THE RELATIONSHIP BETWEEN ELECTRICITY CONSUMPTION AND GROSS DOMESTIC PRODUCT IN THE ASSOCIATION OF SOUTHEAST ASIAN NATION COUNTRIES

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ABSTRACT

This study re-examines the relationship between gross domestic product (GDP) and electricity consumption (EC) in ASEAN countries, by using annual time series data from 1980 to 2011. By using a co-integration test, and the system-based reduced rank regression approach (Johansen test), the relationships were tested for long-term equilibrium in all countries. In addition, the Vector Error Correction Model (VECM) technique was applied to study the direction of variables for short-run relationships. It was found that the GDP and EC of Brunei and Viet Nam were co-integrated, while Singapore, Indonesia, Thailand and Myanmar were unable to be identified. In contrast, Philippines, Malaysia, Cambodia, and Laos were not co-integrated. In addition, for Brunei and Vietnam, the long run relationship between GDP and EC only tended toward EC and away from GDP. Therefore, individual governments should promote sufficient power generation to generate electricity matching future growth.

Keywords: electric consumption, GDP, ASEAN, vector error correction model, Johansen test

INTRODUCTION

The Association of Southeast Asian Nations or ASEAN is a cooperation between Southeast Asian Nations. On 8th August 1967, ASEAN was setup with the ASEAN Declaration in Bangkok. The five founding members are Indonesia, Malaysia, Philippines, Singapore, and Thailand. Today, there are now 10 member countries with 615 million or 8.64 % of the world population: Brunei, Viet Nam, Laos, Myanmar and Cambodia joined in 1984, 1995, 1997, 1997 and 1999, respectively (The ASEAN Secretariat, n.d.).

In 1999, ASEAN planned to become a unitary community with three pillars: ASEAN Political-Security Community, ASEAN Economic Community, and ASEAN Socio-Cultural Community. In particular, the ASEAN Economic Community or AEC was widely mentioned in discussions. The GDP of ten member countries was also considered.

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Since 1970, ASEAN GDP average growth was estimated at 5.75% per year, and the GDP of ASEAN in 2012 was 1,330,797 million US Dollars at constant prices (2005) or 2.43% of the world GDP. The AEC region shows an increasing growth of commerce, travel and investment, and provides opportunities for the member countries to integrate trends of economic growth (See Figure 1). Over the same period of time, electricity consumption (EC) of six countries in ASEAN has increased, while others have remained constant. Trend growth in electricity demand indicates the need for power generation infrastructure in the region (See Figure 1).

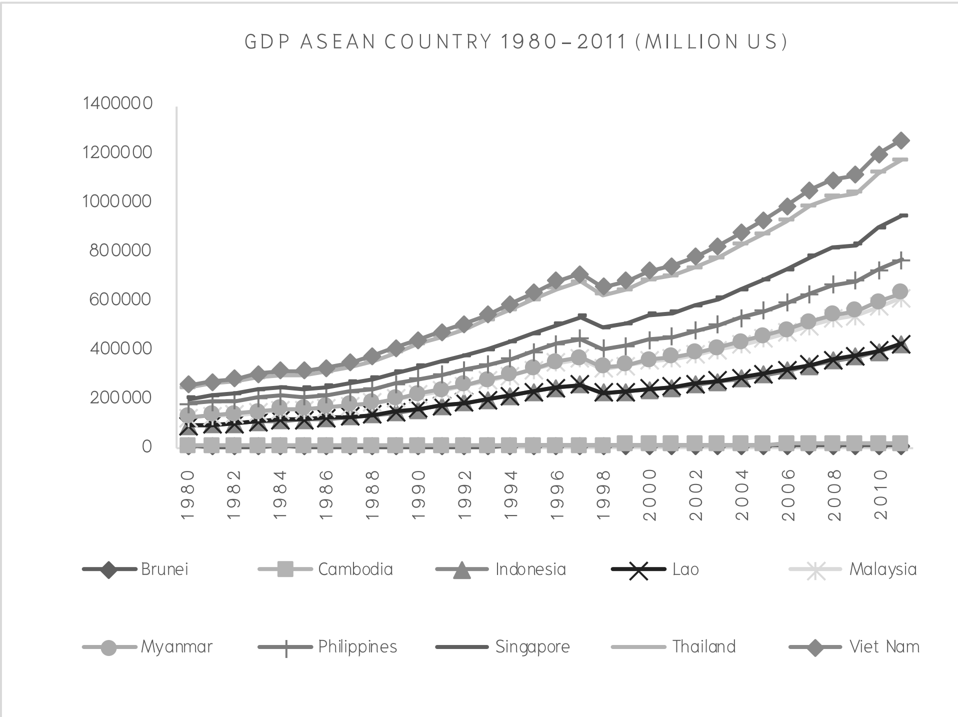

Figure 1 ASEAN Countries' GDP

The causality between EC and economic growth is widely discussed in terms of its negative environmental impact. Electricity generation uses environmental resources, such as oil, coal, natural gas, solar, wind, etc. Unfortunately, generating renewable electricity has a high cost, and is unlikely to meet electricity demand. However, most electricity generation in the world still use non-renewable resources which increases threats from pollution. Consequently, member ASEAN need to find a balance between economic growth and environmental responsibility.

Relationships in many time series were found through the use of the Error Correction Method (ECM), and then the Vector Error Correction Model (VECM). This approach explains the adjustment of error movement to equilibrium by vector equation types. Therefore, this study aims to re-examine the relationship between EC and GDP in ASEAN countries by using annual time series data from 1980 to 2011, totaling 32 years. EC was collected from the U.S. Energy Information Administration (EIA), and GDP was collected from the United Nations Conference on Trade and Development (UNCTAD). This study is separated into five parts: introduction, literature review, methodology, results and discussion, and conclusions and suggestions.

The causality between energy usage and economic growth has attracted the attention of many researchers. Kraft and Kraft's work was the first empirical study dealing with the casual relationship between energy consumption and economic growth (Kraft & Kraft, 1978 in Sheng-Tung Chen, Hsiao-I Kuo, Chi-Chung Chen, 2007). Subsequently, the findings of energy studies, especially electricity studies, have been re-examined and expanded.

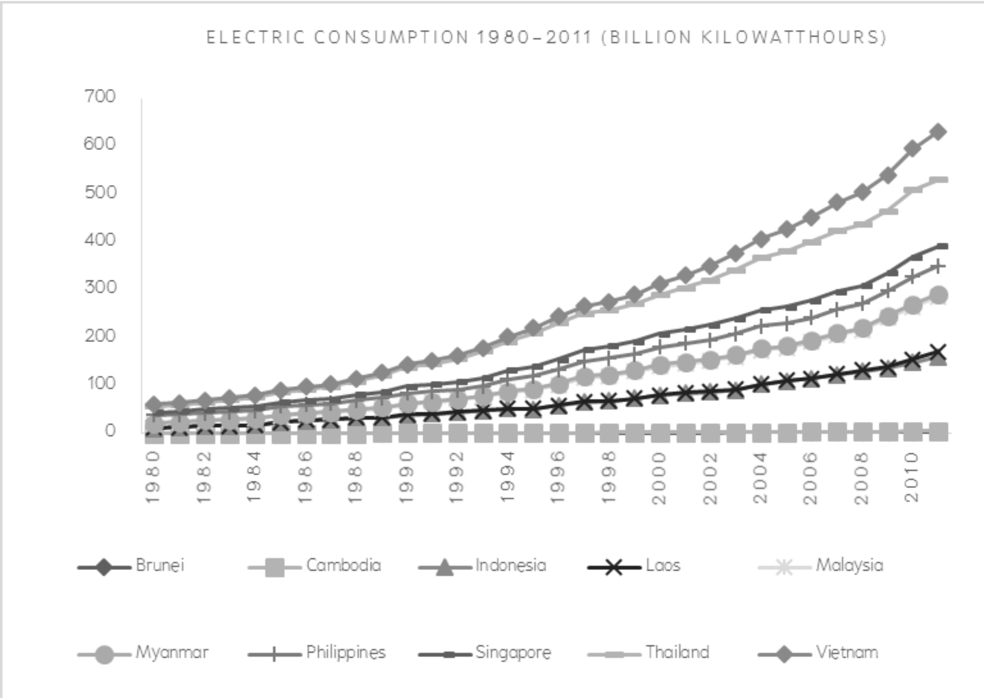

Figure 2 Electricity consumption

The relationship between EC and GDP was proved in numerous studies by employing numerous methodologies; with these studies being partly prompted by the recognition of energy as a factor in economic growth in developing countries. It can be seen many researchers selected a group of countries in the same area or similar background in order to represent their areas for regional policy development. For example, "The relationship between GDP and electricity consumption in 10 Asian countries" by Sheng-Tung Chen, Hsiao-I Kuo, Chi-Chung Chen in 2007, and The "Electricity consumption and economic growth: a time series experience for 17 African countries" by Yemane Wolde-Rufael in 2006. Thus, this study focuses on ASEAN countries to find the causality between EC and GDP to support electricity generation and management strategies.

MATERIALS AND METHODS

After collecting data from 32 years (annual data from 1980 to 2011) of ASEAN GDP from UNCTAD and EC from E.I.A, the data were tested by using the Augmented Dickey-Fuller (ADF) technique to prove the unit root. Most time series data are affected by time trends and usually have a unit root which affects the result; such as, for example, a high R2 and significant but low Durbin-Watson statistics (spurious problem). If they have a unit root, the result in many processes will be renounced. The variables of this study can be tested by employing the following equations:

$$\ln GDP_t = \alpha_1 + \alpha_2 \ln GDP_{t-1} + \sum_{i=1}^{p} \alpha_i \Delta \ln GDP_{t-i} + u_t \tag{1}$$

$$\ln EC_t = \chi_1 + \chi_2 \ln EC_{t-1} + \sum_{j=1}^{p} \chi_j \Delta \ln EC_{t-j} + v_t \tag{2}$$

Where GDP is the real GDP (based year in 2005, US$); EC is the electricity consumption, (kW h); u_t is the error term of GDP unit root testing, and v_t is the error term of EC unit root testing while α_2 and χ_2 are the parameters of the ADF statistic. All variables were transformed into natural logarithms, and then compared α_2 with the McKinnon statistic, if α_2 is less than the McKinnon statistic, GDP is stationary or does not have a unit root. EC will then be stationary too if χ_2 is less than the McKinnon statistic.

When time series variables have a unit root, they are high in R2, but have a lower Durbin-Watson value. However, the relationship between time series variables can be proved if they are co-integrated. An important property of co-integration is that it is a stationary at the same integration order. Thus, if the results are non-stationary at a given level, higher differentiation should be found in the other results.

According to the results from the previous process, the pairs of GDP and EC in each country, which were stationary at the same integration order, were proved to be co-integrated through the Johansen test. The co-integration was also presented by Engle and Granger (1987), who stated that non-stationary time series may have long-run relationships when the deviation of the relationship in the long-run equilibrium is stationary. Even though Engle and Granger test is a simple method of co-integration, it can prove only one equation or one co-integration. Therefore, Johansen improved the method process based on the Vector autoregressive (VAR) model, now known as Multivariate Co-integration.

After classification, the used variables are reformed into the first differentials. They are then transformed into VAR in a reduced form to find any co-integration. The co-integrated model of the Johansen test is applied in this study by employing the following equations:

$$\ln GDP_t = \theta_{11} \ln GDP_{t-1} + \theta_{12} \ln EC_{t-1} + w_t \tag{3}$$

$$\ln EC_t = \theta_{21} \ln GDP_{t-1} + \theta_{22} \ln EC_{t-1} + x_t \tag{4}$$

Transforming into the first differential and VAR

$$\begin{bmatrix} \Delta \ln GDP_t \\ \Delta \ln EC_t \end{bmatrix} = \begin{bmatrix} 1-\theta_{11} & \theta_{12} \\ \theta_{21} & 1-\theta_{22} \end{bmatrix} \begin{bmatrix} \ln GDP_{t-1} \\ \ln EC_{t-1} \end{bmatrix} + \begin{bmatrix} w_t \\ x_t \end{bmatrix} \tag{5}$$

Reducing form to

$$\Delta X_t = \Pi X_{t-1} + \varepsilon_t \tag{6}$$

When X_t is $\begin{bmatrix} \ln GDP_t \\ \ln EC_t \end{bmatrix}$ while X_{t-1} is $\begin{bmatrix} \ln GDP_{t-1} \\ \ln EC_{t-1} \end{bmatrix}$. ε_t is called the vector of error term and ε_t is $\begin{bmatrix} w_t \\ x_t \end{bmatrix}$. Finally, Π is called the vector of parameter and Π is $\begin{bmatrix} \theta_{11-1} & \theta_{12} \\ \theta_{21} & \theta_{22-1} \end{bmatrix}$. The number of co-integrations in a long-run relationship between GDP and EC are represented by Rank of Π. This paper considers the number of co-integrations by using λ_{trace} and $\lambda_{\max}$ eigenvalue.

If they are co-integrated, the direction of the independent variables to the dependent variable can be found. The Error Correction Mechanism is an econometric method which observes error terms of regression. The relationship between independent and dependent variables can be accepted when the coefficient of the error term is negative and not zero. The speed of adjustment in the dependent variable's return to equilibrium is the error term coefficient. The adjustment in the short-run relationship is proved by employing the independent coefficient. If they are not zero, they are running in the direction from independent to equilibrium.

The Vector Error Correction Model has been improved from the VAR model (Bi-Variate Auto regression). It presents short and long term movements of variables which consider the adjustment to terms of the long run effect for each variable. This paper can prove the direction by employing VECM as follows:

$$\Delta \ln GDP_t = \beta_a + \beta_b ECM_{t-1} + \sum_{k=1}^{p} \beta_{k,1} \Delta \ln GDP_{t-k} + \sum_{k=1}^{p} \beta_{k,2} \Delta \ln EC_{t-k} + y_t \tag{7}$$

$$\Delta \ln EC_t = \delta_a + \delta_b ECM_{t-1} + \sum_{k=1}^{p} \delta_{k,1} \Delta \ln GDP_{t-k} + \sum_{l=1}^{p} \delta_{k,2} \Delta \ln EC_{t-k} + z_t \tag{8}$$

Transferring into VAR in:

$$\begin{bmatrix} \Delta \ln GDP_t \\ \Delta \ln EC_t \end{bmatrix} = \begin{bmatrix} \beta_a \\ \delta_a \end{bmatrix} + \begin{bmatrix} \beta_b \\ \delta_b \end{bmatrix} ECM_{t-1} + \begin{bmatrix} \beta_{1,1} & \beta_{1,2} \\ \delta_{1,1} & \delta_{1,2} \end{bmatrix} \begin{bmatrix} \Delta \ln GDP_{t-1} \\ \Delta \ln EC_{t-1} \end{bmatrix} + \begin{bmatrix} y_t \\ z_t \end{bmatrix} \tag{9}$$

When β_b is the speed of adjustment in a long-run relationship running from EC to GDP; δ_b is the speed of adjustment in a long-run relationship running from GDP to EC; and y_t and z_t are error terms. The long-run relationship running from EC to GDP can be accepted when β_b is negative and significant, while a long-run relationship running from GDP to EC can be accepted with the same property of δ_b.

In addition, $\beta_{k,2}$ is the speed of adjustment in a short-run relationship running from EC to GDP in k lag , $\delta_{k,2}$ is the speed of adjustment in a short- run relationship running from GDP to EC in k lag, while, k is a number of lags. The direction of these relations can be found by a short-run relationship. The direction can be accepted when $\beta_{k,2}$ or $\delta_{k,2}$ in all lags is not zero significance in the Wald test.

RESULTS AND DISCUSSIONS

This section explains the results of the study, including the unit root test results, the co-integration test results, the Error Correction Mechanism and the causality results.

TABLE 1: Summary of the causality results between electricity consumption and GDP

Authors	Countries	Methodology	Time Period	Causality relationship
Sheng-Tung Chen, Hsiao-I	China	-Error Correction Mechanism	1971-2001	No causality
Kuo, Chi-Chung Chen	Hong Kong	-Panel Causality test	1971-2001	EC to GDP
	Indonesia		1971-2001	No causality
	India		1971-2001	GDP to EC
	Korea		1971-2001	No causality
	Malaysia		1971-2001	GDP to EC
	Philippines		1971-2001	GDP to EC
	Singapore		1971-2001	GDP to EC
	Taiwan		1971-2001	No causality
	Thailand		1971-2001	No causality
	All		1971-2001	GDP to EC
Barnard Njindan Iyke	Nigeria	VECM	1971-2011	EC to GDP
Salah Abosedra,Abdallah Dah and Sajal Ghosh	Lebanon	-Vector auto regression	1995-2005	EC to economic growth
Hussain Ail Bekhet and Nor Salwati bt Othman	Malaysia	-Vector error correction model	1971-2009	EC to GDP
Ciarreta,A. and Zarraga, A	Austria	-GMM Panel methodology	1970-2004	No causality
	Belgium			
	Denmark			
	Finland			
	France			
	Germany			
	Italy			
	Luxembourg			
	Netherlands			
	Norway			
	Sweden			
	Switzerland			
Firouz Fallzhi	United States	-Markov-switching vector autoregressive	1960-2005	Bi-directional
Chun-Yu Ho, Kam Wing Siu	Hong Kong	-Error correction model	1966-2002	EC to GDP

TABLE I (Contunue): Summary of the causality results between electricity consumption and GDP

Authors	Countries	Methodology	Time Period	Causality relationship
Yuan, Jiahai Zhao, Changhong Yu, Shunkun Hu, Zhaoguang	China	-Granger causality	1978-2004	EC to GDP
Ilhan Ozturk and Ali Acaravci	Albania Bulgaria Hungary Romania	-Autoregressive distributed lag (ARDL)	1980-2006	No causality
Mohammad Salahuddin, Jeff Gow	Gulf Cooperation Council countries	Panel Granger causality	1980-2012	GDP to EC
Yemane Wolde-Rufael	Algeria	-Convertional F-statistic for Granger causality	1971-2001	No causality
	Benin		1971-2001	EC to GDP
	Cameroon		1971-2001	GDP to EC
	Congo, DR		1971-2001	EC to GDP
	Congo, Rep.		1971-2001	No causality
	Egypt		1971-2001	EC to GDP
	Gabon		1971-2001	EC to GDP
	Ghana		1971-2001	GDP to EC
	Kenya		1971-2001	No causality
	Morocco		1971-2001	EC to GDP
	Nigeria		1971-2001	GDP to EC
	Senegal		1971-2001	GDP to EC
	South Africa		1971-2001	No causality
	Sudan		1971-2001	No causality
	Tunisia		1971-2001	EC to GDP
	Zambia		1971-2001	GDP to EC
	Zimbabwe		1971-2001	GDP to EC
Yoo, Seung-Hoon	Korea	-Error correction model	1968-2002	Bi-directional

According to the results in Table 2, there were four variables which were stationary at levels, such as EC in Singapore, Brunei, Indonesia, and Thailand. Singapore and Thailand were significant at the 0.01 level, while Brunei is significant at the 0.05 level. There were fifteen stationary variables including EC of the Philippines, Malaysia, Viet Nam, Cambodia, Myanmar, and Lao P.D.R. which were significant at a 0.01 level, while Brunei is significant at the 0.05 level. In addition, the GDP of Brunei, Malaysia, Cambodia, Lao P.D.R. were significant at the 0.01 level, the GDP of the Philippines and Vietnam were significant at the 0.05 level, while the GDP of Thailand and Singapore were stationary at the 0.1 level. The observed variables of six countries were stationary at the same order of integration (Brunei, Philippines, Malaysia, Vietnam, Cambodia, and Lao P.D.R.)

According to Table 3, Brunei and Vietnam had one co-integration of GDP and EC while other countries did not. The trace Eigenvalue of the co-integration of Brunei and Vietnam were significant at the 0.05 level. In addition, the maximum Eigenvalue of variables of Brunei and Vietnam were significant at the 0.05 and 0.01 levels, respectively. After proving co-integration in the observed variables of each country, the co-integrated variable determined the speed of adjustment to equilibrium; the short-term relationship and the long-term relationship by employing VCEM (see Table 4).

TABLE 2: Unit Root results

Country	Variable	Lag	ADF t- Statistic	
			At level	At first difference
Singapore	lnEC	2	-3.8182***	-0.7579
	lnGDP	2	-1.1402	-2.6747*
Brunei	lnEC	0	-3.1424**	-3.5492**
	lnGDP	0	-0.5824	-8.6099***
Philippines	lnEC	0	0.4168	-4.8847***
	lnGDP	0	1.8667	-3.1549**
Indonesia	lnEC	2	-2.8338*	-2.5376
	lnGDP	2	-1.0215	-2.5538
Malaysia	lnEC	0	-0.9070	-4.3891***
	lnGDP	0	-0.9880	-4.4866***
Vietnam	lnEC	5	0.2039	-2.6895*
	lnGDP	5	1.1790	-3.0645**
Cambodia	lnEC	0	2.5532	-5.2495***
	lnGDP	0	1.0092	-3.9564***
Thailand	lnEC	0	-3.8282***	-2.3742
	lnGDP	0	-2.3234	-2.6504*
Myanmar	lnEC	0	-0.1831	-7.2627***
	lnGDP	0	3.6465	-2.1316
Lao PDR.	lnEC	0	2.3006	-4.5662***
	lnGDP	0	0.6226	-5.3778***

*** Significant level at 0.01, ** Significant level at 0.05 and

* Significant level at 0.1.

In the short-term, there is a uni-directional causality running from GDP to EC for Brunei and Viet Nam. These directions can be explained by the expansion in demand for electrical appliance products as investment increases. Investment has affected the demand for electrical appliance products for offices and other machines. Electrical products and machines in the investment and household sectors increase consumption of electricity. Therefore, a uni-directional causality running from GDP to EC for Brunei and Vietnam was found.

If non-equilibrium in both countries occurs, for Brunei, GDP will run to equilibrium with a speed of adjustment of 12.91% per year, and 22.51% per year for Vietnam.

TABLE 3: Co-integration results

Country	Lag	Eigenvalue		Number of co-integration	
		Trace	Maximum	Trace	maximum
Brunei	1	17.7269**	17.1596**	1	1
Philippines	1	9.0176	9.0085	–	–
Malaysia	1	8.6292	7.6504	–	–
Vietnam	2	18.9998**	18.9988***	1	1
Cambodia	1	12.8147	12.6595	–	–
Lao PD.	1	12.0503	12.0177	–	–

*** Significant level at 0.01, ** Significant level at 0.05 and

* Significant level at 0.1.

TABLE 4: Vector error correction model results

Country	Lag	Error term coefficients		Wald test F-statistic	
		EC to GDP	GDP to EC	EC to GDP	GDP to EC
Brunei	1	-0.0453	-0.1291***	0.3472	6.0855**
Vietnam	2	-0.0322	-0.2251***	1.1653	3.9342**

*** Significant level at 0.01, ** Significant level at 0.05 and

* Significant level at 0.1.

CONCLUSION

This study aims to find a relationship between GDP and EC, the direction of both variables, and the speed of adjustment when running to equilibrium among ASEAN countries by using annual data from 1980 to 2011. The observed variables in Brunei and Vietnam were co-integrated and had a long-term relationship. They ran uni-directionally from GDP to EC. However, the observed variables of the Philippines, Malaysia, Cambodia and Lao were not co-integrated. Both variables of Singapore, Indonesia, and Thailand were not stationary at the same integration order.

For Brunei, the speed of adjustment running from GDP to EC is 12.91 percent, which was slower than Viet Nam which had a speed of adjustment running from GDP to EC at 22.51 percent. According to the results, Brunei and Viet Nam should:

1) Improve the electricity generating system to prepare for increasing electricity demand in the future.

2) Consume electricity efficiently.

3) Build more renewable electricity generations, such as solar cell electricity grid, small electricity generators for manufacturing or farm usage, and others alternative electricity production in each community.

4) Reduce the barriers to entry into electricity markets.

REFERENCES

S Abosedra, A Dah, S Ghosh. "Electricity consumption and economic growth, the case of Lebanon,". Applied Energy. 86(4) : 429–432 : 2009

H Bekhet, N Othman. "Causality analysis among electricity consumption, consumer expenditure, gross domestic product (GDP) and foreign direct investment (FDI): Case study of Malaysia,". Journal of Economics and International Finance. 3(April) : 228–235 : 2011

S Chen, H Kuo, C Chen, "The relationship between GDP and electricity consumption in 10 Asian countries,". Energy Policy. 35(4) : 2611–2621 : 2007

A Ciarreta, A Zarraga, "Economic growth and electricity consumption in 12 European countries: A causality analysis using panel data,". International Conference on The European Energy Market 2009. 1–8 : 2009

F Fallahi. "Causal relationship between energy consumption (EC) and GDP: A Markov-switching (MS) causality,". Energy. 36(7) : 4165–4170 : 2011

C Ho, K Siu. "A dynamic equilibrium of electricity consumption and GDP in Hong Kong: An empirical investigation,". Energy Policy. 35(4) : 2507–2513 : 2007

BN Iyke. "Electricity consumption and economic growth in Nigeria: A revisit of the energy-growth debate,". Energy Economics. 51 : 166–176 : 2015

I Ozturk, A Acaravci. "The causal relationship between energy consumption and GDP in Albania, Bulgaria, Hungary and Romania: Evidence from ARDL bound testing approach,". Applied Energy. 87(6) : 1938–1943 : 2010

M Salahuddin, J Gow. "Economic growth, energy consumption and CO2 emissions in Gulf cooperation council countries,". Energy 73 : 44–58 : 2014

The ASEAN Secretariat. The Founding of ASEAN. [Online] Retrieved from : http://www.asean.org/news/item/the-founding-of-asean. 17 January 2015

Y Wolde-Rufael. "Electricity consumption and economic growth: a time series experience for 17 African countries,". Energy Policy. 34(10) : 1106–1114 : 2006

S Yoo. "Electricity consumption and economic growth: evidence from Korea,". Energy Policy. 33(12) : 1627–1632 : 2005

J Yuan, C Zhao, S Yu, Z Hu. "Electricity consumption and economic growth in China: Co-integration and co-feature analysis,". Energy Economics. 29(6) : 1179–1191 : 2007