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ENERGY CONSUMPTION AND REAL GDP NEXUS: A MALAYSIAN CASE DEMONSTRATING THE IMPORTANCE OF TRADE OPENNESS

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ABSTRACT

The energy issue has been hotly debated whether is about the production, consumption or price due to its major importance in our daily lives where its use is inevitable. The primary objective of this paper is to investigate the long-term relationship between energy consumption and economic output in Malaysia when including trade openness. This focus is motivated by the concern regarding the narrowing gap between energy consumption and production as well as the importance of the export- led growth strategy. Furthermore, this study investigates the role of trade openness in the energy consumption and economic growth nexus. The annual data gathered from 1980 until 2014 utilized the Fully Modified Ordinary Least Square (FMOLS) as the main method and applied the Dynamic Ordinary Least Square (DOLS) for robustness check. The finding shows that energy is a restrictive factor for economic development and any export-led growth strategy implemented must contribute to the vital role of trade openness in order to become a stimulus for real economic growth. Moreover, the result indicates the importance of trade openness in facilitating the impact of energy consumption on economic growth.

Keywords*:* Cobb-Douglas production function; Dynamic OLS; Energy consumption; Fully-Modified OLS; Trade openness; Malaysia

1. INTRODUCTION

There has been a continuous argument among energy economists on the best relationship between energy consumption and output development, and that interchange has led to opposing views on that issue. Based on Ghali and Sakka (2004), the first viewpoint suggested that energy use is seen as a restrictive factor for economic growth. This view is largely due to the knowledge that all other factors of production, for instance, labour and capital, cannot function without energy. On the other hand, in line with the neutrality hypothesis there has been a conflicting point of view wherein energy is assumed to be neutral to economic growth. In other words, the cost of energy is negligible comparatively to the GDP and is unlikely to make any significant contribution on output growth.

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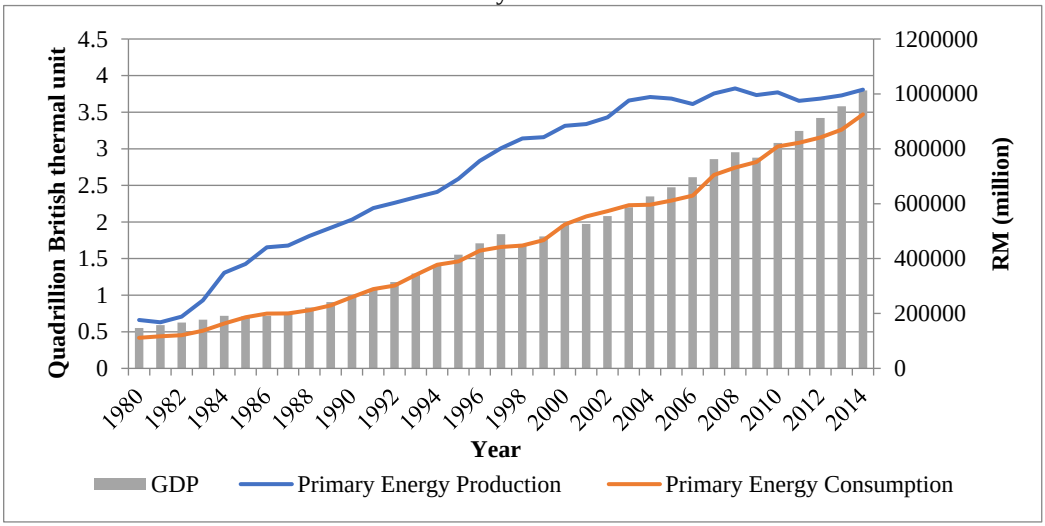
Figure 1 shows Malaysia's primary energy production and consumption versus the nation's Gross Domestic Product (GDP). From Figure 1, there is a very close relationship between energy use and GDP. Hence, from this first impression we can conclude that energy is an essential and necessary input to an economy along with other factors of production, such as capital and labour, to produce output in the case of Malaysia. Since energy is thus a necessary requirement for the economic and social development, it is important also to note that the consumption-production gap is narrowing in Malaysia as per Figure 1. Eventually, we may face challenges in order to sustain our economic growth, as energy supplies may be potentially a "limiting factor to economic growth". This paper shadows the work of Ghali and Sakka (2004); Oh and Lee (2004); Lee and Chang (2005) as well as Stern (1993), all of whom fundamentally contend that energy use is one of the crucial factors in production. Further, by incorporating energy use, capital, and labour to produce output, a production side model can be well utilized.

Figure 1: Malaysia's Primary Energy Production and Energy Consumption compared to the Malaysian GDP



Source: U.S. Energy Information Administration and World Development Indicators

However, the relationship between energy consumption and output needs to be viewed in a broader context. In order to achieve desired economic development, Malaysia has undertaken an export-led growth strategy. Malaysia's exports as a percentage of GDP increased from 41% in 1970 to 82% in 2013[1]. This increase led to recognition by the World Bank wherein Malaysia is acknowledged as one of the eight Southeast Asian countries that has successfully implemented export promotion strategies and achieved a high rate of economic growth[2]. Therefore, the vital role of trade openness as a stimulus to economic growth cannot be ignored, particularly in the context of Malaysia.

[1] These figures were obtained from the World Bank National Account Data. The data is obtained from *http://databank.worldbank.org/data/reports.aspx?source=world-development-indicators*.
[2] Facts are based on a report titled *The East Asian Miracle*.

Since Malaysia is a small-open-developing economy; the international trade is inseparable from its economic progress. Furthermore, the International Chamber of Commerce (ICC) ranked Malaysia at 30 globally in 2013 for its trade openness and is second behind Singapore for the South East Asia region[3]. Fundamentally, with the presence of trade openness this allow developing countries to import equipment, machinery and advance technology from developed countries which lowers the energy intensity leading to production of goods and services with lesser energy consumption (Shahbaz, Nasreen, Ling, & Sbia, 2014). On the other hand, trade openness can also enhance the free flow of trade across borders which increase the import and export goods and services with higher energy consumption (Nasreen & Anwar, 2014). Hence, this paper introduces an interaction term to investigate the relationship between energy consumption and economic growth conditional on the degree of trade openness.

The primary aim of this paper is to examine whether energy consumption serves as a restrictive factor or is actually neutral to economic growth in the case of Malaysia. Further, the inclusion of trade openness into the model is motivated by the fact that Malaysia practices the export-led growth strategy when dealing with its trade. Hence, trade openness plays an important role in fostering the designated export-led growth strategy. These findings will be essential to outline a sustainable resilient plan in facing the growing demand as well as to address the fear of extinction of energy resources while also taking into account the essential role of trade openness in Malaysia

The contributions of this paper are twofold. First, the inclusion of interaction term on the energy consumption and trade openness into the conventional augmented production function to the best of our knowledge has yet to have any papers published on similar issue. Second, fresh insight into the current literature is provided through a sensitivity analysis on the robustness of trade openness. The rest of the paper is thus organized as follows. Section 2 focuses on a literature review regarding the relationship between energy consumption and economic output. A discussion on the model and the description of the data is then presented in Section 3. Next, in Section 4, a discussion of the results is offered. Finally, concluding remarks and policy implications are presented in Section 5.

2. REVIEW OF THE LITERATURE

A massive amount of literature has been produced to examine the causal relationship between energy consumption and economic growth (Masih and Masih, 1996; Cheng, 1998; Oh and Lee, 2004; and Glasure, 2002). However, only a handful have investigated the elasticity of the long-term relationship (Akinlo, 2008; Lee, 2005; Narayan and Smyth, 2008) and incorporated other essential variables into a precise estimation, for example, capital and labour acting as independent variables in addition to the role of energy consumption.

Those who have undertaken a study to investigate this long-term and causality relationship include Lee (2005). The study examined the co-movement and the causality relationship between energy consumption and GDP for 18 developing countries[4]. In the case of Malaysia, it was observed that

[3] The calculation of the trade openness is aggregation based on four components namely observed openness to trade, trade policy, foreign direct investment (FDI) openness and infrastructure of trade.

[4] These countries included South Korea, Singapore, Hungary, Argentina, Chile, Colombia, Mexico, Peru, Venezuela, Indonesia, Malaysia, Philippines, Thailand, India, Pakistan, Sri Lanka, Ghana, and Kenya.

a 1% increase in energy consumption was associated with a 0.80% increase in GDP and found to be significant at 5%. On the other hand, no long-term relationship between capital stock and GDP captured was found for Malaysia. Lee and Chang (2008) added labour input as a new independent variable in addition to the existing capital stock and energy consumption for 16 Asian countries[5]. For Malaysia, a positive and significant relationship was observed between labour input, capital stock and real GDP. However, energy consumption was positively related to real GDP, but not significant.

Rahman et al. (2015) examined the causal relationship between energy consumption and economic productivity at both the aggregated as well as disaggregated levels for the case of Malaysia. The findings identified Malaysia as an energy dependent nation at both the aggregated and disaggregated level. The inefficient energy use is acknowledged in the electricity and coal consumption patterns whereby a negative relationship for Granger causality on GDP and manufacturing growth is observed. Hence, effort in improving energy efficiency and energy saving should be undertaken.

Further still, Apergis and Payne (2009) studied the relationship between energy consumption and economic growth for six Central American countries[6]. Their findings indicated that there exist a positive and significant relationship over the long term, between the variables, and indeed, that finding is in accord with the growth hypothesis. In addition, Narayan and Smyth (2008) explored the relationship between capital formation, energy consumption, and real GDP by incorporating the G7 countries[7]. The results obtained demonstrated that the causality was running from capital formation and energy consumption to real GDP and was positively correlated in the long term. However, Akinlo (2008) investigated the long run relationship utilizing a different method which is the ARDL method. The study examined the causal relationship between energy consumption and economic growth. A total of 11 sub-Saharan countries[8] were incorporated in this study utilizing the ARDL. The conclusion drawn from the ARDL test indicated that there is a positive and significant long run relationship between the energy consumption and economic growth in Senegal and Sudan.

On the other hand, the importance of trade openness when driving the economy and its progress is an established force with many researchers in agreement to the fact that open economies tend to develop more rapidly than their counterpart, closed economies do (Edwards, 1992; Grossman and Helpman, 1990). It is also widely recognized that trade openness will contribute to an increase in the exports of a nation. This well-established export-led growth hypothesis has been widely discussed by many researchers worldwide. The comprehensive literature can be accessed in Giles and Williams (2000a and 2000b).

Essentially Dollar (1992) concluded that open economies grew extraordinarily faster compared to the closed economies from 1976 until 1985. Furthermore, these results were supported by the findings drawn by Sachs et al. (1995) as well as Frankel and Romer (1999) which provided

[5] The 16 Asian countries were China, Hong Kong, India, Indonesia, Iran, Japan, Jordan, South Korea, Malaysia, Pakistan, Philippines, Singapore, Sri Lanka, Syrian Arab Republic, Thailand, and Turkey.
[6] The six countries are Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panama.
[7] These countries included Canada, France, Germany, Italy, Japan, United Kingdom, and the United States.
[8] The eleven sub –Saharan African countries include Cameroon, Cote D'Ivoire, Congo, Gambia, Ghana, Kenya, Nigeria, Senegal, Sudan, Togo and Zimbabwe.

evidence on the positive trade-growth relationship. However, the investigation for 51 less developed countries[9] (LDCs) by Sarkar (2008) provides contradicting results. Sarkar (2008) studied the relationship between openness and growth utilizing the annual data from 1981 until 2002. The findings from the study indicates that majority of LDCs incorporating the East Asian countries experienced no positive long-term relationship between openness and growth during the period spanning from 1961 until 2002.

Moreover, Lean and Smyth (2010) investigated the causal relationship of the augmented production function between the aggregate output, electricity consumption, exports, labour and capital for the case of Malaysia. Essentially, the results indicated the Granger causality relationship runs from export to aggregate output which is consistent with the export-led growth hypothesis. Nasreen and Anwar (2014) examined the causal and co-integration relationship between economic growth, trade openness and energy consumption. The study undertaken incorporated 15 Asian countries[10] and the data set employed ranging from 1980 until 2011. Specifically, for the case of Malaysia, the FMOLS and DOLS test suggest a positive relationship between economic growth and trade openness on energy consumption. Furthermore, Sohag et al. (2015) introduced technological innovation as the new exogenous variable to the existing relationship between economics growth and trade openness on energy consumption. The study adopts the time series annual data spanning from 1985 until 2012 for the case of Malaysia. The finding indicated that the trade openness increases the domestic energy use in the long run. However, the technological innovation plays an essential role in reducing the energy use by improving energy efficiency.

The studies carried out on Malaysia mainly focused on a specific sector rather than the economy as a whole, wherein more interest is given to the relationship between trade openness and growth of the manufacturing sector than to the economy as a whole as measured by GDP. For instance, Okamoto (1994) examined the effect of trade and FDI liberalization policies on the economic performance of Malaysia, emphasizing the productivity of the manufacturing sector. These findings indicated that liberalization policies at large did show positive effects on the economy. On the other hand, the relationship between trade openness and growth with an emphasis given to manufacturing value added was undertaken by Chandran and Munusamy (2009). Their long-term findings indicated that trade openness positively relates to manufacturing growth**.**

This paper incorporates the trade openness into the augmented Cobb-Douglas production function and includes the conventional addition of energy consumption as well as an interaction term. Essentially, this paper contributes to the existing literature, specifically in the case of Malaysia whereby the relationship between trade openness and output is investigated on an aggregated level rather than simply choosing to focus only on a particular sector besides introducing an interaction term to examine the relationship between energy consumption and economic growth conditioned by degree of trade openness.

[9] The 51 countries included are Algeria, Argentina, Bangladesh, Bolivia, Botswana, Brazil, Burkina Faso, Cameroon, Chile, Congo, Costa Rica, Cote d'Ivoire, Dominican Republic, Ecuador, Egypt, El Salvador, Fiji, Gabon, Gambia, Ghana, Guatemala, Haiti, Honduras, India, Indonesia, Jamaica, Jordan, Kenya, Korea, Madagascar, Malawi, Malaysia, Mauritius, Mexico, Nigeria, Pakistan, Panama, Paraguay, Peru, Philippines, Rwanda, Senegal, Sierra Leon, Singapore, Sri Lanka, Thailand Trinidad and Tobago Tunisia Uruguay, Venezuela as well as Zimbabwe.

[10] The 15 Asian countries included are Pakistan, India, Bangladesh, Sri Lanka, Philippines, Thailand, Indonesia, China, Malaysia, Japan, Jordan, Iran, Korea Dem., Nepal and Vietnam.

3. RESEARCH METHODOLOGY

3.1. Model

This study employed the Cobb-Douglas production function to investigate the relationship between energy consumption and economic output with the inclusion of trade openness. The augmented Cobb-Douglas production function can thus be represented by:

$$LY_t = \alpha + \beta_1 LK_t + \beta_2 LL_t + \beta_3 LE_t + \beta_4 TO_t + \beta_5 (LE_t \, x \, TO_t) + \varepsilon_t \quad (1)$$

where LY_t indicates the log transformation for output, LK_t denotes the log transformation for capital stock, LL_t represents the log transformation of labour, LE_t shows the log transformation of energy consumption, TO_t is trade openness measured by the ratio of trade as a % of GDP which can be substituted for export/GDP, import/GDP or foreign direct investment (FDI) as a % of GDP if the sensitivity analysis is undertaken, $LE_t \, x \, TO_t$ demonstrates the interaction term between energy consumption and trade openness and ε_t exhibits the white noise. Also, α indicates the constant term and β captures the coefficient for the variables[11]. This study also uses FDI as an alternative proxy to measure trade openness because FDI is commonly used to measure capital openness (Shahbaz, Lahiani, Abosedra, & Hammoudeh, 2018). Usually a highly open nation also welcome FDI into a country. Inflows of FDI into a country are associated with technology spill over from advance countries to developing countries which lowers the energy intensity leading to production of goods and services with lesser energy consumption. Hence, it is expected that capital openness will have a similar effect as trade openness on energy consumption-economic growth nexus.

The expected sign for the relationship between capital stock and real GDP as well as energy consumption and real GDP was expected to be positively related (Lee, 2005). In addition, the relationship between labour inputs and real GDP was also expected to be positively related (Lee and Chang, 2008). Essentially, capital, labour, and energy are utilized as the input of production in which an increase in these inputs will ultimately increases the output. Next, trade openness was added into the model because Malaysia practices export-led growth strategy in dealing with its trade. Hence, trade openness plays an important role in fostering the export-led growth strategy. This will be essential in order to outline sustainable resilient plan in facing the growing demand as well as the fear of extinction of the energy resources besides taking into account the essential role of trade openness. Trade openness is expected to have a positive relationship with real GDP. This expectation is supported by the view that increased trade openness will lead to an increase in the demand for exports which will thereby contribute to an increase in real economic activity (Okamoto, 1994; Chandran and Munusamy, 2009). Fundamentally, the difference between the coefficient for energy consumption, β_3 and trade openness, β_4 indicates the general effect of energy consumption and trade openness on economic growth. On the other hand, the coefficient of the interaction term between energy consumption and trade openness, β_5 denotes the differential effect in economies that have higher degree of trade openness. Hence, a positive relationship between energy consumption and trade openness increases the economic growth. In a nutshell, all the independent variables in Equation (1) were expected to have a positive relationship with real GDP.

[11] Trend had been included in the preliminary analysis to capture the technological progress, however it is not statistically significant in all models, therefore it has been dropped from the final model.

3.2. Methodology

The estimation method for the relationship between energy consumption and economic activity will begin with the estimation of the univariate time series properties through the unit root test. After the order of integration is ascertain which is at I(1); the Johansen Multivariate Co-integration Test is utilized to detect the presence of the long run relationship. Next, the long run relationship is estimated through the Fully-Modified Ordinary Least Square (FMOLS). This is then followed by the robustness check utilizing Dynamic Ordinary Least Square (DOLS). Last but not least, a sensitivity analysis is undertaken to test for the consistency of the newly introduced variable which is the trade openness. Four proxies for trade openness namely trade/GDP, export/GDP, import/GDP, and FDI/GDP one at a time substituted to see how the results will change. The model is sensitive if the result turns out to be greatly different. The model is robust if the sign of all the estimated coefficients are widely consistent over alternative proxies.

The FMOLS method is a semi-parametric approach that is often utilized for the estimation of a single co-integrating relationship with the condition that all of the variables have to be I(1) variables. According to Amarawickrama and Hunt (2008), the FMOLS method allows for appropriate corrections for endogeneity and serial correlation effects to avoid any inference complications with the static Engle Granger (EG) method in which t-tests for estimated long run coefficients are valid. Nevertheless, there are two circumstances that are considered necessary for any application of the FMOLS method to be suitable. First and foremost, there needs to be only one co-integrating vector. Next, the independent variables should not be co-integrated among themselves. On the other hand, DOLS method can cope with small sample size as well as any dynamic sources of bias and is perceived to improve on the Ordinary Least Square (OLS) method. It is one more simple approach to use to construct an asymptotically efficient estimator to eliminate feedback in the co-integrating system. Further, this method augments a co-integrating regression with lags and leads by asymptotically eliminating any potential bias due to endogeneity or serial correlation.

Based on Pedroni (2000), the FMOLS test necessitates fewer assumptions and tends to be more robust. Furthermore, it can also correct for endogeneity and serial correlation problems besides asymptotically eliminating sample bias. Kao and Chiang (2000) concluded that the DOLS method has a smaller bias comparatively to that for FMOLS for a single regressor. Nonetheless, FMOLS is utilized as the main estimation method for this paper, fundamentally because DOLS involves adding lead and lags of the independent variables. This choice will essentially lead to a severe loss of degree of freedom because this study undertakes several independent variables as well as employs a limited sample size (Liddle, 2012). However, the results from DOLS can serve as a viable robustness test for FMOLS.

3.3. Dataset

The relationship between energy consumption and economic activity with the inclusion of trade openness in this research employed the annual data spanning from 1980 until 2014. The data on economic output is a proxy for real GDP, whereas the data on the independent variables for capital stock is a proxy using real gross capital formation and expressed in local currency. The labour variable represents the total labour force in the market. Energy consumption is in kg of oil

equivalent per capita and trade openness wherein four proxies are utilized namely trade/GDP[12], export/GDP, import/GDP, and FDI/GDP whereby net inflows foreign direct investment were utilised. All data were obtained from the World Development Indicators database except for the labour data, which were acquired from the Department of Statistics in Malaysia. Table 1 indicates the descriptive statistics for the data set employed in this study. It is observed that the output (LY) has the highest volatility recorded by the standard deviation. According to the maximum and minimum, it is indicated that all the data is in the positive range. Also, all the variables are negatively skewed except for FDI/GDP.

Table 1: Descriptive statistics

Variables	LY	LK	LL	LE	Trade / GDP	Export / GDP	Import / GDP	FDI / GDP
Mean	26.74	25.39	15.95	7.45	1.29	0.71	0.58	3.97
Median	26.85	25.61	15.99	7.55	1.45	0.77	0.64	4.04
Maximum	27.64	26.27	16.47	8.00	1.75	0.98	0.77	8.76
Minimum	25.72	24.34	15.42	6.76	0.70	0.36	0.32	0.06
Std. Dev.	0.60	0.60	0.30	0.41	0.35	0.20	0.15	1.90
Skewness	-0.21	-0.45	-0.06	-0.33	-0.49	-0.44	-0.54	0.40
Kurtosis	1.71	1.88	1.97	1.67	1.70	1.79	1.69	3.46

4. RESULTS

It is fundamental to determine the stationarity of the variables whether I(0) or I(1); a series of unit root tests were thus conducted which include Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests. The unit root test is conducted before examining the presence of co-integration. It is a challenging task in deciding which unit root test is the best. Nonetheless Enders (1995) proposed that conservative choice is to use both the Augmented Dickey-Fuller (1981) and Phillips-Perron (1998). Ultimately, if results from both the unit root tests reinforce each other; this will indicate that the test results are reliable. The lag length for ADF has been established using the Schwarz Information Criterion (SIC). On the other hand, the PP bandwidth selection is determined by the Newey-West Bandwidth.

According to Table 2, the results for both ADF and PP unit root test clearly indicate that the null hypothesis of a unit root cannot be rejected at 1% and 5% level for all the variables in their level. Nonetheless, the null hypothesis is rejected at first difference at 1% and 5% significant level. Hence, the results clearly show that all the variables are integrated of order one, I(1). Therefore, the findings denote that all the variables are non-stationary in levels whereas stationary in their first differences.

In a nutshell the findings from both the unit root tests conform the fact all the variables are I(1) process. Thus, by fulfilling the pre-requisite requirement that all the variables are of the same order in which in this case is of I(1) (Mohamed Nor and Raja Abdullah, 2013). Next is to proceed to test for the presence of long run relationship by employing the Johansen and Juselius Multivariate Co-integration Test. The result is presented in Table 3. It shows presence of co-integration for all the

[12] The calculation of trade is tabulated by having the sum of exports and imports of goods and services.

proxies based on the adjusted statistics. Next, is to ascertain the long run relationship. In order to examine the long run relationship, the Fully-Modified Ordinary Least Square (FMOLS) founded by Philips and Hansen (1990) test is adopted as the main method whereas Dynamic Ordinary Least Square (DOLS) developed by Stock and Watsons (1993) were employed for robustness checks. The estimated long-run relationship for FMOLS and the robustness check by DOLS are presented in Table 4.

Table 2: Unit root test results

Variable	Augmented Dickey-Fuller (ADF)				Phillips-Perron (PP)			
	Level		First Difference		Level		First Difference	
	Intercept	Trend and Intercept	Intercept	Trend and Intercept	Intercept	Trend and Intercept	Intercept	Trend and Intercept
LY	-1.03[0]	-1.25[0]	-4.69[0]^{a}	-4.70[0]^{a}	-0.99[1]	-1.41[2]	-4.71[1]^{a}	-4.70[0]^{a}
LK	-1.11[0]	-1.92[0]	-4.97[0]^{a}	-4.89[0]^{a}	-1.14[1]	-2.07[1]	-4.95[3]^{a}	-4.87[3]^{a}
LL	-0.53[0]	-2.62[4]	-5.24[1]^{a}	-5.13[1]^{a}	-0.53[4]	-2.79[4]	-6.06[3]^{a}	-5.96[3]^{a}
LE	-1.15[0]	-1.74[0]	-6.28[0]^{a}	-6.33[0]^{a}	-1.33[5]	-1.71[1]	-6.39[3]^{a}	-6.82[6]^{a}
Trade / GDP	-1.59[0]	-0.17[0]	-4.81[0]^{a}	-4.24[2]^{b}	-1.57[5]	-0.03[9]	-4.86[6]^{a}	-5.32[3]^{a}
Export / GDP	-1.76[0]	1.60[3]	-4.39[0]^{a}	-4.48[2]^{a}	-1.70[3]	0.84[3]	-4.46[5]^{a}	-5.35[3]^{a}
Import / GDP	-1.40[0]	-1.22[0]	-4.99[0]^{a}	-5.07[0]^{a}	-1.39[5]	-1.34[3]	-4.94[7]^{a}	-5.03[3]^{a}
FDI / GDP	-1.71[7]	-2.81[0]	-6.26[0]^{a}	-6.15[0]^{a}	-2.59[8]	-2.88[1]	-6.35[2]^{a}	-6.24[2]^{a}

Notes: a, b and c denote significance at 1%, 5% and 10% level. For ADF tests, figure in the parenthesis represents the optimum lag length selected based on the Schwarz Information Criterion (SIC). For PP tests, figure in the bracket indicates the bandwidth selected based Newey-West Bandwidth.

In a nutshell the findings from both the unit root tests conform the fact all the variables are I(1) process. Thus, by fulfilling the pre-requisite requirement that all the variables are of the same order in which in this case is of I(1) (Mohamed Nor and Raja Abdullah, 2013). Next is to proceed to test for the presence of long run relationship by employing the Johansen and Juselius multivariate co-integration test. The result is presented in Table 3. It shows presence of co-integration for all the proxies based on the adjusted statistics. Next, is to ascertain the long run relationship. In order to examined the long run relationship, the Fully-Modified Ordinary Least Square (FMOLS) founded by Philips and Hansen (1990) test is adopted as the main method whereas Dynamic Ordinary Least Square (DOLS) developed by Stock and Watsons (1993) were employed for robustness checks. The estimated long-run relationship for FMOLS and the robustness check by DOLS are presented in Table 4.

Table 3: Results for Johansen and Juselius multivariate co-integration test

Y = f (LK, LL, LE, TRADE/GDP, LE*TRADE/GDP)							
Rank	**Eigen Value**	**Trace**			**Maximal Eigenvalue**		
		Statistics	**Adjusted Statistics**	**Critical Value (5%)**	**Statistics**	**Adjusted Statistics**	**Critical Value (5%)**
r = 0	0.76	112.44	70.27[b]	69.82	45.28	28.30	33.88
r = 1	0.64	67.16	41.97	47.86	33.04	20.65	27.58
r = 2	0.59	34.12	21.32	29.80	28.56	17.85	21.13
r = 3	0.13	5.55	3.47	15.49	4.61	2.88	14.26
r = 4	0.03	0.94	0.59	3.84	0.94	0.59	3.84
Y = f (LK, LL, LE, EXPORT/GDP, LE*EXPORT/GDP)							
Rank	**Eigen Value**	**Trace**			**Maximal Eigenvalue**		
		Statistics	**Adjusted Statistics**	**Critical Value (5%)**	**Statistics**	**Adjusted Statistics**	**Critical Value (5%)**
r = 0	0.91	136.97	66.28	69.82	73.33	35.48[b]	33.88
r = 1	0.67	63.64	30.79	47.86	33.91	16.41	27.58
r = 2	0.47	29.73	14.38	29.80	19.46	9.42	21.13
r = 3	0.22	10.27	4.97	15.49	7.68	3.71	14.26
r = 4	0.08	2.59	1.25	3.84	2.59	1.25	3.84
Y = f (LK, LL, LE, IMPORT/GDP, LE*IMPORT/GDP)							
Rank	**Eigen Value**	**Trace**			**Maximal Eigenvalue**		
		Statistics	**Adjusted Statistics**	**Critical Value (5%)**	**Statistics**	**Adjusted Statistics**	**Critical Value (5%)**
r = 0	0.77	128.66	80.42[b]	69.82	47.02	29.39	33.88
r = 1	0.74	81.64	51.03	47.86	42.53	26.58	27.58
r = 2	0.64	39.11	24.45	29.80	32.75	20.47	21.13
r = 3	0.18	6.36	3.98	15.49	6.31	3.95	14.26
r = 4	0.00	0.05	0.03	3.84	0.05	0.03	3.84
Y = f (LK, LL, LE, FDI, LE*FDI)							
Rank	**Eigen Value**	**Trace**			**Maximal Eigenvalue**		
		Statistics	**Adjusted Statistics**	**Critical Value (5%)**	**Statistics**	**Adjusted Statistics**	**Critical Value (5%)**
r = 0	0.92	153.80	74.42[b]	69.82	77.30	37.40[b]	33.88
r = 1	0.67	76.51	37.02	47.86	34.56	16.72	27.58
r = 2	0.58	41.95	20.30	29.80	26.71	12.93	21.13
r = 3	0.38	15.24	7.37	15.49	14.84	7.18	14.26
r = 4	0.01	0.40	0.19	3.84	0.40	0.19	3.84

Notes: Model included 3 lags on each variable as suggested by VAR order selection. Also, b indicates 5% significance level.

Table 4 shows a summary of the estimated long run coefficients for FMOLS and DOLS. First, we will test the basic model that included only labour and capital (Model 1a and 1b). Then, we will add energy consumption into the model (Model 2a and 2b). Finally, we will add trade openness and interaction term into the model (Model 3a, 3b, 4a, 4b, 5a, 5b, 6a and 6b). Four alternative proxies namely sum of exports and imports of goods and services to GDP, export to GDP, import

to GDP ratio and FDI to GDP will be used for trade openness. Model 3a for FMOLS indicates the main results for this paper, whereas Model 3b for DOLS serves as robustness check.

According to the FMOLS findings from Model 3a in Table 4, all the estimated coefficients are statistically significant and carry the expected positive sign. These findings mean that an increase in capital (LK), energy consumption (LE), and trade openness (trade /GDP) will increase output (LY). This result is in accordance with the theory that states that as capital input, energy consumption, and trade openness increase, output will also increase. Also, the interaction term has positive relationship between energy consumption and trade openness which contributes positively to the economic growth. Our results (Model 3a) show that a 1% increase in the LK increases the LY by 0.15% and that relationship is significant at a 1% level. This finding is also in accordance with Lee (2005) whereby the author found a positive and significant relationship at 5% level for LK and LY at a magnitude of 0.24%. Besides that, the estimated coefficient of labour (LL) was positive and consistent with the theory, thus predicting that an increase in labour increases output and is statistically significant at 1% level. Further, LE is also positively related to LY, a finding that is consistent with those of Lee and Chang (2008). It was also observed that a 1% increase in the LE is associated with a 0.39% increase in the LY and is significant at 1%. These findings coincide with our expectations wherein energy serves as a vital and necessary input along with the factors of production needed to produce output.

Additionally, trade openness (trade/GDP) carried a positive sign. As expected, trade openness will be positively related to LY and thus in accordance with the studies conducted by Okamoto (1994) as well as Chandran and Munusamy (2009), which found a positive relationship between trade openness and growth with an emphasis on the manufacturing sector. Based on Table 4, a 1% increase in the trade openness (trade/ GDP) indicates an increase in the LY by 0.15% at a 1% significant level. Further, this result also supports the notion that an increase in trade openness will escalate the demand for exports and ultimately boost real economic activity. Moreover, the positive and statistically significant at 1% level coefficient of the interaction term indicates between the energy consumption and trade openness indicates that energy consumption contributes to higher level of economic growth when the country is highly open. This is reasonable since country which is highly open, generally able to import energy saving equipment which increase the production of good and services by utilizing lesser energy.

For a robustness check, the DOLS were conducted, and those findings are indicated in Model 1b to Model 6b. Generally, it is observed that the findings for DOLS are similar to the findings for the FMOLS estimation in terms of the estimated sign and significance. A sensitivity analysis was undertaken to provide a robustness check on our variable of interest as well as the new addition introduced in this paper; that new addition was none other than the interaction term between energy consumption and trade openness [(trade/GDP) * LE].

Models 1a, 2a, 4a, 5a, 6a for FMOLS indicate the findings for the sensitivity analysis whereas Models 1b, 2b, 3b, 4b, 5b, 6b for DOLS shows the robustness check. The basic model for production shows that capital and labour were positively related to output and significant at 1% level for FMOLS (Model 1a). As for DOLS (Model 1b), the results were consistent with the findings from FMOLS. Next, when energy consumption is added to the model (Models 2a and 2b); capital, labour, and energy consumption appear to be positively related to real GDP and significant at 1% for both FMOLS and DOLS. In addition, it was clearly seen that the signs were consistent

even though trade openness and interaction term had been replaced with other proxy (Models 4a, 5a, 6a and Models 4b, 5b, 6b). All the variables are in accordance with the expected signs except for FDI (Model 6a and 6b) but it is not statistically significant. These findings ultimately indicate that capital, energy consumption, and trade openness do play a crucial role in the production of output in the case of Malaysia. Also, the positive relationship in the interaction term suggest that the relationship between energy consumption and trade openness leads to economic growth.

Table 4: Summary of the long-term coefficients for the FMOLS and DOLS tests

Variables	FMOLS					
	Model 1a	**Model 2a**	**Model 3a**	**Model 4a**	**Model 5a**	**Model 6a**
LK	0.25[a]	0.09[a]	0.15[a]	0.18[a]	0.06[b]	0.12[a]
LL	1.57[a]	0.80[a]	1.06[a]	1.05[a]	1.08[a]	0.77[a]
LE	-	0.78[a]	0.39[a]	0.37[a]	0.45[a]	0.77[a]
Trade/GDP	-	-	0.15[a]	-	-	-
(Trade/GDP) * LE	-	-	0.24[a]	-	-	-
Export/GDP	-	-	-	0.23[a]	-	-
(Export/GDP) * LE	-	-	-	0.43[a]	-	-
Import/GDP	-	-	-	-	0.50[a]	-
(Import/GDP) * LE	-	-	-	-	0.41[a]	-
FDI	-	-	-	-	-	0.00
FDI*LE	-	-	-	-	-	-0.01
Variables	**DOLS**					
	Model 1b	**Model 2b**	**Model 3b**	**Model 4b**	**Model 5b**	**Model 6b**
LK	0.25[a]	0.11[a]	0.16[a]	0.19[a]	0.09[a]	0.15[a]
LL	1.56[a]	0.80[a]	0.97[a]	0.97[a]	0.99[a]	0.69[a]
LE	-	0.75[a]	0.46[a]	0.44[a]	0.51[a]	0.78[a]
Trade/GDP	-	-	0.13[b]	-	-	-
(Trade/GDP) * LE	-	-	0.25[a]	-	-	-
Export/GDP	-	-	-	0.20[b]	-	-
(Export/GDP) * LE	-	-	-	0.42[a]	-	-
Import/GDP	-	-	-	-	0.40[a]	-
(Import/GDP) * LE	-	-	-	-	0.48[a]	-
FDI	-	-	-	-	-	-0.01
FDI*LE	-	-	-	-	-	0.00

Notes: The Model included a linear trend to capture technological progress. The chosen optimal lag for FMOLS is based on the Schwarz criterion; lead and lag for DOLS is (1, 0). a, b and c indicate significance at the 1%, 5% and 10% levels.

5. CONCLUSIONS, DISCUSSIONS AND POLICY IMPLICATIONS

The changes regarding energy whether in the production, consumption, or the price of energy do play an essential key role in determining the health of a nation's economy. These changes will have a meaningful impact on a country's economy performance if they are not handled wisely, precisely, and in a timely fashion. This study aims to investigate the role of energy consumption on the economic growth whether is restrictive or neutral. In addition, this study also investigates whether

trade openness matters for energy consumption and economic growth nexus. This is motivated by the fact that Malaysia is a highly open economy. Also, the fact that trade openness can either increases or decrease the energy consumption.
The findings indicate that an increase in capital, energy consumption, and trade openness can be a vital factor for the input of production and indeed lead to an increase in the GDP for Malaysia. Profoundly, the findings from this paper are an essential contribution for the consideration of those policy makers who are steering the economic policy outlined for Malaysia. First and foremost, the findings are drawn from a long- term relationship between energy consumption and economic output using the augmented Cobb-Douglas production function, which indicates that capital, energy consumption, and trade openness serve as essential inputs of production when generating Malaysia's output.

Energy consumption is positive and significantly relates to output. Therefore, energy is an important factor of growth. As we have acknowledged, Malaysia relies largely on non-renewable energy, mainly liquid fuel, to fulfil its domestic energy demand. Since, its petroleum is depleting; Malaysia should be prepared to source alternative energy to face and meet that challenge effectively. The world today is moving toward greater use of green and clean energy. Hence, policymakers should focus on policy outlines that will encourage the utilization of such renewable energy, as it ultimately does less harm to the environment. The government can also encourage greater usage of renewable energy at various levels besides incentivize Malaysian research and development (R&D) to work toward an increase in the use of renewable energy in the future.

Moreover, trade openness also appears to be a significant contributor to Malaysia's economic output. Fundamentally, the positive and significant relationship of the interaction term between energy consumption and trade openness indicates the importance of trade openness in facilitating the impact of energy consumption on economic growth. This factor denotes that the trade liberalization effort undertaken by the Malaysian government has so far paid off and indeed been validated through strong economic performance. Therefore, Malaysia should continue this export-led growth strategy, and policymakers should design new policies that further promote exports. Nevertheless, appropriate realignment of trade liberalization policies from time to time does remain essential in order to ensure continuous positive impact to total economic output. Additionally, a more active role can be played by the government through ASEAN Free Trade (AFTA) so as to harvest and maintain a positive relationship with the neighbouring countries and thereby ensure a trade liberalization environment that is fully conducive to a positive Malaysian economy and its continued growth in the future.

Last but not least, although this study is done on Malaysia, we can generalize the results of our study to other small and open economy. We concluded that capital and energy are important factors for the economic growth. Nevertheless, trade openness also contributes to the economic growth. Future study can extend the study by applying the model to other countries.

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