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RESEARCH ARTICLE

The determinants of electricity consumption for ASEAN countries

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Abstract

This study investigates causal relationships between electricity consumption (EC) of seven ASEAN countries with the chosen determinants such as gross domestic product (GDP), exports (EXP) and carbon dioxide emission (CO2) by using vector autoregressive (VAR) framework and vector error correction (VEC) model for the period from 1980-2015. The findings show that the effect of the chosen determinants is different among the seven countries. Within the sample period, by utilizing Granger causality test, out of the seven countries, only four revealed either unidirectional or bidirectional causality running from EC to the three determinants, GDP, EXP and CO2. Whereas, thru forecast error variance decomposition (FEVD), the forecasting beyond the sample period uncovered there is a possibility that a shock to EC will also spread to GDP, EXP and CO2. Therefore, the present study suggests that ASEAN should take note in designing their electricity policy, since electricity affect and in the same time is affected by other factors. In addition, ASEAN also should find solutions on how to control CO2 emission through EC.

***Keywords*:** Electricity consumption, VEC model, Granger causality, forecast error variance decomposition

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INTRODUCTION

The U.S. Information Administration stated that electricity is the world's fastest-growing form of end-use energy consumption, where the world net electricity generation increases by 69 percent from 21.6 trillion kWh in 2012 to 25.8 trillion kWh by 2020. According to National Energy Education Development (NEED) Project, the U.S. Department of Energy divides energy users into different categories, which is residential, commercial, industrial, electric power, and transportation. They also stated that electricity is a secondary source of energy, where other energy sources are used to generate electricity. It also means that electricity is neither renewable or non-renewable energy. Electricity demand among the non-Organization for Economic Cooperation and Development (non-OECD) economies continues to increase even though world gross domestic product (GDP) growth slows (U.S. Energy Information Administration). Non-OECD countries are divided into five regional subgroups based on International Energy Outlook 2016. The five regional subgroups are non-OECD Europe and Eurasia, non-OECD Asia, non-OECD Middle East, non-OECD Africa and non-OECD Americas. ASEAN belongs to the group of non-OECD Asia countries.

The Association of Southeast Asian Nations (ASEAN) was established on 8 August 1967 in Bangkok, Thailand. ASEAN currently consists of ten member nations of Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand and Vietnam. ASEAN is one of the most active and fastest growing economic regions in the world (ASEAN Center for Energy). According to ASEAN Plan of Action for Energy Cooperation 2016, ASEAN knows the critical role of an efficient, reliable and resilient electricity infrastructure in encouraging regional economic growth and development. ASEAN is home to 616 million people and is continuing to experience robust population growth and quick urbanization (International Energy Agency).

Based on the report by the International Energy Agency, it stated that energy demand in ASEAN correlates with economic activity. It also mentioned that the total final energy consumption grows an average two percent per year, driven by ongoing urbanization and increament in economic activities. In addition, ASEAN Plan of Action for Energy Cooperation in 2016 stated that electricity demand in ASEAN is expected to grow by five percent to six percent per year from year 2016 until 2020. As the ASEAN economy continues to progress, their carbon dioxide emissions have also become crucial in the economic growth and the quality of the environment. Regarding the issue of carbon dioxide emissions, the idea of a 'low carbon city' and a 'green economy' has been increasingly popular among developing nations in ASEAN.

Therefore, the aim of the present study is to examine the determinants of the ASEAN electricity consumption based on causal relationships within and outside the sample period. In order to accomplish this aim, the VAR framework is employed. ASEAN country such as Brunei and Vietnam, which are not often studied by other researchers are included in the present study. The seven ASEAN countries that are covered in the present study will provide information to policymakers and related institution to make comparison and strengthen their economic system.

The rest of this paper consists of another four sections. Section 2 elaborates about the literature reviews. Section 3 provides information related to variables used and the methodology employed. Section 4 discusses the analysis and findings. Lastly, Section 5 concludes the results.

SUMMARY OF PREVIOUS STUDIES

Studies on the determinants of electricity consumption (EC) have been published since 1970s. Most of the studies were focusing on the bivariate relationship between EC and gross domestic product (GDP) or gross national product (GNP) as a proxy of economic growth. One

of the earliest study was by Kraft and Kraft [1] where they found evidence of a unidirectional causal relationship between the GNP to EC in the United State. In 2004, Jumbe [2] studied the cointegration and causality between EC and GDP in Malawi. He discovered evidence from Granger-causality results that there was bidirectional causality between EC and GDP. On the other hand, Shiu and Lam [3] used vector error correction model (VECM) over the period 1971 till 2000 to attain unidirectional Granger causality from EC to GDP in China. Meanwhile, Fatai et al. [4] obtained evidence of unidirectional relationship from GDP to EC for Indonesia and bidirectional Granger causality for Thailand and Philippines. Yoo [5] studied the causality between EC and GDP in Korea using Granger causality test and found that there exists bidirectional causality between electricity consumption and GDP.

Later, Yoo [6] employed Hsiao version of the Granger causality method to study the causal relationship between EC and economic growth in the ASEAN countries. He uncovered a unidirectional relationship from GDP to EC for Indonesia and Thailand and bidirectional relationship between EC and GDP for Malaysia and Singapore. This finding is also supported by Yoo and Kim [7] where they revealed unidirectional causality running from GDP to EC for Indonesia. In contrast, Chen et al. [8] disclosed unidirectional long-run causality from EC to GDP for Indonesia and unidirectional short-run causality from GDP to EC for Malaysia, Singapore and Philippines. Meanwhile, Squalli [9] performed a study for Organization of the Petroleum Exporting Countries (OPEC) members. The finding showed unidirectional relationships from EC to GDP for Fiji and other six OPEC member countries; in which includes Algeria, Indonesia, Iraq, Kuwait, Libya and Venezuela. In addition, the findings show bidirectional relationship for Iran, Nigeria, Qatar, Saudi Arabia and UAE. He concluded that economics in Indonesia, Nigeria, Iran, Qatar and Venezuela depend on electricity.

Meanwhile, study by Lee and Chang [10] using panel data analysis depicted a causal relationship between EC and GDP for 16 Asian countries within year 1971 until 2002. Besides, Narayan et al. [11] also discovered significant positive impact from EC to GDP for all G7 countries except for USA using structural vector autoregressive model. However, Tang [12] reexamined the relationship between EC and GNP as an economic growth proxy rather than GDP in Malaysia for 31 years by using the VAR models. His findings showed long-run bidirectional relationship and concluded that electric consumption was an important factor for Malaysia's economic development since Malaysia is an energy dependent country.

Consequently, by utilizing the Pedroni panel cointegration to investigate the long-run relationship between EC and economic growth for 15 transition countries, Acaravci and Ozturk [13] observed no long-term relationship between EC and GDP. In other words, they stated that the EC related policies have no effect on the level of real output in the long run in those countries. In other case, Chandaran et al. [14] examined the electricity consumption and growth nexus in Malaysia for 32 years using autoregressive distributed lag (ARDL) model. The results denoted long-run causality unidirectional from EC to GDP in Malaysia and suggested that Malaysia is an energy dependent country. Later, Apergis and Payne [15] analyzed the relationship between EC and economic growth for 88 countries. The results of their study showed that there was bidirectional causality between EC and economic growth in both short-run and long-run for high income country panel.

Then, Ozturk and Acaravci [16] continued their investigation but now focusing on 11 Middle East and North Africa (MENA) countries. They attained unidirectional causal from EC to GDP either short-run or long-run for five MENA countries. Xiao et al. [17] studied the relationship between EC and economic growth in China using the same VECM method as Ozturk and Acaravci [16] and found the unidirectional causality from EC to GDP. They indicated that electric power supply can become the restricting factor to economic growth and the shortage of electric supply can obstruct economic growth in China. Kantar and Keskin [18] conducted a study in 30 Asian countries for 37 years using the hierarchical structure methods to examine relationship between energy consumption and economic growth. They found a strong relationship between energy consumption and economic growth for all income groups. Meanwhile, Tang and Tan [19] study found bidirectional causality between EC and economic growth both in short-run and long-run in Malaysia.

In a mean time, Ganjouhaghighi [20] explored the relationship between EC and GDP in Iran by using the VAR model and revealed unidirectional causality from GDP to EC. While the report by Pradhan and Badir [21] of the panel VAR model showed unidirectional causal running from EC to GDP for ASEAN countries. Furuoka [22] investigated the causal linkages between EC and economic development in 12 Asian countries for the year 1971 till 2011. The finding exposed the unidirectional causality from economic development to EC for East Asian countries and opposite causal relationship for South Asian countries. Dogan [23], Iyke [24] and Kumar et al. [25] studies found the same result of unidirectional causal running from EC to GDP in Turkey, Nigeria and Gibraltar with different periods of time. Recently, Salahuddin and Alam [26] investigated the short-run and long-run effect of information communication technology used and economic growth on EC by using the OECD panel data of year 1985 till 2012. Their study found unidirectional causal relationship from EC to economic growth and suggested that the OECD countries need to track policies that will improve electricity generation efficiency that will have no adverse effect on their economic growth. While, Kumari and Sharma [27] discovered unidirectional causality running from GDP to EC in India during year 1974 to 2014.

Despite most researchers are focusing on the bivariate relationship between EC and GDP, there are also some researchers that considered other determinants such as exports (EXP), carbon dioxide emissions (CO2) and urbanization in their analysis. Such as, Narayan and Smyth [28] investigated the causal relationship between EC, EXP and GDP for a panel data of Middle Eastern countries. The finding from the Granger causality test showed that there is short-run unidirectional causality from EC to GDP and from GDP to exports. Moreover, there was long-run Granger causality link running from EXP and EC to GDP and from EXP and GDP to EC. Next, Lean and Smyth [29] examined causal relationship between CO2 emissions, EC and real output in ASEAN using the panel VECM for the period of 1980 until 2006. The results from panel Granger causality showed evidence of short-run Granger causality from CO2 emissions to EC and also a long-run unidirectional panel Granger causality from EC and CO2 emissions to GDP. The unidirectional results implied that ASEAN-5 were energy dependent economies. Then, Shahbaz et al. [30] explored relationship between GDP, EC, urbanization and environmental degradation in UAE over the period 1975 till 2011 by using the VECM Granger causality. The findings showed that there was long-run bidirectional causality between EC and CO2 emissions and bidirectional causality between export and economic growth. While, Salahuddin et al. [31] found unidirectional causal relationship from EC to CO2 emissions in Gulf Cooperation Council countries by using panel data of year 1980 till 2012.

As summary, previous studies showed that the main determinant used was GDP as applied in either single or cross-country studies. Moreover, there are mixed findings concerning the causal link between EC and GDP across different countries. Depending on the methodology utilized, period of study, and countries, the focal of causality between EC and some economic determinants has remained empirically difficult to understand and controversial. This present study consists of ASEAN countries that are rarely studied in previous research like in Azam et al. [32] which they used Brunei and Vietnam. Moreover, there are no other studies in which have examined the causal relationship between EC, GDP, EXP and CO2 emissions within one multivariate model. Hence, this is a different point of view that this study addresses and also efficiently combines the literatures on the EC and GDP nexus, the EC and EXP nexus and the EC and CO2 emissions nexus.

DATA AND METHODS

Data

This study focuses on seven selected countries namely Brunei, Indonesia, Malaysia, Philippines, Singapore, Thailand and Vietnam.

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The rest of ASEAN members are excluded due to unavailability of data for the period of the study. Annuals time series data of electricity consumption (EC), gross domestic product (GDP), exports (EXP) and carbon dioxide emission (CO2) for 36 years from 1980 to 2015 are used. The data for all variables except CO2 are taken from The World Bank Indicator, meanwhile for CO2, are taken from Global Carbon Atlas. All the data are standardized by converting into natural logarithm before further analysis. Table 1 shows the description and definition of each variable.

Table 1 Variables Description

No.	Variable Name	Description	Definition
1.	EC	Electricity consumption (kWh per capita)	Electric power consumption measures the production of power plants and it is a combination of heat and power plants less transmission, distribution, and transformation losses and own use by heat and power plants.
2.	GDP	GDP per capita (current US$)	Gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for reduction and degradation of natural resources.
3.	Exports	Export value index (2000 = 100)	Export values are the current value of exports (f.o.b.) converted to U.S. dollars and expressed as a percentage of the average for the base period (2000). United Nations Conference on Trade and Development's (UNCTAD) export value indexes are reported for most economies.
4.	CO2	CO2 emissions (metric tons per capita)	Carbon dioxide emissions are those steaming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring.

Estimation strategy

Before any modelling are done by using vector auto-regression framework, all the variables need to be checked for stationarity. A series is said to be stationary if its mean and variance are constant over time and auto-covariance remain constant at various lags. Stationary is an important in modelling time series data in order to avoid spurious results. Gujarati and Porter [33] stated that unit root test has become widely popular over the past several years to test stationarity. However, Brooks [34] argued that it is better to jointly use of stationary and unit root tests for stationary testing which is known as confirmatory data analysis. Thus, the present study will apply the ADF test by Dickey and Fuller [35] with the null hypothesis of unit root while the KPSS test by Kwiatkowski et al. [36] with the null hypothesis of stationary.

Next, Johansen-Juselius (JJ) cointegration test by Johansen and Juselius [37] are applied for long run inference among all the series. Johansen [38] defined two test statistics for cointegration under their method which are the Trace Test (λ_{trace}) and the Maximum Eigenvalue Test ($\lambda_{\max}$). Since the results of the two tests arel not be always the same, $\lambda_{\max}$ is preferred if the results of both tests are conflicted. According to Enders [39], $\lambda_{\max}$ should be preferred in deciding the number of cointegrating equations since it has a sharper alternative hypothesis than the λ_{trace} .

Given the existence of cointegration by the JJ test, there probably is a unidirectional or bidirectional causality running between the variables. However, the causal direction cannot be captured by the JJ test. Therefore, the dynamic Granger causality test by Granger [40] is utilized in this study. According to Granger [41] as cited by Sami [42], if a pair of first differences, $I(1)$ series were cointegrated, then there must a unidirectional causality running in either way. However, if a pair of series is not cointegrated, the causality can be tested by estimating vector autoregressive (VAR) model in the first difference form. While, if series are nonstationary but after first differencing become stationary and are cointegrated, then estimation of vector error correction (VEC) model is needed. In the present study, the VEC model for each country can be written as follows.

$$\Delta EC_t = \alpha + \sum_{i=1}^{k} \beta_i \Delta EC_{t-1} + \sum_{i=1}^{k} \gamma_i \Delta GDP_{t-i} + \sum_{i=1}^{k} \phi_i \Delta EXP_{t-i} + \sum_{i=1}^{k} \varphi_i \Delta CO2_{t-i} + \delta \varepsilon_{t-1} + \mu_t,$$

$$\Delta GDP_t = \alpha + \sum_{i=1}^{k} \beta_i \Delta GDP_{t-1} + \sum_{i=1}^{k} \gamma_i \Delta EC_{t-i} + \sum_{i=1}^{k} \phi_i \Delta EXP_{t-i} + \sum_{i=1}^{k} \varphi_i \Delta CO2_{t-i} + \delta \varepsilon_{t-1} + \mu_t,$$

$$\Delta EXP_t = \alpha + \sum_{i=1}^{k} \beta_i \Delta EXP_{t-1} + \sum_{i=1}^{k} \gamma_i \Delta GDP_{t-i} + \sum_{i=1}^{k} \phi_i \Delta EC_{t-i} + \sum_{i=1}^{k} \varphi_i \Delta CO2_{t-i} + \delta \varepsilon_{t-1} + \mu_t,$$

$$\Delta CO2_t = \alpha + \sum_{i=1}^{k} \beta_i \Delta CO2_{t-1} + \sum_{i=1}^{k} \gamma_i \Delta GDP_{t-i} + \sum_{i=1}^{k} \phi_i \Delta EXP_{t-i} + \sum_{i=1}^{k} \varphi_i \Delta EC_{t-i} + \delta \varepsilon_{t-1} + \mu_t,$$

where α is a constant, $\beta, \gamma, \phi, \varphi$ are the coefficients for each variable, μ_t is the serially uncorrected error terms and ε_{t-1} refers to the error correction term originated from the long-run cointegrating relationship.

Granger causality test answers a simple question of "Do changes in *X* cause changes in *Y*?". Meanwhile, Gujarati and Porter [33] stated that the Granger causality test examined the information relevant to the association prediction of the respective variables within the duration of the data. They also mentioned about various matters that need to be identified before investigating the Granger causality tests which are the variables involved are stationary, the number of lagged terms introduced are important and the error term entering the causality is uncorrelated.

The last procedure in the analysis is the Forecast Error Variance Decomposition (FEVD). Brooks [34] stated that FEVD offers a slightly different method for examining VAR/VEC model. The FEVD reveals how much of the future uncertainty of one time series was due to future shocks into the other time series in the multivariate model. The aim is to examine the effects between time series outside the estimated sampling period. Therefore, the FEVD provides information about the importance of each random innovation in affecting the variables in the VAR/VEC model. Shock to the variable will directly affect that variable, but it will also be transferred to all the other variables in the system through the dynamic structure of the VAR/VEC model.

RESULTS AND DISCUSSION

Time series plot

This section briefly discusses about the trend of time series data of each variable involved for each ASEAN country. Time series plot are used to present the patterns and behavior of the time series data. The *y*-axis and *x*-axis of the time series plot each represents the observations and time intervals. Based on Fig. 1 there is increasing fluctuate pattern for electricity consumption (EC) from 1980 until 2015 for all the ASEAN countries.

However, the gross domestic product (GDP) in Fig. 2 portrays a different behavior. It can be seen that most of the ASEAN countries were affected by the 1997 financial crisis. Their GDP is either drop severely or just mild. Nevertheless, Vietnam is the only country where their GDP does not drop during the crisis period. Next, Fig. 3 presents the exports (EXP) of each ASEAN country during the sampling period. Except for Brunei, all other countries exhibit upward trend in their EXP. Whereas, Fig. 4 also displays a constant increase of carbon dioxide

emission (CO2) for Indonesia, Malaysia, Philippines, Thailand and Vietnam. As for Brunei and Singapore, the CO2 fluctuates inconsistently during the study period.

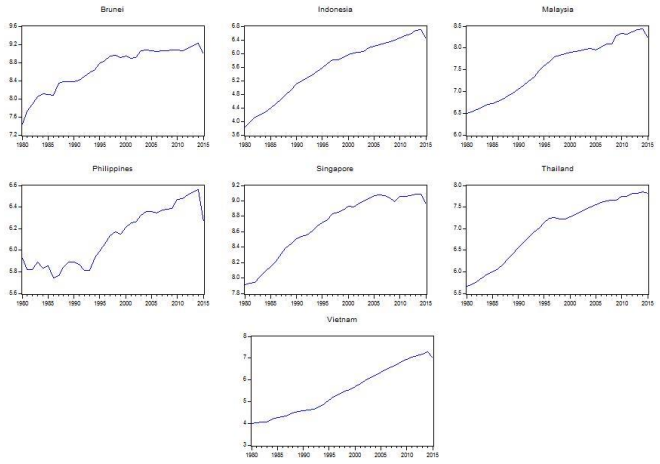

Fig. 1 Time series plot of EC

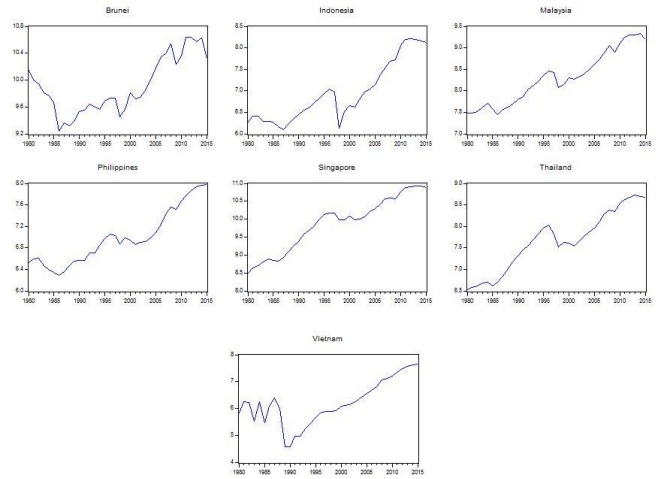

Fig. 2 Time series plot of GDP

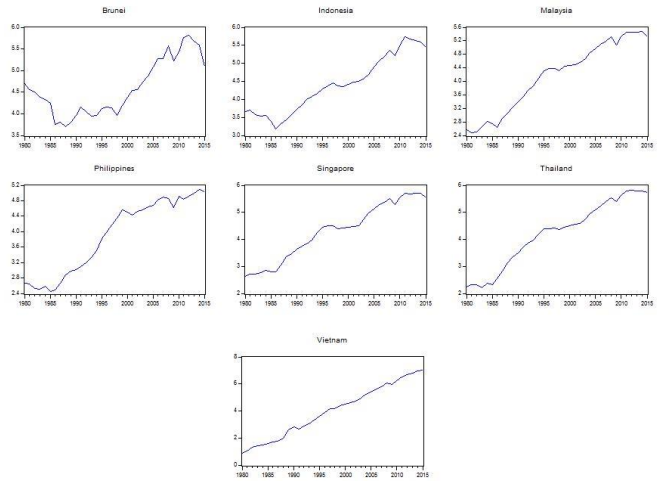

Fig. 3 Time series plot of EXP

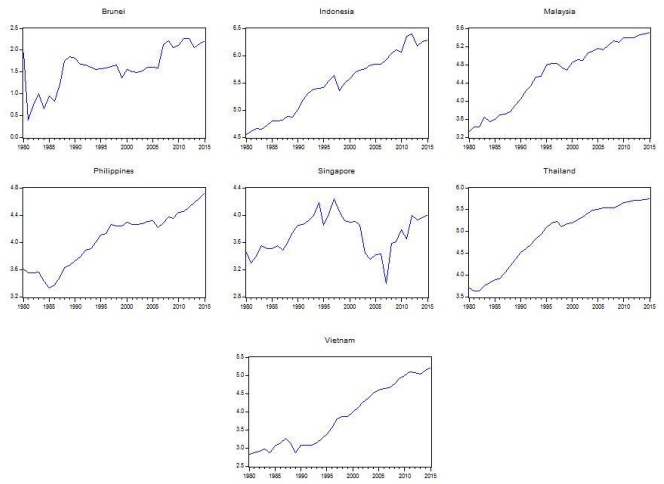

Fig. 4 Time series plot of CO2

Descriptive analysis

The descriptive analysis presented the statistics of mean, standard deviation (Std Dev), skewness and kurtosis for each country. These statistics provide the indication of the data distribution. Table 2 shows the electricity consumption (EC) for the seven ASEAN countries. It appears that Singapore and Brunei which is classified as a high-income economy by the World Bank have the highest average of EC while Vietnam and Indonesia which is classified as the lower-middle income economy has the lowest. However, Vietnam's EC is the most volatile. Overall, the distribution of EC for all the countries are skewed and platykurtic.

Table 2 Descriptive statistics for EC

Country	Mean	Std Dev	Skewness	Kurtosis
Brunei	8.67	0.46	-0.89	2.80
Indonesia	5.55	0.86	-0.52	2.00
Malaysia	7.56	0.63	-0.32	1.66
Philippines	6.11	0.26	0.12	1.53
Singapore	8.68	0.39	-0.72	2.16
Thailand	6.99	0.71	-0.56	1.91
Vietnam	5.49	1.10	0.17	1.58

Similar to the previous results, it can be seen in Table 3 and Table 4 that the gross domestic product (GDP) and exports (EXP) for a high-income economy countries such as Brunei and Singapore are the highest whereas low-middle income economy country such as Vietnam is the lowest. However, the carbon dioxide emission (CO2) in Table 5 indicates that Brunei also has the lowest average follows by Singapore and Vietnam. This finding implies that although Brunei and Singapore used a lot of electricity, they also have a mechanism to cope with the releasing of CO2. In addition, GDP, EXP and CO2 display skewed and platykurtic distribution.

Table 3 Descriptive statistics for GDP

Country	Mean	Std. Dev.	Skewness	Kurtosis
Brunei	9.90	0.41	0.39	1.98
Indonesia	6.94	0.69	0.69	2.15
Malaysia	8.29	0.61	0.25	1.85
Philippines	6.98	0.50	0.62	2.26
Singapore	9.87	0.75	-0.31	1.90
Thailand	7.65	0.69	-0.12	1.93
Vietnam	6.19	0.82	0.02	2.43

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Table 4 Descriptive statistics for EXP

Country	Mean	Std. Dev.	Skewness	Kurtosis
Brunei	4.59	0.64	0.48	1.95
Indonesia	4.40	0.77	0.23	1.84
Malaysia	4.14	1.02	-0.31	1.70
Philippines	3.88	0.95	-0.28	1.42
Singapore	4.29	1.03	-0.21	1.75
Thailand	4.20	1.21	-0.33	1.86
Vietnam	3.99	1.93	-0.03	1.72

Table 5 Descriptive statistics for CO2

Country	Mean	Std. Dev.	Skewness	Kurtosis
Brunei	1.60	0.47	-0.70	3.04
Indonesia	5.46	0.56	-0.08	1.80
Malaysia	4.58	0.71	-0.40	1.73
Philippines	4.04	0.39	-0.29	1.85
Singapore	3.71	0.28	-0.29	2.54
Thailand	4.91	0.72	-0.57	1.87
Vietnam	3.86	0.83	0.24	1.50

Stationary test

Before further analyses, stationarity of time series data for those countries that are under investigating are determined, to ensure the criterion of using vector autoregression (VAR) or vector error correction model (VECM) is matched. Brooks [34] stated that if dataset, Y_t is nonstationary, Y_t must be differenced d times before it becomes stationary, and the dataset is said to be integrated of order d, $Y_t \sim I(d)$. Moreover, following Brooks [34], this study employs confirmatory data analysis by using ADF and KPSS tests. The test results are shown in Table 6. According to ADF and KPSS tests, all data series at the level are nonstationary based on the indication of non-rejection of the null hypothesis of the ADF test and rejection of the KPSS test. However, after the first differenced, all data series are stationary. This is showed by rejecting of the null hypothesis for the ADF test, but, the null hypothesis for KPSS test of the first differenced data is accepted.

Cointegration test

After the order of stationary of all the time series data have been established, the analysis continues to find the existence of long-term relationships between EC, GDP, EXP and CO2 in Brunei, Singapore, Malaysia, Thailand, Indonesia, Philippines and Vietnam using JJ cointegration test. The four variables for each of the seven countries are tested to find whether the variables are cointegrated. It is crucial to decide the optimum lag length for this test. Here, an Akaike Information criterion (AIC) is used to decide the optimum lag length.

Table 6 Stationary Test Results

Country	Variables	ADF		KPSS		Stationary
		Level	1st diff.	Level	1st diff.	
Brunei	EC	-2.35	-4.23**	0.22**	0.10	*I*(1)
	GDP	-2.83	-5.38**	0.46**	0.29	*I*(1)
	EXP	-2.37	-4.47**	0.18**	0.24	*I*(1)
	CO2	-2.01	-11.2**	0.58**	0.12	*I*(1)
Indonesia	EC	0.66	-3.65**	0.19**	0.08	*I*(1)
	GDP	-2.00	-5.73**	0.15**	0.13	*I*(1)
	EXP	-2.76	-3.93**	0.66**	0.14	*I*(1)
	CO2	-3.35	-5.93**	0.70**	0.15	*I*(1)
Malaysia	EC	-2.22	-2.63*	0.68**	0.35	*I*(1)
	GDP	-2.36	-4.87**	0.67**	0.06	*I*(1)
	EXP	-0.79	-4.93**	0.15**	0.23	*I*(1)
	CO2	-1.27	-6.43**	0.17**	0.22	*I*(1)
Philippines	EC	-2.29	-3.77**	0.64**	0.16	*I*(1)
	GDP	-1.72	-4.10**	0.64**	0.25	*I*(1)
	EXP	-1.26	-4.87**	0.66**	0.16	*I*(1)
	CO2	-2.01	-4.62**	0.66**	0.14	*I*(1)
Singapore	EC	-2.00	-4.67**	0.19**	0.09	*I*(1)
	GDP	-1.98	-3.51**	0.68**	0.15	*I*(1)
	EXP	-1.08	-4.04**	0.68**	0.16	*I*(1)
	CO2	-2.81	-7.61**	0.12*	0.10	*I*(1)
Thailand	EC	0.38	-4.01**	0.18**	0.45	*I*(1)
	GDP	-2.39	-3.56**	0.67**	0.07	*I*(1)
	EXP	-0.64	-3.94**	0.15**	0.17	*I*(1)
	CO2	-1.92	-3.61**	0.17**	0.32	*I*(1)
Vietnam	EC	-0.93	-3.94**	0.16**	0.20	*I*(1)
	GDP	-0.36	-1.70*	0.19**	0.22	*I*(1)
	EXP	-2.98	-5.43**	0.71**	0.22	*I*(1)
	CO2	-1.96	-5.08**	0.15**	0.19	*I*(1)

Note: *, **, *** represent the rejection of the null hypothesis at 1%, 5% and 10% significance level, respectively.

Base on the AIC, the optimum lag order is one for Brunei, Indonesia, Malaysia, and the Philippines, whereas it is two for Singapore, Thailand and Vietnam. In this JJ cointegration test, the long-term relationship among variables are tested on the grounds of two tests, namely the Trace Statistic, λ_{trace} and the Max-Eigen Statistic, $\lambda_{\max}$. As pointed out in the last section, λ_{trace} is preferred than $\lambda_{\max}$ when there is conflicting conclusion. The results are reported in Table 7.

Table 7 JJ cointegration test for seven ASEAN

Country	H_a (No. of CE(s))	Trace Statistic, λ_{trace}	Max-igen Statistic, $\lambda_{\max}$
Brunei	At least 1	60.14**	29.82**
	At most 1	30.32**	18.76
	At most 2	11.56	8.93
	At most 3	2.62	2.62
Indonesia	At least 1	56.10**	27.64**
	At most 1	28.46	18.34
	At most 2	10.11	9.87
	At most 3	0.24	0.24
Malaysia	At least 1	55.63**	28.93**
	At most 1	26.69	17.39
	At most 2	9.30	6.17
	At most 3	3.12	3.12
Philippines	At least 1	48.76**	29.17**
	At most 1	19.59	13.28
	At most 2	6.30	5.59
	At most 3	0.70	0.70
Singapore	At least 1	53.09**	27.36**
	At most 1	25.73	15.28
	At most 2	10.44	8.80
	At most 3	1.64	1.64
Thailand	At least 1	69.10**	32.58**
	At most 1	36.52**	26.12**
	At most 2	10.39	7.49
	At most 3	2.90	2.90
Vietnam	At least 1	48.58**	23.10
	At most 1	25.47	13.24
	At most 2	12.23	9.34
	At most 3	2.88	2.88

Note: *, **, *** represent the rejection of the null hypothesis at 1%, 5% and 10% significance level, respectively and CE is cointegrating equation.

Results in Table 7 reveal that the null hypothesis of no cointegrating equation can be rejected at the 5% significance level for all the countries involved. Furthermore, five of the countries show the existence of one cointegrating equation, whereas Brunei and Thailand exhibit two cointegrating equations. The existence of cointegration among the series suggests that although in the short run they may diverge, however, in the long run all the series will have equilibrium relationship.

Granger causality test

From the previous section, the results verified that all the series became stationary after first differencing and are cointegrated, thus vector error correction (VEC) model will be used to model the relationship. While, the number of lags for the VEC model for each country is based on the optimum lag that being chosen by AIC from the JJ Cointegration test. Therefore, the VEC model of lag one is estimated for Brunei, Indonesia, Malaysia, and the Philippines, while the VEC model of lag two for Singapore, Thailand and Vietnam. Nonetheless, the VEC model estimation for all the countries are not shown instead the Granger Causality test results is presented. This is because Granger Causality test results are derived from the VEC model estimation. However, VEC model estimation for each country is dynamically stable and no serial dependence. This is confirmed by Fig. 5 which reveales that most of the inverse roots of autoregressive (AR) characteristic are within or near the unit circle. While, LM test until lags 4 in Table 9 validates the independent of the model residuals for each country as the hypothesis null of no serial correlation cannot be rejected. These results indicate the estimation of VEC model is not spurious.

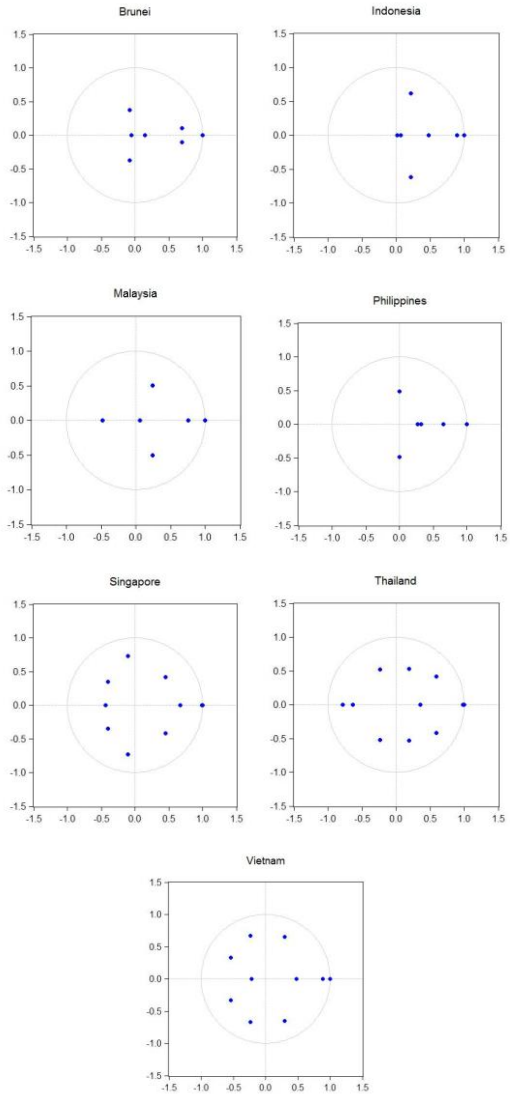

Fig. 5 Inverse roots of AR characteristic

Tang [43] mentioned that the existence of cointegration only explains the presence of causality. However, it does not point out the actual direction of causation. In order to confirm the direction of causal relationships, VECM-based Granger causality test are carried out. Table 8 depicts the results of Granger Causality Test for the seven ASEAN countries. A close examination of the table disclose a bidirectional causality between EC and GDP and between EC and CO2 in Indonesia. Moreover, a bidirectional causality is also revealed between EC and CO2 in Malaysia. In addition, EC also Granger-caused EXP in Malaysia. Next, a bidirectional connection is uncovered between EC and EXP and unidirectional connection between EC and GDP in Singapore. While, there is only unidirectional relationships

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from EXP to EC in Thailand. Nevertheless, no causal relationship between EC and other determinants are found in Brunei, Philippines and Vietnam.

Table 8 Results for Granger causality tests

Country	IV	DV			
		EC	GDP	EXP	CO2
Brunei	EC	-	0.05	0.004	0.26
	GDP	0.51	-	0.31	4.59**
	EXP	0.11	0.30	-	3.14***
	CO2	0.19	2.14	0.61	-
Indonesia	EC	-	3.52***	1.35	3.22***
	GDP	3.02***	-	0.86	0.01
	EXP	2.32	0.41	-	2.34
	CO2	7.96**	0.52	1.89	-
Malaysia	EC	-	0.82	3.07***	9.40**
	GDP	1.00	-	3.24***	0.19
	EXP	0.14	0.26	-	0.04
	CO2	4.13**	1.36	1.35	-
Philippines	EC	-	0.12	2.52	0.06
	GDP	0.39	-	2.95***	1.87
	EXP	0.43	0.87	-	0.88
	CO2	0.31	0.46	0.41	-
Singapore	EC	-	16.38**	13.66**	0.16
	GDP	2.69	-	5.49***	6.74**
	EXP	6.24**	14.26**	-	3.34
	CO2	2.02	10.27**	14.46**	-
Thailand	EC	-	0.70	1.74	0.04
	GDP	2.66	-	5.16***	1.23
	EXP	5.39**	5.05***	-	5.73**
	CO2	1.02	0.48	4.38	-
Vietnam	EC	-	3.42	0.80	2.17
	GDP	0.49	-	4.51	3.21
	EXP	0.20	0.17	-	4.78***
	CO2	1.30	4.91***	6.60**	-

Note: *, **, *** represent the rejection of the null hypothesis at 1%, 5% and 10% significance level, respectively, the cell values are the test statistics based on Chi-square, IV is the independent variable and DV is the dependent variable.

Table 9 VEC residual serial correlation LM test

Country	Lags	LM Statistics	*p*-value
Brunei	1	9.542	0.88
	2	12.20	0.72
	3	15.11	0.51
	4	7.86	0.95
Indonesia	1	15.63	0.47
	2	21.00	0.17
	3	10.01	0.86
	4	12.99	0.67
Malaysia	1	11.07	0.80
	2	12.71	0.69
	3	17.04	0.38
	4	8.81	0.92
Philippines	1	7.61	0.95
	2	7.42	0.96
	3	12.87	0.68
	4	11.32	0.78
Singapore	1	9.02	0.91
	2	18.43	0.29
	3	13.50	0.63
	4	11.75	0.76
Thailand	1	17.50	0.35
	2	18.49	0.29
	3	21.96	0.14
	4	7.59	0.96
Vietnam	1	13.55	0.63
	2	9.01	0.91
	3	5.64	0.99
	4	10.61	0.83

From the above finding, Indonesia electricity consumption (EC) and GDP/CO2 are jointly ascertained and affected at the same time. Any changes in the EC will also influence GDP/CO2 and vice versa as most of the studies only find unidirectional from EC to GDP [8,17, 29]. An economic growth promotes development of EC and may harms the environment through the CO2 in Indonesia. Thus, policymaker needs to promote energy efficiency policy and the usage of renewable energy to curb the effects of global warming. The same policy is also needed to be implemented by Malaysia as any changes in EC will results in changes in CO2 and vice versa. Malaysia government may follows the UAE government policy in introducing many projects with a green energy to reduce CO2 emmision as mentioned in Shahbaz et al. [30]. Furthermore, the EC also plays a vital role in increasing the export in Malaysia. Thus, policymakers in Malaysia need to find balance between increasing export but at the same time reducing CO2 level.

Conversely, a two ways relationship appears between EC and EXP in Singapore. As a developed country with the highest export and import in ASEAN since 2010 (ASEAN Community in Figures (ACIF)), Singapore is focusing on producing end goods from material they imported. Such industries increase the use of electricity and will boast the GDP. This finding is inline with Yoo [6]. Lastly, electricity consumption is an important factor as Thailand is moving to be an industrialized country. Thailand is an export dependent country where their total export is the second highest in ASEAN (ASEAN Community in Figures (ACIF)).

In addition, another interesting finding from Table 8 that can be highlighted is GDP Granger caused CO2 in Brunei but it is the opposite in Singapore and Vietnam. This shows that Singapore and Vietnam follow the Environmental Kuznets Curve (EKC) hypothesis which is the environmental quality deteriorates at initial stage of the economic growth and improves in later stage as economy develops. Moreover, only a unidirectional causality exists in the Philippines that is from GDP to EXP.

Forecast Error Variance Decomposition (FEVD)

The Granger causality test in the last section provides information regarding the relationship between electricity consumption and the three determinants within the sample period from 1980 to 2015. The present study continues by forecasting the relationship beyond the sampling period by using FEVD. The FEVD forecasts the relative magnitude in percentage of shock on a variable that are transmitted not only to the variable, but also to the other variables within the multivariate system. The results of FEVD from the VEC model are given in Table 10. Here only the results for EC are presented. As the data used in the modelling is an annual data, thus the forecast is for 2, 4, 6, 8 and 10 years ahead.

A close inspection of Table 10 reveals some interesting results. Referring to the previous Granger causality test, it was discovered that no unidirectional or bidirectional causality between EC and the other determinants in Brunei, Philippines and Vietnam. However, FEVD found different trend between the EC with the determinants in the Philippines. As can be seen in Table 10, any shock on the EC of Philippines is resulting a 77% shock by EC itself, and also transmitted to GDP by 13%, EXP by 4% and CO2 by 5% after 4 years. However, after 10 years, any shock on EC only impacts the EC itself by 45%, but it spreads to the GDP by 28%, EXP by 20% and CO2 by 7%. Thus, in the long term any variation in the Philippines' EC will also influence their GDP, EXP and CO2. This is due to the fact that the Philippines is an emerging market and developing economies, which has an economy transitioning from agriculture based to more on services and manufacturing. This will increase the electricity demand and will cause the electricity supply to generate more domestic production. Nonetheless, the shock on Brunei's EC, Vietnam's EC and Thailand's EC just show mild effects on their GDP, EXP and CO2.

Meanwhile, a shock after 10 years on the EC of Malaysia and Indonesia will transfer mainly to EXP by more than 20%. The reason behind this finding is that both countries are moving toward industrialized country in order to achieve developed country status. Any growth of electricity consumption will rise the production. As for Singapore, about 94% shocks in the EC is dominated by its own shock,

while other determinants contribute only 6% to the fluctuation of EC in the second year forecasting. However, after 10 years, the shock spread mainly to Singapore's GDP by 27%. Thus, in the future, fluctuation on electricity consumption will affect the GDP. It means the finding of a unidirectional relationship by the Granger causality test from EC to GDP will remain in the future.

Table 10 FEVD results for EC

Country	Yearly	EC	GDP	EXP	CO2
Brunei	2	95.74	1.50	1.64	1.11
	4	92.31	1.43	2.69	3.56
	6	89.60	0.98	2.49	6.90
	8	87.38	0.72	2.19	9.69
	10	85.71	0.59	1.91	11.77
Indonesia	2	96.21	0.24	3.22	0.31
	4	80.58	0.75	10.36	8.29
	6	70.88	1.20	16.77	11.13
	8	66.86	1.30	20.12	11.71
	10	64.05	1.32	22.33	12.28
Malaysia	2	94.99	0.50	4.47	0.02
	4	81.88	1.16	16.64	0.30
	6	76.78	0.95	22.02	0.23
	8	74.61	0.82	24.37	0.18
	10	73.23	0.76	25.83	0.16
Philippines	2	95.48	2.61	0.00	1.89
	4	77.22	13.28	3.99	5.49
	6	64.04	19.36	9.99	6.59
	8	53.01	24.18	15.76	7.03
	10	44.82	27.56	20.45	7.15
Singapore	2	94.66	4.143	0.92	0.26
	4	82.19	11.67	3.47	2.65
	6	75.71	18.40	2.17	3.70
	8	69.73	23.96	1.79	4.51
	10	64.47	27.37	2.40	5.74
Thailand	2	96.13	1.97	1.09	0.79
	4	92.01	6.62	0.66	0.70
	6	92.73	5.90	0.39	0.97
	8	93.56	4.97	0.52	0.92
	10	93.92	4.35	1.01	0.70
Vietnam	2	96.94	0.86	1.12	1.06
	4	94.04	0.99	0.32	4.63
	6	93.15	1.18	0.14	5.52
	8	92.71	1.20	0.08	5.99
	10	92.27	1.25	0.06	6.40

CONCLUSION

This present study examines the relationship between electricity consumption (EC) and some determinants such as gross domestic product (GDP), exports (EXP) and carbon dioxide emissions (CO2) for the period 1980-2015 among seven ASEAN countries. Moreover, this study includes Brunei and Vietnam, which are not often analyzed in previous studies. The method employs is VAR framework. Empirical results have established that all the time series data for each country are stationary at first differenced and they are cointegrated. Thus, for each country there is casual relationship among the four variables, namely, the EC, GDP, EXP and CO2.

Granger causality approach has recognized a bidirectional between EC and CO2 in Malaysia and Indonesia. Thus, both of these countries need to focus more on renewable energy to cope with CO2 increases. Furthermore, Indonesia also an energy dependent economy as a bidirectional causality was revealed between EC and GDP. In addition, the forecast error variance decomposition (FEVD) found shock disseminate among EC, GDP and EXP in Philippines. Therefore, in future Philippines will be an energy dependent economy and they need to utilize renewable energy sources to reduce the greenhouse gas emission. Nevertheless, no relationship was discovered between EC and their determinants in Brunei and Vietnam. The reason behind this finding is that Brunei's economy depends on petroleum rather than manufacturing which needs electricity to generate outputs. While, Vietnam is still an agricultural based economy and the operations of planting and harvesting are still using traditional methods thus they are less dependent on electricity. To sum up, ASEAN needs policies that will ensure uninterrupted supply of energy in order to promote export from industrial outputs that will boast their GDP, while at the same time to use the renewable energy and push for conservation of electricity policy.

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