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Dynamic Cointegration Link between Energy Consumption and Economic Performance: Empirical Evidence from Malaysia

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***Abstract*—During the past three decades, demand for energy in Malaysia grew rapidly, increasing at an average rate of 5% in the 1980s and 12% in 2009, surpassing the gross domestic product growth of 5%; and 3% over the corresponding period. The main objective of this study is to identify sustainability between energy consumption and economic performances during the past three decades by applying Ordinary Least Square Engel-Granger (OLS-EG), Dynamic Ordinary Least Square (DOLS), Autoregressive Distributed Lag (ARDL) bounds testing approach and Error Correction Model (ECM). Utilizing data from 1971-2008, the findings of this study reveals that there is a bidirectional co-integration effects between total energy consumption and Malaysia's economic performance. The key result from this study shows that, energy consumption in Malaysia is on sustainable limits with 57% speed of adjustment to reach long run equilibrium caused by short run shocks in Malaysia's economic performance.**

***Index Terms*—ARDL, DOLS, economic performance, energy consumption, OLS-EG**

I. Introduction

Throughout the years, the government of Malaysia has formulated numerous energy related policies in order to ensure long-term reliability and security of energy supply for sustainable socio-economic development in the country [22]. The Fuel Diversification Policy in Malaysia was continuously reviewed to ensure that the country is not too dependent on a single source of energy. Since 1980, the Malaysian government has implemented four fuel diversification strategies in the energy mix which are the oil, natural gas, hydro and coal. Meanwhile, the renewable energy development in Malaysia is still in early stage and expected to be contributing to Malaysia's energy production in up-coming years. Malaysia's economy also has contracted more sharply than expected in 2009, causing export to plunge where fixed investment and private consumption also declined. Government action to mitigate the decline included two fiscal stimulus packages, an easing of monetary policy, and a relaxation of local-equity requirements for foreign investment. Most economies have increased their energy productivity.

Like most developing countries in Asia region, Malaysia is also an energy intensive growing economy as shown in Fig. 1 [31]. Comprehensively, it can be seen that the energy use in Malaysia increased rapidly as the economic growth increased clear illustrate through Fig. 2 [31]. Surprisingly, it seems that the Malaysia's economic growth was volatile over-time, but the level of energy use maintain with an increasing trend. Compare to 5 ASEAN countries, Singapore is leading in term of energy use for the past 3 decades and followed by Malaysia, Thailand, Indonesia and Philippines. It's quit an interesting figure that we should highlight here because, although Singapore is categorize as a small country, but the amount of energy use is higher than other ASEAN countries [7]. Secondly, all of the 5 ASEAN countries have an increasing trend of total energy use although most of the countries do not achieve continuous economic growth for the past 3 decades. Actually, the GDP per energy unit differs between economies because economies use energy more or less efficiently and because of differences in industrial structures. For instant, agriculture and service sectors generate higher GDP per energy unit than manufacturing sector. Therefore, if two economies have identical industrial structures, differences in GDP per energy unit will reflect differences in the efficiency of energy use. Similarly, if a country produces more GDP per unit over time, this implies better energy efficiency only if the industrial structure has not change [7, 22, 31].

The objective of this study is to determine the sustainability and cointegration between total energy consumption and economic growth for Malaysia using time series data in the long run and short run using empirical approach. This paper is thus organized as follows. The second section focuses on literature review, the third section deals with methodology, the fourth section discusses the empirical findings and the final section concludes.

II. Literature Review

A brief review of literature to date indicates that the study done by Kraft and Kraft [15] is pioneer in the study of causal relationship between energy consumption and income growth. Kraft and Kraft's have provided evidence to support unidirectional causality running from income to energy consumption for the United States from 1947-1974 periods. This implies that energy conservation policies may be initiated without deteriorating economic side effects [8]. Since this study established, several authors have joined the

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debate, some who have opposed and empirically challenged Kraft and Kraft's initial findings; and others who have supported their views. Following their seminal work, the subsequent studies of Akarca and Long [2], Yu and Choi [34], Erol and Yu [12], Abosedra and Baghestani [1]; Hwang and Gum [13]; and Ang [5] which differ in terms of the time period covered, country chosen, econometric techniques employed, and the control variables used in the estimation, have either confirmed or contradicted the results of Kraft and Kraft's results (Ang, [4]).

For instant, Yu and Choi [34] have studied the causal linkages between gross national income and various types of energy consumption for a number of countries. The interesting part is, they did not find any causal linkages for the United States, United Kingdom and Poland; but they found a causal relationship between income and total energy consumption for South Korea; and unidirectional causality total energy consumption and income for the Philippines. Yu and Jin [35] also have study the cointegration scenario between energy consumption and output growth in the United States using monthly data. Again, the results indicates that energy consumption do not have long run causality with income and employment. Furthermore, Chebbi and Boujelbene [10] have investigates the linkages between economic growth, energy consumption and CO_2 emission by applying Tunisian data over the period of 1971-2004. Additional variable used in this study indicates, the economic growth, energy consumption and CO_2 emission are related in the long run and provide some evidence of inefficient use of energy in Tunisia, since environmental pressure tends to rise faster than economic growth. Meanwhile in short run, the results indicate economic growth with a positive causal influence on energy consumption growth.

Recent studies have tended to focus on error correction model and cointegration approach (Masih and Masih [18]; Asafu-Adjaye [6]; Stern [28]; Chang and Wong [9]; Jumbe [14]). Most of these studies used Granger causality analysis with causal relation analysis. Jumbe [4] for example has applied the Granger causality and ECM techniques using 1970-1999 data for Malawi to examine cointegration and causal relation between electricity consumption and GDP growth. Altinay and Karagol [3], Mazumder and Marathe [20]; and Mehrara [21] has also investigates the causal relationship between electricity consumption and economic growth. For example, Altinay and Karagol [3] done his study in Turkey and found that both of the series were stationary process around the structural break. Thus, two different methodologies have been employed to test the Granger non-causality analysis. Mazumder and Marathe [20] examined the causal relationship between per capita electricity consumption and per capita GDP in Bangladesh using cointegration and ECM. The finding indicates that there was unidirectional causality running from per capita GDP using per capita electricity consumption. Meanwhile, Mehrara [21] have used examined the causal relationship between per capita energy consumption and per capita GDP in a panel cointegration analysis of 11 oil exporting countries (Iran, Kuwait, Saudi Arabia, United Arab Emirates, Bahrain, Oman, Algeria, Mexico, Venezuela and Ecuador). The results imply that energy conservation done through reforming energy price policies has no damaging repercussions on economic growth for oil exporting countries.

Wolde-Rufael [30] has applied a cointegration test and a modified version of the Granger causality test to investigate the long run and causal relationship between per capita GDP and per capita energy use for 19 African countries for the 1971-2001 periods. Unfortunately, the results did not provide a definite stance on the existence or non-existence of a long run or a causal relationship between energy consumption and economic growth. While, Lee [17] re-investigated the co-movement and the causality relationship between energy consumption and GDP in 18 developing countries, using data for the 1975-2001period and employing panel stationary tests, heterogeneous country effect. The long run relationship was estimated using fully modified ordinary least square techniques (FMOLS). The evidence showed that there is long run and short run causalities running from energy consumption to GDP, but no evidence of bidirectional causality. This result indicated that energy conservation might harm economics growth in developing countries regardless of being transitory or permanent. On the other hand, Odhiambo [24] in his study on Tanzania using time series data from 1971 to 2006 found a unidirectional causal flow of total energy consumption and economic performance using ARDL approach and concluded that energy consumption spurs economic growth in Tanzania.

Most of past studies have applied the Granger causality analysis with ECM techniques to identify the causal relationship between electricity consumption, economic growth; and CO_2 emissions [5, 16, 32]. Unlike majority of previous studies, this study used combination of OLS-EG, DOLS, ARDL and ECM approaches to identify the long run and short run elasticity between total energy consumption and economic performance for Malaysia. This study will fulfill the gaps, especially studies regarding energy consumption and economics sustainability for Malaysia using econometrics modeling.

III. Data and Estimation Techniques

The data used in this study are the total energy consumption and economic growth for the entire period of 1971-2008. Prior to the empirical analysis, both variables are transformed into logarithm form. Both of the data used in this study gathered from the World Development Indicators [31]. A simple origin destination model between total energy consumption (kg of oil equivalent per capita) and economic growth (proxy to economic performance) can be written as follows:

$$EC_t = f(GDP_t)$$

Where;
EC_t – Total energy consumption
GDP_t – Economic performance

To avoid the spurious regression and random walk problem, stationary tests were conducted for both series used in this study to ensure they were stationary before applying the Engle-Granger cointegrating test or well known as OLS-EG. The simplest version of the model to be analyzed is the random walk as shown in equation (1):

$$y_t = \gamma y_{t-1}+\varepsilon_t \text{ where } \varepsilon_t \sim N[0,\sigma^2] \quad (1)$$

The advantage of this formation is that it can accommodate higher-order autoregressive processes in ε_t. The basic problem that encountered in the use of ADF tests is the lack power of the tests. The power of a test is its ability to detect a false null hypothesis and it is measured by the probability of rejecting the null hypothesis when it is false. It has been proved; using Monte Carlo simulations, the power of the unit root tests is very low. Therefore, many alternative stationary tests been suggested, in some cases to improve on the finite sample properties and in others to accommodate more general modeling framework. To test the order of integrations, this study employs ADF and PP tests. It is widely acknowledged that ADF and PP tests are command stationary tests applied in macroeconomics variable studies recently. The regression equation for the ADF test can be written as shown in equation (2):

$$\Delta Y_t = \alpha_t + \beta_t \gamma_t + \rho Y_{t-1} + \sum_{i=1}^{q} \delta \Delta Y_{t-1} + \varepsilon_t \quad (2)$$

Where, the ‘γ’ symbol denotes time trend, Y is the variable in estimation procedure, ε_t represent the distributed random error tem with zero value of mean and constant variance. The PP statistic test may be computed for the same function forms as been discussed earlier to overcome the weakness of ADF stationary test estimation:

$$y_t = \delta_t + \gamma_0 y_{t-1} + \gamma_1 y_{t-1} + ... + p\Delta y_{t-p} + \mu_t \quad (3)$$

$$y_y = \delta_t + \gamma y_{t-1} + \gamma_1 \Delta y_{t-1} + \gamma_2 \Delta y_{t-2} + ... + \gamma_p \Delta y_{t-p} + \varepsilon_t \quad (4)$$

Eventually, by combining the ADF and PP procedure, it is likely to provide more clear-cut conclusion with regard to the order of integration for both of the series. Actually, the ADF and PP stationary tests does not follow a normal distribution even when the sample size is very large or asymptotically. The EC and GDP is assume to be sustainable when unit root testing for stationary involves for the residual series and the results indicate results as *I*(0). However, if the stationary test indicates *I*(1), therefore both variables are not cointegrated and unsustainable limits. The Ordinary Least Square (OLS) is consistent with simple regression tests, but in some circumstance the regression result not able to declare the cointegration relation between the dependent and independent variables in long run. To overcome this problem, Dynamic Ordinary Least Square (DOLS) estimator has been proposed by Stock and Watson [29]. DOLS estimator of the cointegrating regression equation includes both dependent and independent variables which is in *I*(0) stationary level and the leads and lags of explanatory variables in *I*(1) level. This DOLS estimation allows for simultaneity bias and has introduces the dynamic specification of the OLS estimation model [19]. The following equation indicates this studies DOLS specification model:

$$EC_t = \beta_0 + \beta_1 GDP_t \sum_{j=-p}^{p} \vartheta_j \Delta GDP_{t-j} + \varepsilon_t \quad (5)$$

Where EC is the total energy consumption, GDP is the economic performance indicator variable and Δ represent the lag operator. The lag operator of this study is identified using the minimum value of AIC, which can be indicate through the unrestricted vector autoregressive (VAR) operation system by applying the lag length criteria identification technique. Furthermore, DOLS estimation also able to present evidence base on Monte Carlo simulations, where the estimators are more robust in small range of samples compare to alternative approaches. According to Stock and Watson [29], the presence of leads and lags of different variables which has integration vectors, eliminates the bias of simultaneity within a sample and DOLS estimates have better small sample properties and provide superior approximation to normal distribution. Meanwhile, the ARDL bound test developed by Pesaran, Shin and Smith [26] is used in study to identify the long run relationship between EC and GDP. It is believed that ARDL estimation technique has a numerous advantages compared to other integration estimation techniques. The main advantage of ARDL is because of it flexibility, which is can be applied when the variables are in different order on integration [25]. The ARDL model used in this study can be expressed as follows:

$$\Delta EC_t = \alpha_0 + \sum_{i=1}^{n} \beta_1 \Delta EC_{t-i} + \sum_{i=0}^{n} \varphi_2 \Delta GDP_{t-i} + \delta_3 GDP_{t-1} + \delta_4 EC_{t-1} + \mu_t \quad (6)$$

$$\Delta GDP_t = \alpha_0 + \sum_{i=1}^{n} \beta_1 \Delta GDP_{t-i} + \sum_{i=0}^{n} \varphi_2 \Delta EC_{t-i} + \delta_3 GDP_{t-1} + \delta_4 EC_{t-1} + \mu_t \quad (7)$$

The first part of equation (6) and (7) with β and φ represent the short run dynamics of the model. Meanwhile, the second part with δ shows the long run dynamics between EC and GDP. The null hypothesis of both equations is $\delta_3=\delta_4=0$ and is tested against the alternative hypothesis $\delta_3\neq\delta_4\neq0$ by judging using the F-statistics. This ARDL approach will estimate $(p+1)^k$ numbers of regression in order to obtain optimal lag length for each variable of this study [27]. Where the p is representing the maximum number of lags which will be used and ‘k’ is the number of long run relationship estimated using ARDL approach of estimation. Once long run relationship exists between GDP and EC, therefore the error correction model can be estimate easily. The estimated ECM term should have a negative sign and statically significant. Generally, the estimated value of ECM term will indicate the speed of adjustment to long run equilibrium in response to the disequilibrium caused by short run shocks of the previous period. The short run relation model with ECM term can be express as follow:

$$\Delta EC_t = \beta_0 + \sum_{i=1}^{n} \beta_1 \Delta GDP_{t-i} + ECM_{t-1} \quad (8)$$

After the long run and short run relationship between both variables identified, then the stability Cumulative Sum of Recursive Residuals (CUSUM) and Cumulative Sum of Square of Recursive Residuals (CUSUMQ) tests will be conducted in order to find out the stability between the estimated series through this study.

IV. Empirical Findings

Table I summarizes the outcome of the ADF and PP stationary tests. The null hypothesis tested is that the variable under investigation has a unit root against the alternative that it does not. The lag-length is chosen using the AIC after testing for first and higher order serial correlation in the residuals. In the first half of Table I, the null hypothesis has a unit root cannot be rejected by both ADF and PP tests. However, after applying the first difference, both ADF and PP tests reject the null hypothesis.

TABLE I. Result Of Stationary Tests With Trend

	ADF Test (τ)	*I*(d)	PP Test (Z_τ)	*I*(d)
$Growth_t$	-3.691[1]	-	-3.103[1]	-
EC_t	-2.699[0]	-	-2.677[1]	-
$\Delta Growth_t$	-4.576[0]	*I*(1)	-4.469[3]	*I*(1)
ΔEC_t	-7.200[0]	*I*(1)	-8.472[8]	*I*(1)

Figure in [ ] indicates the lag length based on the AIC for ADF test and Newey-West using Kernel Bandwidth value for PP test.

Since the data appear to be stationary by applying the ADF and PP tests in first differences, therefore this study will not perform further stationary tests. The null hypothesis has a root has been rejected in both ADF and PP tests at levels *I*(1), not in *I*(0). This means that the energy consumption and economic growth time series follows a random walk pattern, which possesses a purely non-predictable component. After finding the integration level of both variables, the second step is to identify the lag length criteria. In this study, the lag length criteria was obtain from unrestricted VAR estimation results which based on the minimum value of AIC and SBC. In this study the AIC indications will be used consistently throughout all of findings required the minimum AIC values. Based on the VAR estimation, the minimum value of AIC and SBC is equal to 2 and therefore the total number of regression estimated through ARDL approach is equal to $(p+1)^k=(2+1)^2=9$ [27]. The lag length criteria results are reported in Table II as follows:

TABLE II. Selection Of Lag Length Criteria

Lag Order	Akaike Information Criteria (AIC)	Schwartz Bayesian Criteria (SBC)
1	-3.882	-3.618
2	-4.129[(a)]	-3.685[(a)]
3	-4.038	-3.409

[(a)] refers to minimum lag length selection criteria

Table III shows the results of long run cointegration testing approach using OLS-EG and DOLS approaches. The results appear to provide evidence for the existence of long run integration between EC and GDP using OLS-EG and DOLS approach. The OLS-EG method is based on Engle-Granger method which has been developed by Engle and Granger [11]. This OLS-EG method is based on the analyzing stationary of error term series obtained using simple OLS estimation technique and the estimation result indicate that there is a long run relationship between EC and GDP series. The ADF and PP tests applied on error term series were in stationary at *I*(0). This means that there exists a cointegration relationship between EC and GDP series. On the other hand, in this study DOLS approach were also applied in order to identify dynamic long run cointegration between EC and GDP.

The DOLS estimation results are reported in the second half of Table III were the adjusted R^2 is equal to 0.98 and this indicates a good-fit situation of the series. The elasticity of DOLS estimation shows that in the long run, GDP simulates EC around 58%, but the leads and lags impact does not indicate any interesting results except ΔGDP_{t+2} with 19% of simulation effects with 10% significant level. The fact is when the OLS-EG and DOLS equations is estimated, the economic performance, the coefficient of the GDP shows the expected sign. Furthermore, this study also employed some of important diagnostic tests to prove the stability of the model used in this study. This study has passed the autoregressive conditional heteroscedasticity (ARCH), Breusch-Godfred serial correlation test, and Jarque-Bera normality tests. Using the OLS-EG estimation technique, the diagnostic test statistics indicates heteroscedasticity, normality and serial correlation problems. This is not a surprising indication because OLS estimation technique with huge series of data usually faced this problem although the series have good-fit of adjusted R^2. Once the DOLS estimation technique takes into account in this study, there is no evidence of heteroscedasticity and serial correlation problems appeared. The Jarque-Bera normality test also has not reject the null hypothesis; and this confirms that the estimated residual is normal distribute.

TABLE III. Estimated Long Run Coefficients

Dependent: EC_t	OLS-EG	t-Statistic	DOLS	t-Statistic
Constant	-5.692[(a)] (0.073)	15.280	-7.021[(a)] (0.397)	-17.655
GDP_t	0.526[(a)] (0.015)	34.560	0.579[(a)] (0.015)	36.509
ΔGDP_{t+1}			0.016 (0.111)	0.144
ΔGDP_{t-1}			-0.121 (0.100)	-1.207
ΔGDP_{t+2}			0.191[(c)] (0.112)	1.718
ΔGDP_{t-2}			0.027 (0.098)	0.276
PP (τ) ADF (Z_τ)	-7.197[(a)] -8.730[(a)]			
Diagnostic test statistics				
Adj. R^2	0.971		0.98	
χ^2_{Hetero}	9.350 [0.004]		0.454 [0.901]	
$\chi^2_{Normality}$	8.903 [0.012]		0.626 [0.731]	
χ^2_{Serial}	4.594 [0.017]		0.398 [0.675]	

[(a), (b)] and [(c)] denote statistically significant at 1%, 5% and 10% level and figure in ( ) and [ ] indicates standard error and p-values respectively. The heteroscedasticity and serial correlation is based on F-statistic value.

Having found that there is a long run relationship between EC and GDP by applying the OLS-EG and DOLS approach, the next step is to confirm the long run relationship using

ARDL bound testing procedure. As been illustrated in Table II, the order of lags on the first different obtained from unrestricted VAR model using AIC indicates both model have the same lag order, which is lag 2. The results reported in Table IV indicate that the null hypothesis of cointegration is rejected at the 1% of significant level using ADRL bound test of Narayan [23] and the F-statistic compared against the Narayan critical table with intercept and no trend. The calculated F-statistics are higher than the upper bound critical value at the 1% level. This implies clear evidence of cointegration relationship between EC and GDP in the long run.

TABLE IV. ARDL BOUND TEST FOR LONG RUN COINTEGRATION

Dependent variable	Calculated F-statistic	Lag Order	Relationship
$EC_{GDP}(EC \mid GDP)$	4.837[(a)]	2	Cointegrated
$GDP_{EC}(GDP \mid EC)$	5.789[(a)]	2	Cointegrated

[(a)] denotes statistically significant at 1% level and critical value bounds are from Table F in Narayan, 2005. The F-statistic value with 1% significance level in *I*(0) and *I*(1) equal to 3.957 and 4.530 respectively. The lag order selection is based on AIC.

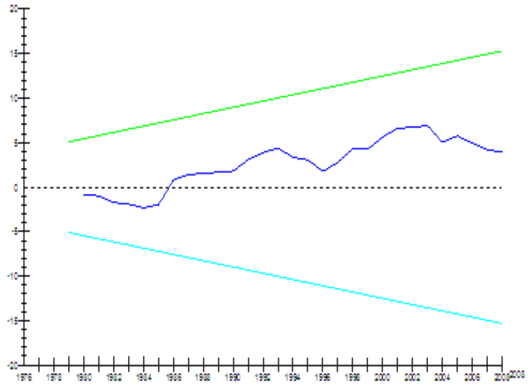
The short run relationship between EC and GDP presented in Table V is estimated by using ECM representation of the ARDL (1,0) specification. As been mention, the ARDL (1,0) is selected on the basis of AIC using unrestricted VAR estimation approach. The sign of GDP coefficient is same as in the long run and theoretically with expected sign with 1% significant level. The short-run GDP elasticity is equal to 0.32 and this value is lower than the long run GDP elasticity level. Furthermore, the estimated error correction term is equal to -0.57 and significant at the 1% level. This clearly shows that, the speed of adjustment is quit fast with 57% to reach long run equilibrium level in response to the disequilibrium caused by short run shocks of previous period. The ECM regression results reported in Table V also seems to fit with diagnostic test statistics such as heteroscedasticity, normality and serial correlation tests, besides the R^2 which equal to 0.43. All diagnostic test statistics have not rejected the null hypothesis and therefore there is no evidence of chronic stability problem appeared from the ARDL-ECM estimation results.

TABLE V. ARDL(1,0) MODELWITH ECM ESTIMATES

Dependent: ΔEC_t	Coefficient	t-statistics	Prob.
Constant	-3.884[(a)] (0.928)	-4.185	0.000
ΔGDP_t	0.328[(a)] (0.072)	4.550	0.000
ECM_{t-1}	-0.577[(a)] (0.122)	-4.733	0.000
Diagnostic test statistics			
Adjusted R^2 = 0.413, F(2,33) = 13.327[0.000] χ^2_{Hetero} =0.408 [0.527], $\chi^2_{\text{Normality}}$ = 1.061 [0.588] χ^2_{Serial} =0.890 [0.353]			

[(a)] denote statistically significant at 1% level and figure in [ ] indicates p-value.

Finally, recursive estimation using CUSUM and CUSUM square tests found that the parameters remain stable over the entire study period because both of the recursive lines are in the bound. Besides that, the recursive results also do not indicate any structural breaks for the entire period of this study. These indications clearly illustrated through Fig. 3 and 4.



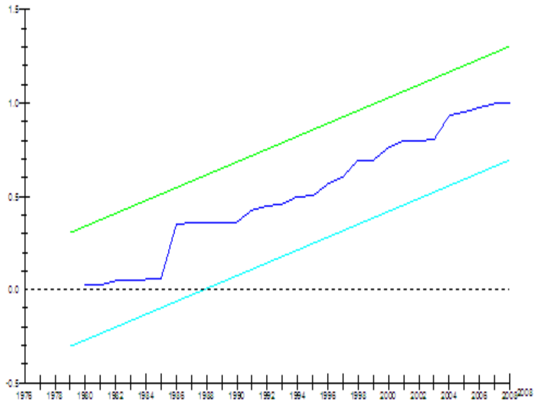


Figure 1. Plots of cusum and cusumq

V. CONCLUSION REMARKS

By utilizing data for the period 1971-2008, the results from time series analysis reveal that energy consumption and Malaysia's economic growth are cointegrated in the long run and short run by using three distinctive empirical technique such as the OLS-EG, DOLS, ARDL and ECM. Secondly, this study attempt to address the country energy consumption and economics performance vice versa which several previous studies does not clearly address. The ARDL bound test procedure shows there in bidirectional causal relation between both EC and GDP variables used in this study. Overall, energy consumption in Malaysia is on sustainable limits with comparable high speed of adjustment from disequilibrium level following short run shocks. As highlighted by Mohamed and Lee [22], the Malaysian energy sector is still dependent on non-renewable resources such as coal, fossil fuels and natural gas as major source of energy generation from past few decades until now. These sources of energy always face unstable price transmission in the open economy. Therefore, fuel price crises may harm the sustainable growth of Malaysia's economy and as a consequent it may reflect on the energy production in future because the per unit energy cost will increase and burden the government to produce energy for the citizen. In summary, due to the topical importance of the sustainable relationship between energy consumption and economic growth empirical findings, the Malaysian government should be extra careful in implementing the use of fuel as main source of energy generation and should think about other relevant source of energy such as solar, nuclear, and landfill gas in future.

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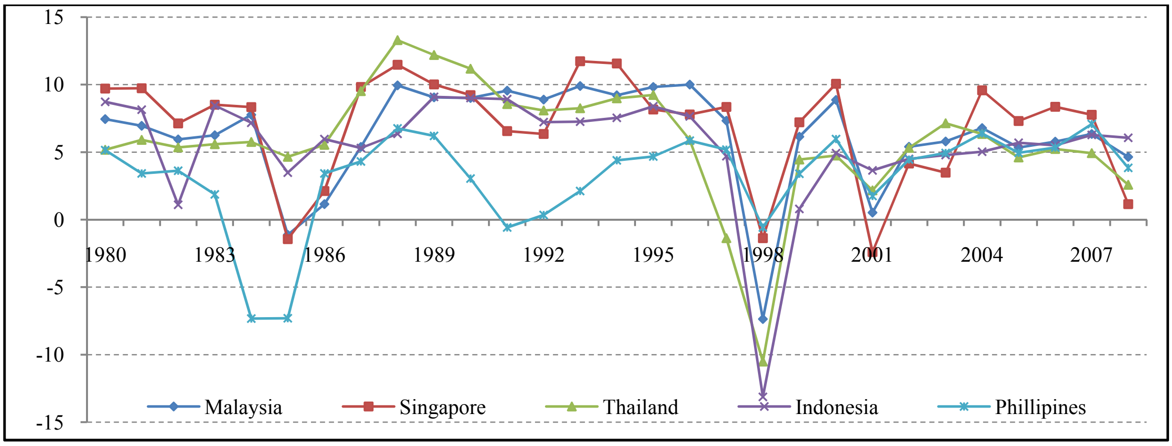

Figure 2. Economic growth in selected ASEAN countries

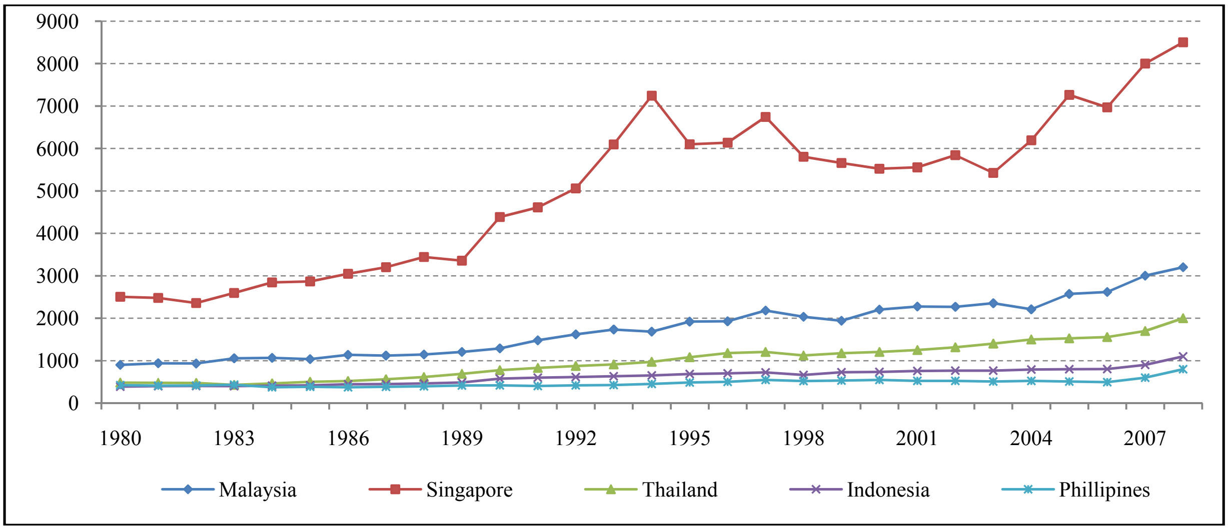

Figure 3. Energy use in selescted ASEAN countries (kg of oil equivalent per capita)