).

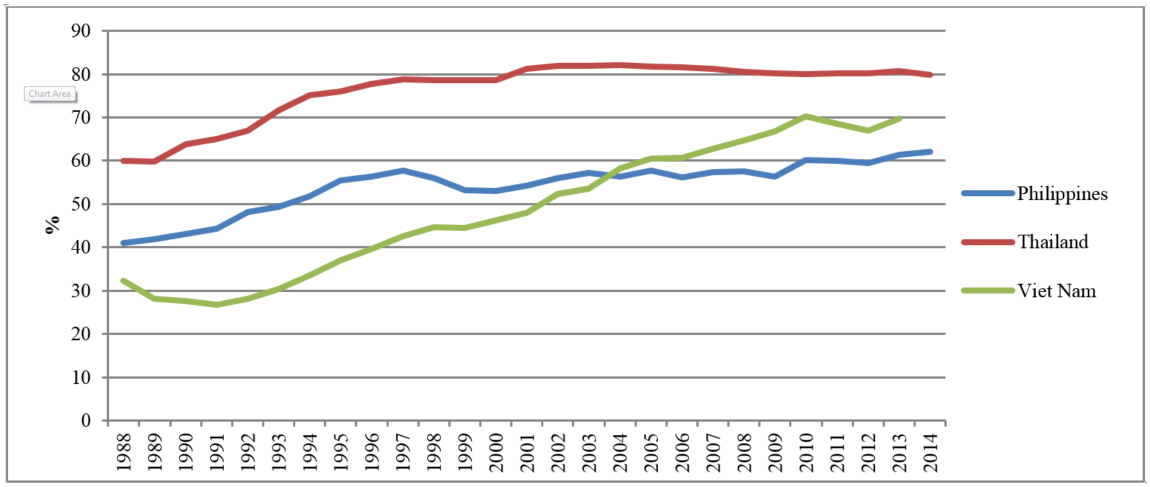
Fossil fuel consumption of the three countries tended to grow from 1988 to 2014. By 2014, the rate of fossil fuel consumption in Thailand reached nearly 80 percent, while that of the Philippines accounted for 62 percent. Fossil fuel consumption in Vietnam has more than doubled from about 32 percent in 1988 to nearly 70 percent in 2013. These results imply a heavy reliance of the three countries on fossil fuel (Figure 2).

Figure 1: *Per capita energy use of selected countries in Southeast Asia (1988-2014)*



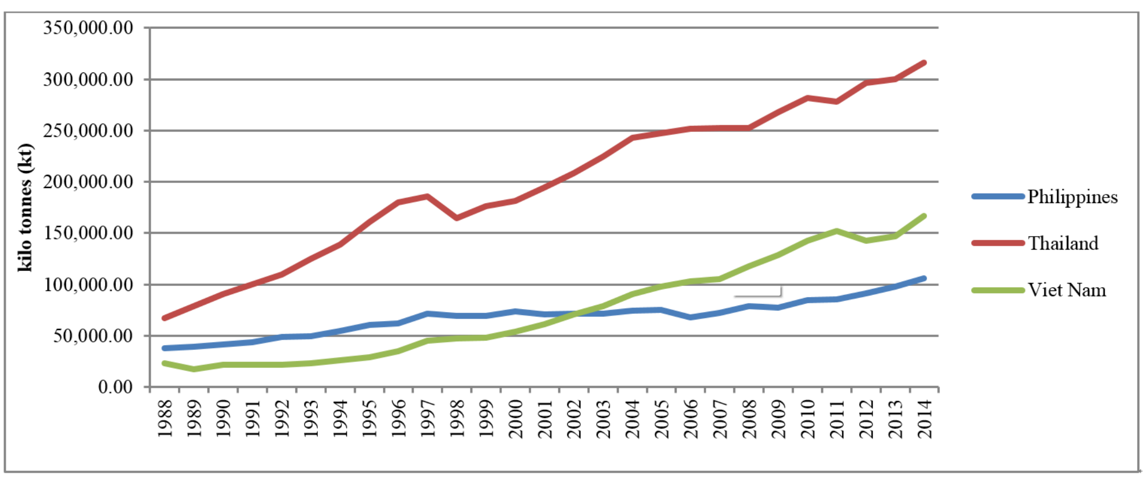
Source: [15]

Figure 2: *Fossil fuel consumption of selected countries in Southeast Asia (1988-2014)*



Source: [16]

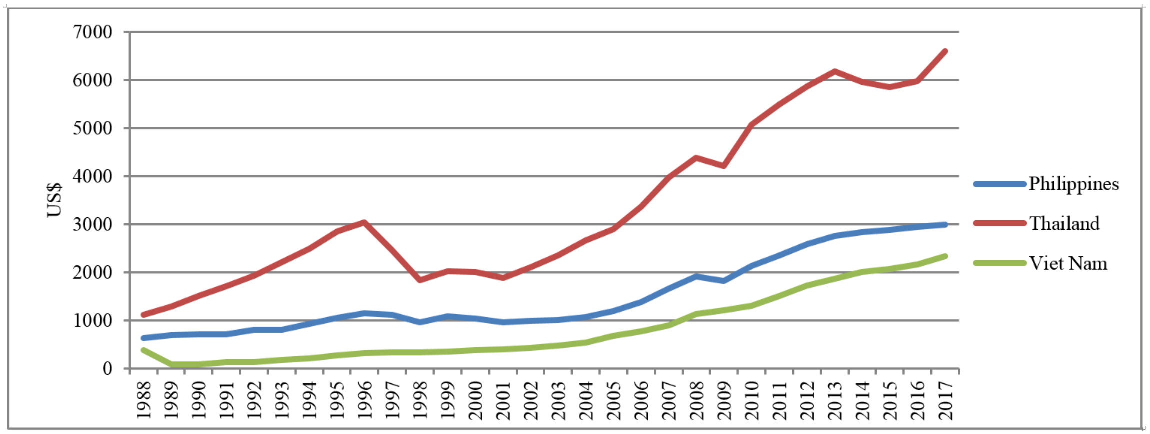
Figure 3: *Per capita carbon dioxide emissions of selected countries in Southeast Asia (1988-2014)*



Source: [17]

Per capita CO_2 emissions in the three countries tended to increase for 27 years (1988-2014). In this period, per capita CO_2 emissions in Thailand were the highest, as they increased by a factor of 4.7 from about 67,000 kt in 1988 to about 316,000 kt in 2014. Per capita CO_2 emissions of Vietnam rose by a factor of 7.1 from about 23,000 kt in 1988 to about 166,000 kt in 2014, while per capita CO_2 emissions of the Philippines increased by a factor of 2.8 in the same period (Figure 3). The increase in per capita CO_2 emissions in the three countries reflects a rapid expansion of industrialization and urbanization along with degradation of the environment.

Figure 4: *GDP per capita of selected countries in Southeast Asia (1988-2014)*



Source: [18]

GDP per capita of the three countries rapidly increased for three decades (1988-2014). Thailand became the leading country, when its GDP per capita reached nearly US$ 6,600 in 2017, followed by the Philippines (nearly US$ 3,000), and Vietnam (about US$ 2,300). From 1988 to 2014, GDP per capita of the Philippines increased by a factor of 4.6, while the growth of Vietnam increased by a factor of 6 (Figure 4). These results reflect the achievement of these countries in fostering economic growth in recent decades.

Table 2: *Characteristics of energy use, fossil fuel consumption, CO_2 emissions and economic growth of selected countries in Southeast Asia*

Variable	Mean	SD	Min	Max
Per capita energy use	644.51	500.18	0	1991.6
Fossil fuel consumption	53.24	24.02	0	82.1
Per capita CO_2 emissions	1.45	1.27	0	4.6
GDP per capita	1,905.74	1584.79	94.3	6593.8

Source: Author, 2019

Per capita energy use and fossil fuel consumption of the Philippines, Thailand, and Vietnam account for about 644 kg of oil and 53 percent, respectively, on average. The average per capita CO_2 emissions and GDP per capita of the three countries account for 1.45 metric tons and about US$ 1,900, respectively (Table 2).

4.2. The relationships between energy use, fossil fuel consumption, carbon dioxide emissions, and economic growth in Southeast Asia

4.2.1 Implementation of the unit root test

The unit root test is carried out to check the stationarity of the time series variables $_2$. In this study, the Augmented Dickey-Fuller (ADF) test is used to examine the stationarity of per capita energy use, fossil fuel consumption, per capita CO_2 emissions, and GDP per capita in the three Southeast Asian countries with the following hypotheses: Null hypothesis (H_0): The variables contain a unit root. Alternative hypothesis (H_a): The variables do not contain a unit root.

Table 3: *The ADF test for the unit root*

Variables	Level	1st difference	2nd difference
LnPer capita energy use	T-statistic: -3.18 P-value: 0.02 Critical values: 1% level: -3.52 5% level: -2.89 10% level: -2.58	T-statistic: -3.56 P-value: 0.00 Critical values: 1% level: -3.52 5% level: -2.90 10% level: -2.58	T-statistic: -4.15 P-value: 0.00 Critical values: 1% level: -3.52 5% level: -2.90 10% level: -2.58
LnFossil fuel consumption	T-statistic: -3.20 P-value: 0.01 Critical values: 1% level: -3.52 5% level: -2.89 10% level: -2.58	T-statistic: -3.54 P-value: 0.00 Critical values: 1% level: -3.52 5% level: -2.90 10% level: -2.58	T-statistic: -4.14 P-value: 0.00 Critical values: 1% level: -3.52 5% level: -2.90 10% level: -2.58
LnPer capita CO_2 emissions	T-statistic: -1.59 P-value: 0.48 Critical values: 1% level: -3.52 5% level: -2.89 10% level: -2.58	T-statistic: -1.71 P-value: 0.42 Critical values: 1% level: -3.52 5% level: -2.90 10% level: -2.58	T-statistic: -1.72 P-value: 0.41 Critical values: 1% level: -3.52 5% level: -2.90 10% level: -2.58
LnGDP per capita	T-statistic: -1.82 P-value: 0.36 Critical values: 1% level: -3.52 5% level: -2.89 10% level: -2.58	T-statistic: -2.66 P-value: 0.07 Critical values: 1% level: -3.52 5% level: -2.90 10% level: -2.58	T-statistic: -2.31 P-value: 0.16 Critical values: 1% level: -3.52 5% level: -2.90 10% level: -2.58

Source: Author's calculation, 2019

Results show that we cannot reject the null hypothesis because the P-values of all variables are greater than the critical values at the 1%, 5%, and 10% levels, thus implying that variables exhibit a unit root (Table 3).

4.2.2 Determination of the lag length

The purpose of this step is to identify the optimal lag for the VAR model. If the lag is used too little, then the residual of the regression will not show the white noise process; thus, the actual error could not be accurately estimated by the model [14].

Table 4: *Selection of the lag length*

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-286.78				0.010	6.762	6.808	6.876
1	5.12	583.82	16	0.000	0.000	0.345	0.575	0.916*
2	26.24	42.24	16	0.000	0.000	0.226	0.640	1.254
3	40.75	29.02	16	0.024	0.000	0.261	0.858	1.745
4	101.03	120.56*	16	0.000	5.6E-06*	-0.768*	0.012*	1.172

Endogenous: LnPer capita energy use LnFossil fuel consumption LnPer capita CO_2 emissions LnGDP per capita
Exogenous: Constant
Number of observations = 86

Source: Author's calculation, 2019

Note: *denotes lag order selected by the criterion; LL means log likelihood values; LR represents sequential modified LR test statistics; FPE denotes final prediction error; AIC means Akaike information criterion; HQIC represents Hannan-Quinn information criterion; and SBIC means Schwarz's Bayesian information criterion.

As seen in Table 4, results suggest that the optimal lag length in this case is four lags because this value is recommended by the FPE, AIC, and HQIC indicators, while one lag is recommended by only SBIC. Therefore, four lags (the number of lag is equal to 4) is chosen to run the VAR model in the next step.

4.2.3 Estimation of the VAR model

We found that GDP per capita positively affects per capita CO_2 emissions, thus implying that economic growth in addition to industrialization and urbanization are the main drivers behind the increase in CO_2 emissions in the Philippines, Thailand, and Vietnam. We also found that per capita energy use has a positive relationship with GDP per capita reflecting that economic growth of the three countries still heavily depends on energy consumption. Additionally, Fossil fuel consumption was found to negatively affect GDP per capita, thus suggesting that the expansion in fossil fuel consumption such as coal, oil, and natural gas slowdowns the economy. Therefore, due to overwhelming exploitation of fossil fuel in recent decades, fossil fuel should be gradually substituted by alternative energy sources such as solar, wind, and tidal power to promote economic development and protect the environment. Finally, per capita CO_2 emissions were found to positively affect GDP per capita (Table 5).

Table 5: *Estimation of the VAR model*

Variables	Coefficient	Standard error	t	P-value
LnPer capita energy use				
LnPer capita energy use				
L1	2.249	2.31	0.97	0.335
L2	-4.032	3.21	-1.25	0.215
L3	0.893	3.30	0.27	0.788
L4	1.555	2.34	0.66	0.510
LnFossil fuel consumption				
L1	-2.089	3.55	-0.59	0.559
L2	6.068	4.97	1.22	0.226
L3	-2.015	5.09	-0.40	0.693
L4	-2.069	3.56	-0.58	0.563
LnPer capita CO_2 emissions				
L1	0.507	0.92	0.55	0.586
L2	-1.259	1.20	-1.05	0.298
L3	-0.094	1.19	-0.08	0.937
L4	0.396	0.94	0.42	0.677
LnGDP per capita				
L1	0.507	0.92	0.55	0.586
L2	-1.259	1.20	-1.05	0.298
L3	-0.094	1.19	-0.08	0.937
L4	0.396	0.94	0.42	0.677
Constant	5.340	3.50	1.52	0.132
LnFossil fuel consumption				
LnPer capita energy use				
L1	0.820	1.45	0.56	0.575
L2	-2.490	2.02	-1.23	0.223
L3	0.625	2.07	0.30	0.764

L4	0.957	1.47	0.65	0.519
LnFossil fuel consumption				
L1	-0.373	2.24	-0.17	0.868
L2	3.745	3.12	1.20	0.235
L3	-1.368	3.20	-0.43	0.671
L4	-1.257	2.24	-0.56	0.577
LnPer capita CO_2 emissions				
L1	-0.273	0.90	-0.30	0.764
L2	1.651	1.13	1.46	0.150
L3	-1.469	1.18	-1.24	0.220
L4	0.446	1.01	0.44	0.660
LnGDP per capita				
L1	0.344	0.58	0.59	0.557
L2	-0.827	0.75	-1.09	0.277
L3	-0.033	0.75	-0.04	0.965
L4	0.242	0.59	0.41	0.686
Constant	3.271	2.20	1.48	0.143
LnPer capita CO_2 emissions				
LnPer capita energy use				
L1	0.033	0.31	0.10	0.917
L2	-0.285	0.43	-0.65	0.518
L3	0.444	0.45	0.99	0.328
L4	-0.362	0.32	-1.13	0.262
LnFossil fuel consumption				
L1	0.032	0.48	0.07	0.947
L2	0.364	0.67	0.54	0.593
L3	-0.693	0.69	-1.00	0.322
L4	0.532	0.48	1.09	0.278
LnPer capita CO_2 emissions				
L1	0.665***	0.19	3.38	0.001
L2	0.366	0.24	1.49	0.140
L3	0.293	0.25	1.14	0.257
L4	-0.296	0.21	-1.35	0.180
LnGDP per capita				
L1	0.307**	0.12	2.42	0.018
L2	-0.436***	0.16	-2.66	0.010
L3	0.116	0.16	0.72	0.476
L4	-0.049	0.12	-0.38	0.705
Constant	0.566	0.47	1.18	0.241
LnGDP per capita				
LnPer capita energy use				
L1	-0.227	0.27	-0.81	0.419
L2	0.330	0.38	0.85	0.398
L3	1.020**	0.39	2.56	0.013
L4	-1.196***	0.28	-4.23	0.000
LnFossil fuel consumption				
L1	0.385	0.42	0.90	0.372
L2	-0.534	0.59	-0.89	0.376

L3	-1.423**	0.61	-2.32	0.023
L4	1.704***	0.42	3.97	0.000
LnPer capita CO_2 emissions				
L1	-0.022	0.17	-0.13	0.898
L2	-0.236	0.21	-1.09	0.279
L3	0.805***	0.22	3.55	0.001
L4	-0.507**	0.19	-2.62	0.011
LnGDP per capita				
L1	1.386***	0.11	12.41	0.000
L2	-0.576***	0.14	-3.98	0.000
L3	0.288**	0.14	2.00	0.049
L4	-0.186	0.11	-1.63	0.107
Constant	0.575	0.42	1.36	0.178

Notes: L1, L2, L3, L4 mean lag 1, lag 2, lag 3, and lag 4, respectively; *** and ** denote statistical significance at 1% and 5%, respectively

4.2.4 Testing the Granger causality

The purpose of this step is to assess the predictive capacity of a single variable on other variables [19]. In this study, hypotheses are tested as follows:

Testing the relationship between per capita energy use and other variables: Null hypothesis (H_0): Per capita energy use does not cause fossil fuel consumption, per capita CO_2 emission, and GDP per capita. Alternative hypothesis (H_a): Per capita energy use causes fossil fuel consumption, per capita CO_2 emission, and GDP per capita.

Testing the relationship between fossil fuel consumption and other variables: Null hypothesis (H_0): Fossil fuel consumption does not cause per capita energy use, per CO_2 emission, and GDP per capita. Alternative hypothesis (H_a): Fossil fuel consumption causes per capita energy use, per capita CO_2 emission, and GDP per capita.

Testing the relationship between per capita CO_2 emission and other variables: Null hypothesis (H_0): Per capita CO_2 emission does not cause per capita energy use, fossil fuel consumption, and GDP per capita. Alternative hypothesis (H_a): Per capita CO_2 emission causes per capita energy use, fossil fuel consumption and GDP per capita.

We found directional relationships from per capita CO_2 emission to GDP per capita; from GDP per capita to per capita energy use; from GDP per capita to fossil fuel consumption; and from GDP per capita to per capita CO_2 emission (Table 6).

4.2.5 Examination of eigenvalue stability

The goal of this step is to examine stability of the eigenvalues in the VAR model. All the eigenvalues lie inside the unit circle, and we can conclude that the VAR model satisfies the stability condition (Figure 5).

4.2.6 Performance of the Johansen co-integration test

The Johansen cointegration test is performed to examine the long run relationship among variables. If variables are cointegrated, it suggests that there is a long-term relationship among variables [19].

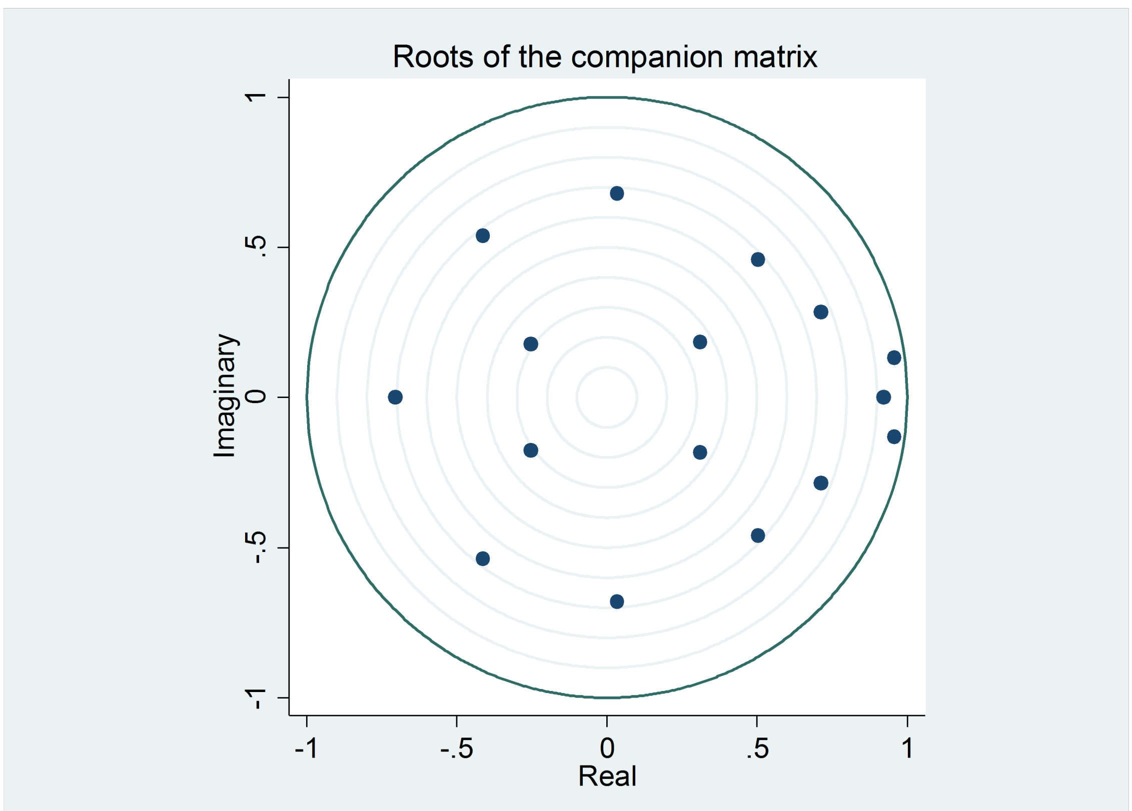
The hypothesis to be tested is identified as follows: Null hypothesis (H_0): There is no cointegration among variables. Alternative hypothesis (H_a): There is cointegration among variables.

Table 6: *Results of the Granger causality Wald test*

Directional relationship	Probability	Conclusion
Per capita energy use → Fossil fuel consumption	0.70 >0.05	Accept H_0
Per capita energy use → Per capita CO_2 emission	0.45 >0.05	Accept H_0
Per capita energy use → GDP per capita	0.51 >0.05	Accept H_0
Fossil fuel consumption → Per capita energy use	0.68 >0.05	Accept H_0
Fossil fuel consumption → Per capita CO_2 emission	0.49 >0.05	Accept H_0
Fossil fuel consumption → GDP per capita	0.52 >0.05	Accept H_0
Per capita CO_2 emission → Per capita energy use	0.51 >0.05	Accept H_0
Per capita CO_2 emission → Fossil fuel consumption	0.60 >0.05	Accept H_0
Per capita CO_2 emission → GDP per capita	0.04 <0.05	Reject H_0
GDP per capita → Per capita energy use	0.00 <0.05	Reject H_0
GDP per capita → Fossil fuel consumption	0.00 <0.05	Reject H_0
GDP per capita → Per capita CO2 emission	0.01 <0.05	Reject H_0

Source: Author's calculation, 2019

Figure 5: *Checking eigenvalue stability*



Source: Author's calculation, 2019

In this study, the Johansen cointegration test is performed using the trace test. The trace test is a likelihood-ratio-type test, which operates under different assumptions in the deterministic part of the data generation process [20].

Table 7: *Results of trace statistic in the Johansen co-integration test*

Maximum rank	LL	Eigenvalue	Trace statistic	5% critical value	1% critical value
0	1.26		57.93	47.21	54.46
1	15.33	0.27	29.79*1	29.68	35.65
2	22.90	0.15	14.65*5	15.41	20.04
3	26.99	0.08	6.47	3.76	6.65
4	30.23	0.07			

Source: Author's calculation, 2019
Notes: *1 and *5 denote the number of co-integrations (ranks) chosen to accept the null hypothesis at 1% and 5% critical values, respectively

As seen in Table 7, we cannot reject the null hypothesis in rank one (cointegration) and rank two (two levels of cointegration) because the trace statistic is less than the critical values at the 1% and 5% levels (29.79 < 35.65 and 14.65 < 15.41), thus implying that there is cointegration among variables at the 1% critical value and there are two levels of cointegration among variables at the 5% critical value.

4.3. Discussion

We found that GDP per capita positively affects per capita CO_2 emissions, suggesting that the growth of GDP has caused an increase in CO_2 emissions in recent years. We also found that per capita energy use has a positive relationship with GDP per capita, thus implying that energy use is a positive contributor to economic growth of the three countries, whereas fossil fuel consumption negatively affect GDP per capita. Due to overwhelming exploitation of fossil fuel in recent decades, the use of alternative energy sources such as solar, wind, and tidal power should be encouraged in the Philippines, Thailand, and Vietnam to foster economic growth and reduce environmental pollution. Additionally, per capita CO_2 emissions are found to positively affect GDP per capita, thus implying that economic growth of the three Southeast Asian countries still relies on the manufacturing sector that releases a huge amount of CO_2. Results show that there are directional relationships running from per capita CO_2 emission to GDP per capita; from GDP per capita to per capita energy use; from GDP per capita to fossil fuel consumption; and from GDP per capita to per capita CO_2 emission. We found that there is a cointegration among variables at the 1% critical value and there are two levels of cointegration among variables at the 5% critical value.

Unlike Bimanatya and Widodo (2017) [6], who claimed that there is a directional causality between economic growth and oil consumption in Indonesia, we found that there is a directional causality running from GDP per capita to fossil fuel consumption, and fossil fuel consumption negatively affects GDP per capita in the Philippines, Thailand, and Vietnam. Therefore, the use of fossil fuel consumption should be reduced and replaced with alternative energy sources that may reinvigorate the economy and protect the environment. Finally, Palanca-Tan et al. (2016) [7] found that economic growth has a positive relationship with CO_2 emissions in the Philippines, while our study concluded that economic growth positively impacts CO_2 emissions in lag 1, but it has a negative relationship with CO_2 emissions in lag 2, thus implying that the three countries tend to develop their economies along with environmental protection.

5. CONCLUSION AND POLICY IMPLICATIONS

This article assesses the relationships between per capita energy use, fossil fuel consumption, per capita CO_2 emissions, and GDP per capita of three developing countries in Southeast Asia between 1988 and 2017. We found that GDP per capita has a positive relationship with CO_2 emissions, while per capita energy use positively affects GDP per capita. Fossil fuel consumption is found to negatively affect GDP per capita, while per capita CO_2 emissions have a positive relationship with GDP per capita.

We recommend policies to reduce CO_2 emissions and achieve sustainable development in Southeast Asia. First, economic growth should be encouraged along with protecting the environment because it increases CO_2 emissions. We propose a reduction in fuel and CO_2 emissions by 16 percent applied to light-duty vehicles and up to 26 percent applied to both light-duty and high-duty vehicles in Southeast Asia. For example, 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 [21]. Second, fossil fuel consumption should be controlled, since an increase in fossil fuel consumption leads to a decrease in GDPs of the Philippines, Thailand, and Vietnam. Thus, renewable power, smart and efficient power grids, energy efficient transport, and advanced energy technology are feasible solutions, since they assist in reducing the dependence of the three countries on fossil fuels such as coal, oil, and natural gas. Third, advantages in exporting greenhouse gas should be efficiently exploited by Southeast Asian countries because the profit of this region from the global carbon market is predicted to increase from 32 percent to 53 percent between 2010 and 2050. Finally, cooperation among countries in the region should be facilitated by reducing land-use emissions and replacing carbon-intensive fuels with cleaner alternatives [1].

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