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Jerome Kueh, Josephine Yau, Audrey Liwan
Faculty of Economic and Business, Universiti Malaysia Sarawak, 94300 Kota Samarahan, Sarawak, Malaysia

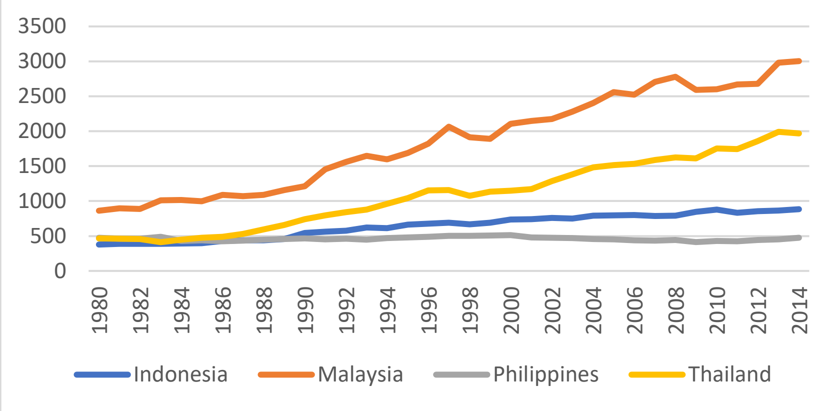
Yong Sze Wei
Faculty of Business and Management, Universiti Teknologi MARA, 94300 Kota Samarahan, Sarawak, Malaysia
Email: kshjerome@unimas.my

Abstract
The aim of the study is to investigate the impact of energy consumption on economic growth in ASEAN-4 countries as a whole. In addition, the effect of the non-linearity of the relationship between energy consumption and growth is examined using Threshold Analysis method for the period of 1980 to 2014. Empirical findings indicate that energy consumption has significant positive impact on economic growth in ASEAN-4 countries in the long-run. Furthermore, the non-linearity results show that the impact of the energy consumption on growth become greater when the energy consumption is above the threshold level. This implies that more usage of energy may contribute to the economic growth.
Keywords: Energy Consumption, ASEAN-4, Non-Linearity.

Introduction

Energy demand remain as critical issue in the developed and developing countries, especially in Association of Southeast Asian (ASEAN) region due to the need of energy for development purpose. According to World Energy Outlook 2017 report, the energy demand for ASEAN countries indicating growth of 70% since 2000 and accounted for 5% of total global energy demand.

Figure 1: Energy Consumption of ASEAN-4 Countries from 1980 – 2014



Source: World Development Indicator, World Bank

Figure 1 depicts the level of energy consumption of ASEAN-4 countries namely Indonesia, Malaysia, Philippines and Thailand from 1980 to 2014. Overall, there is an increasing trend of energy consumption for Malaysia and Thailand. In 1980, the level of energy consumption of Malaysia and Thailand stood at approximately 862 kg of oil and 460 kg of oil, respectively. Prior to the 1997 Asian Financial crisis, the energy consumption in Malaysia recorded approximately 2,065 kg of oil in 1997 and declined to approximately 1,892 kg of oil in 1999. Meanwhile, Thailand recorded slight decrease from approximately 1,159 kg of oil in 1997 to approximately 1,074 kg of oil in 1998. Although there was a reduction in the energy consumption aftermath 1997 Asian Financial crisis, the energy consumption in both countries exhibit any increasing trend and reached approximately 3,003 kg of oil and approximately 1,969 kg of oil, respectively, in 2014. In contrast, the energy consumption level is relatively lower in Indonesia and Philippines. The energy consumption trend in Indonesia is showing increasing trend from approximately 378 kg of oil in 1980 to approximately 884 kg of oil in 2014. Nevertheless, the energy consumption trend in Philippines exhibits minor changes with approximately 473 kg of oil in 1980 to approximately 474 kg of oil in 2014.

Although, energy is highly demanded for development purpose, however, high level of energy consumption in the long-run may be detrimental to the economic growth of ASEAN-4 countries. This can be seen from the environmental point of view where energy usage may lead to pollution such as carbon emission. Although most of the literature support the positive association between energy consumption and economic growth, but limited concern on the possibility of the different impact of energy on growth based on threshold effect. Therefore, viewing the dynamic development in the energy sector in ASEAN region, it is essential to understand the effect of the energy consumption towards economic growth of ASEAN-4 countries by taking into account the threshold effect. The objective of the study is:

- to investigate the impact of the energy consumption towards economic growth of ASEAN-4 countries as a whole.
- to identify the turning point of the energy consumption and heterogeneous effects either above or below the threshold level on economic growth of ASEAN-4 countries.

Literature Review

There are a wide range of literatures discussing about the role of the energy demand on economic growth. Most of the studies support the positive energy-growth association (such as Rahman et al., 2015; Kasperowicz, 2014; Yildrim et al., 2014; Adhikari and Chen, 2012; Narayan and Smyth, 2008; Lee, 2005; Soytas and Sari, 2003; Imran and Siddiqui, 2010; Masih and Masih, 1996). The following section provide several discussions about the literatures of the relationship between energy consumption and economic growth.

Among a few studies supporting energy-led-growth hypothesis are as followed. Narayan and Smyth (2008) examined the association between capital formation, energy consumption, and real GDP for sample of G7 countries (Canada, France, Germany, Italy, Japan, United Kingdom and United States). Their empirical findings showed that the causality was running from capital formation and energy consumption have positive impact on growth in the long-run. Kasperowicz conducted study on 12 European countries from 2000 to 2012 and empirical outcome support energy leg growth relationship. Meanwhile, Rahman et al. (2015) investigated the causal linkage between energy consumption and economic productivity of Malaysia where their study includes disaggregate levels of energy on growth. They discovered that type of energy that have negative impact on growth are coal and electricity consumption due to inefficiency. Yildrim et al. (2014) reexamined the association between energy consumption and growth of Indonesia, Malaysia, Philippines, Singapore and Thailand via panel data causality. Their empirical results indicated that energy-growth only valid for Indonesia, Malaysia and Philippines.

Adhikari and Chen (2012) examined the long-run relationship between energy consumption and economic growth for 80 developing countries from 1990 to 2009 where sample countries was classified into three income groups: upper middle income countries, lower middle income countries and low income countries. Empirical results showed that significant positive association between energy consumption and economic growth for upper middle income countries and lower middle income countries. Imran and Siddiqui (2010) studied the relationship between energy consumption and economic growth for the panel of three SAARC countries using panel error correction model. Their causality results support the positive relationship between energy consumption and growth. Lee (2005) examined co-movement and the causality of energy-growth relationship for 18 developing countries from 1975 to 2001. The results showed evidence of long-run and short-run causalities from energy consumption to GDP only for the sample countries. Soytas and Sari (2003) investigated energy-growth for G7 countries and emerging markets. Their results revealed positive relationship between energy consumption and economic growth can be observed in only in France, Japan, Germany and Turkey.

It can be seen that most of the literatures support the energy-led-growth relationship. However, as far as concern, none are examining the possibility of different impact of energy on growth when considering the threshold effect of energy level.

Methodology

The data used in this study were obtained from World Development Indicator (WDI) from 1980 to 2014. These aggregate data of ASEAN-4 countries comprise of gross domestic product per capita as dependent variable, energy usage (kg of oil equivalent per capita) as the main independent variable, total trade and domestic private credit as control variables. All the data were transformed into logarithm in order to standardized the measurement units.

The empirical model for this study can be formed as below:

$$LGDP_t = \beta_0 + \beta_1 LEU_t + \beta_2 LT_t + \beta_3 LDC_t + \varepsilon_t \quad (1)$$

where $LGDP$ is logarithm of Gross Domestic Product, LEU is logarithm of energy usage, LT is logarithm of trade, LDC is logarithm of domestic credit and ε refers to disturbance. β_0 is the intercept while β_1, β_2, and β_3 are the coefficients of the parameters of estimate.

Augmented Dickey-Fuller (ADF) (1979), Philip Perron (PP) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) are utilized to test the stationarity of the time series variables.

Augmented Dickey-Fuller (ADF) Unit Root Test

Augmented Dickey-Fuller (ADF) (1979) unit root test is employed to test the time series properties to evade spurious regression. Equation (2) indicates the equation for the ADF test.

$$\Delta Y_t = \beta_0 + \beta_1 t + \theta_1 Y_{t-1} + \sum \theta_{2j} \Delta Y_{t-j} + \varepsilon_t \quad (2)$$

where Y_t is variable of interest, Δ is to differencing operator, t is to time trend and ε is to the error term. The parameters to be estimated are β_0, β_1, θ_1 and θ_{2j} where the null and alternative hypotheses are as followed:

$$H_0: \theta_1 \geq 0$$
$$H_a: \theta_1 < 0$$

when the value of computed test statistic is larger than the critical value, the null hypothesis of Y_t has a unit root or non-stationary can be rejected and vice versa.

Phillips-Perron (PP) Unit Root Test

Phillips and Perron (PP) (1988) unit root test also incorporated in this study to deal with serial correlation and heteroscedasticity in the errors. PP has test regression as follow:

$$\Delta y_t = \beta' D_t + \pi y_{t-1} + \mu_t \quad (3)$$

where μ_t is $I(0)$ and may be heteroscedasticity. The PP tests will modify the test statistic $t_n = 0$ and $T_{\pi\hat{}}$ to correct the serial correlation and heteroscedasticity in the errors μ_t.

Kwiatkowski Phillips Schmidt Shin (KPSS) Unit Root Test

KPSS is different from others unit root test which the null hypothesis of this test is opposite with others unit root test such as ADF test and PP test. KPSS test is based on residuals from OLS regression, the LM statistic is defined as follow:

$$LM = \sum_t \frac{S(t)^2}{(T^2 f_0)} \quad (4)$$

where f_0 is an estimator of the residual spectrum at frequency zero and where $S(t)$ is a cumulative residual function.

Johansen and Juselius Cointegration Test (JJ Test)

The purpose of this test is to test the existence of long-run equilibrium in the model. There are two measurements, which are trace test and maximum eigenvalue tests. The equation for trace test is expressed as below:

$$\lambda_{trace} = -T \sum_{i=r+1}^{n} \ln(1 - \hat{\hat{\lambda}}_i) \quad (5)$$

where T represents the number of valid observations, $\hat{\hat{\lambda}}_i$ is the i^{th} largest estimated eigenvalue. The null hypothesis for likelihood ratio trace test is the r < 0 whereas the alternative hypothesis is r $\leq 1, r \leq 2, \ldots r \leq p$.
The equation for maximum eigenvalue test is expressed as below:

$$\lambda_{max} = -T\ ln\left(1 - \hat{\lambda}_{r-1}\right) \qquad (6)$$

where T represents the number of valid observations, $\hat{\hat{\lambda}}_i$ is the i^{th} largest estimated at (r-1). The null hypothesis of this maximum eigenvalue test is equal to r cointegrating vector and r+1 is the alternative hypothesis.

Threshold Regression
The threshold regression analysis is adopted to identify the threshold level and estimate the effect of the energy consumption on growth as either above or below the threshold level. Equation (7) and (8) depict the setup of the threshold regression.

$$LGDP_t = \beta_1 + \beta_{11}LEU_t + \beta_{12}LT_t + \beta_{13}LDC_t + \varepsilon_{1t} \qquad if \quad LEU_t \leq \theta \qquad (7)$$

$$LGDP_t = \beta_2 + \beta_{21}LEU_t + \beta_{22}LT_t + \beta_{23}LDC_t + \varepsilon_{2t} \qquad if \quad LEU_t > \theta \qquad (8)$$

where θ is the threshold level. The threshold values are identified via minimization of the sum of squared errors across the estimated models (Bai and Perron, 2003).

Empirical Findings
Table 2 shows the results of unit root tests based on ADF, PP and KPSS to test the stationarity of the variables. Under the ADF and PP unit root tests, all the variables are non-stationary at level due to non-rejection of the null hypothesis of contain unit root. However, the variables are stationary after first difference. In term of KPSS results, null hypothesis of contain no unit root is rejected and this implies non-stationary at level, but become stationary after first difference. In summary, the time series variables in the model are *I*(0) at level and *I*(1) at first difference.

Table 2: Unit Root Test Results

	Augmented Dickey-Fuller (ADF)		**Philips Perron (PP)**		**Kwiatkowski-Phillips-Schmidt-Shin (KPSS)**	
Variables	**At Level**	**First Difference**	**At Level**	**First Difference**	**At Level**	**First Difference**
LGDP	-2.2262(1)	-4.1574(0)***	-1.9218(2)	-4.1845(1)***	0.1086(4)**	0.0815(1)
LEU	-1.1535(0)	-5.0727(0)***	-1.3781(3)	-5.0523(2)***	0.1596(4)**	0.1607(2)
LT	-0.4393(0)	-4.7623(0)***	-0.6406(2)	-4.7570(2)***	0.1762(4)**	0.2512(3)
LDC	-2.0155(1)	-3.9123(0)***	-2.0124(3)	-3.8368(2)***	0.1625(4)**	0.2255(3)

Notes: Asterisks *, ** and *** denote significance levels: 10%, 5% and 1%. LGDP = logarithm of GDP per capita, LEU = logarithm of Energy Usage, LT = logarithm of total trade and LDC = logarithm of domestic private credit. Automatic lag selection by Schwarz Info Criterion (SIC) for ADF. Values in parenthesis under ADF refers to lag and under PP and KPSS refers to bandwidth. Null hypothesis under ADF test and PP test state that time series variable is non-stationary, while null hypothesis under KPSS test states that time series variables is stationary.

The same integration order of the time series variables under the unit root tests enable testing of long-run equilibrium using Johansen and Juselius (1990) cointegration test. Based on the cointegration test results in Table 3, empirical results show that null hypothesis of no-cointegrating vector can be rejected. This indicates presence of one cointegrating vector in the system. Therefore, this implies existence long-run equilibrium relationship between the variables.

Notes: Trace refers to Likelihood Ratio Trace Test while Max refers to Maximum Eigenvalue Test. *k* denotes as the optimal number of lag and r denotes as the number of cointegration vector(s). The lag length chooses according to the Schwartz criterion (SC). Asterisks ** indicate as the rejection of null hypothesis at 5% significance level.

Table 3: Result of Johansen Cointegration Test

k=2, r=1

Hypothesis		Test statistic		Critical values (95%)	
H_0	H_1	Trace	Max	Trace	Max
r = 0	r=1	61.36733**	38.1903**	47.8561	27.5843
r≤ 1	r=2	23.1769	19.2137	29.7970	21.1316
r≤ 2	r=3	3.9631	3.9631	15.4947	14.2646
r≤ 3	r=4	0.0005	0.0005	3.8414	3.8414

Next, Table 4 shows the regression results with non-threshold estimation and with threshold estimation as either below or above the threshold level. Under the non-threshold result, energy consumption has a significant positive impact on economic growth in ASEAN-4 countries with coefficient of 1.578. This finding is consistent with previous studies such as Rahman et al. (2015); Kasperowicz (2014); Yildrim et al. (2014); Adhikari and Chen (2012); Narayan and Smyth (2008); Lee (2005); Soytas and Sari (2003); Imran and Siddiqui (2010); and Masih and Masih (1996). Trade has inverse relationship with economic growth but domestic credit is statistically insignificant. In Table 5, threshold test result indicates that null hypothesis of non-threshold is rejected at 5% significance level. The *F*-statistic value of 16.59 is greater than *F*-critical value of 16.19. This implies that existence of threshold in the model. The threshold level is 8.20, where it is approximately 3,640 kg of oil.

Table 4: Linear Regression Result

Variables	Coefficients	*t*-statistic
	Non-Threshold	
LEU	1.5782***	42.7751
LT	-0.3917***	-7.1926
LDC	0.0248	0.5332
C	16.5669***	90.8974

Notes: Asterisks *, ** and *** denote significance levels: 10%, 5% and 1%. LGDP = logarithm of GDP per capita, LEU = logarithm of energy usage, LT = logarithm of total trade, LDC = logarithm of domestic private credit and c = constant.

Table 5: Threshold Test

Null Hypothesis	*F*-statistic	*F*-critical value	Threshold Level
0 vs 1	16.59**	16.19	8.20

Notes: Asterisks ** denotes significance level of 5%. *F*-critical value is based on Bai-Perron (Econometric Journal, 2003).

This study further examines the possibility of the non-linearity of the relationship between energy consumption and economic growth of ASEAN-4 as a whole as shown in Table 6. Under the threshold result where energy consumption is below 8.20 level, energy consumption has significant positive impact on growth with coefficient of 0.675. In addition, trade and domestic credit also depict positive impact on growth with coefficients of 0.428 and 0.454, respectively. Under the threshold result where energy consumption is above 8.20 level, energy consumption still has positive impact with larger coefficient of 1.525. Nevertheless, trade and domestic credit have inverse impact of growth. Empirical findings show that the impact of the energy consumption on growth become greater from coefficient of 0.675 when below the threshold level of 8.20 and become 1.525 when above the threshold of 8.20. This signifies the essential of the energy consumption where the impact of energy consumption on growth become larger when exceeding the 8.20 threshold level or 3,640 kg of oil.

Table 6: Non-Linear Regression Results

Variables	Coefficients	*t*-statistic
	Threshold: LEU ≤ 8.20	
LEU	0.6745***	5.1900
LT	0.4277***	3.9839
LDC	0.4538***	5.5636
C	16.8089***	42.5578
	Threshold: LEU > 8.20	
LEU	1.5245***	37.6543
LT	-0.4988***	-9.5431
LDC	-0.0249***	-0.3815
C	17.9532***	28.5371

Notes: Asterisks *, ** and *** denote significance levels: 10%, 5% and 1%. LGDP = logarithm of GDP per capita, LEU = logarithm of energy usage, LT = logarithm of total trade, LDC = logarithm of domestic private credit and c = constant.

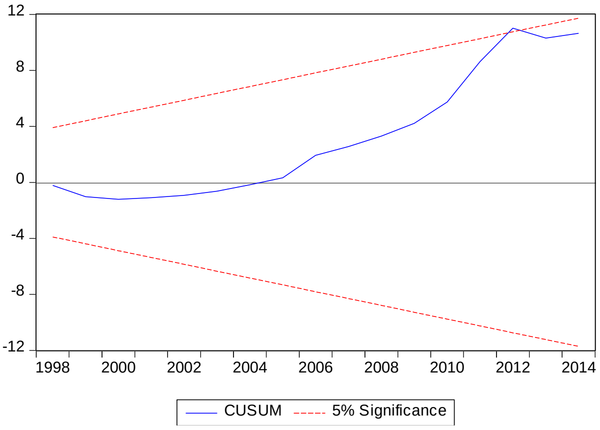
Table 7 shows the diagnostic tests results for the model. The Jarque Bera Normality test result indicates the residuals are normally distributed where the null hypothesis of the residuals is normally distributed cannot be rejected. There is also no serial correlation problem where the null hypothesis no serial correlation cannot be rejected under the Breusch-Godfrey Serial Correlation LM Test. Furthermore, the variances are homoscedastic where the null hypothesis of variances are constant cannot be rejected under the Heteroskedasticity White Test. There is also no misspecification in the model under the Ramsey RESET Test. The results of the CUSUM test and CUSUM^2 show that the models are stable.

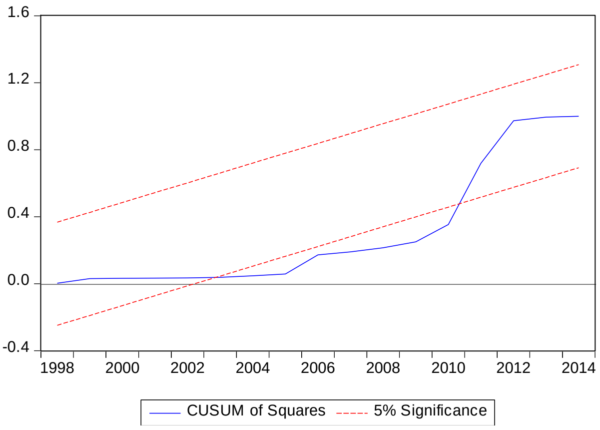
Table 7: Diagnostic Tests

Tests	Coefficients
Normality Test Jarque Bera	1.8347 [0.3995]
Breusch-Godfrey Serial Correlation LM Test:	1.8068 [0.1850]
Heteroskedasticity Test: White	0.9969 [0.5102]
Ramsey RESET Test	0.276981 [0.6031]
CUSUM test	Stable
$CUSUM^2$ test	Stable

Notes: Values in the bracket refers to probability.

Figure 2: Stability Test





Conclusion

This study intends to examine the impact of energy consumption on economic growth in ASEAN-4 countries as a whole. The effect of the non-linearity of the relationship between energy consumption and growth is examined via Threshold Analysis method using annual data from 1980 to 2014. Empirical results show that energy consumption has significant positive impact on economic growth in the panel ASEAN-4 countries. This signifies the importance of the energy usage in stimulating the economic growth in the region. Furthermore, the non-linearity results show that the impact of the energy consumption on growth become greater when the energy consumption is above the threshold level of approximately 3,640 kg of oil. Initial energy consumption will contribute to growth and when it reaches beyond the threshold level, the impact of the energy consumption on growth become larger. This implies that energy consumption remains key contributor to economic growth in ASEAN-4 countries.

This study contributes to the field in term of identifying the threshold level of energy consumption. Despite examining the linearity long-run impact on growth, this study examines the possibilities of non-linearity impact of energy consumption on growth in ASEAN-4 region.

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