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INVESTIGATING THE DETERMINANTS OF RENEWABLE ENERGY CONSUMPTION IN MALAYSIA: AN ARDL APPROACH

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ABSTRACT

It is vital for Malaysia to increase the consumption of renewable energy to reduce its dependence on dirty fossil fuels for electricity generation. This paper attempts to investigate the factors affecting renewable electricity consumption in Malaysia. Specifically, our study aims to explore the long-run relationship among renewable electricity consumption, economic growth, CO_2 emissions, foreign direct investment and trade openness over the period 1980 to 2015. By employing autoregressive distributed lag (ARDL) bounds testing cointegration approach, we find that economic growth and foreign direct investment (FDI) are the major drivers for renewable electricity consumption. Trade openness, however, is found to have a negative impact on renewable electricity consumption in the long-run. Interestingly, the effect of CO_2 emissions on renewable electricity consumption is not significant. Moreover, the vector error correction model (VECM) Granger causality test discovers the existence of a unidirectional causality relationship running from GDP to renewable electricity consumption, confirming the validity of conservation hypothesis in Malaysia. Some important policy implications are also discussed.

Keywords: Renewable electricity consumption; GDP; ARDL bounds testing; VECM Granger causality test

1. INTRODUCTION

In recent decades, the issue of global warming has become a worldwide concern. According to scientists, the burning of fossil fuels particularly coal to generate electricity is the main human

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activity that has caused climate change. However, the good news is, the problem of global warming can be mitigated by switching to renewable energy sources, such as wind and solar power. As a way to reduce CO_2 emissions that have led to climate change, many countries have started to look for alternative energy sources rather than depending solely on fossil fuels for electricity production. For Malaysia, the gradual adoption of renewable energy to replace the use of non-renewable sources particularly in power sector is crucial due to two very important reasons. First, Malaysia has been relying on fossil-based energy sources, such as coal and oil for electricity production, particularly in the power sector that contribute to the emissions of greenhouse gases. According to Klugman (2011), Malaysia has recorded the third highest annual growth rate of 4.7% for CO_2 emissions in the world from 1970 to 2008. In terms of CO_2 emissions from electricity production, it is predicted that the pollution intensity of CO_2 will increase from 298,339kt in 1999 to 800,519kt by 2020 (Basri, Ramli, & Aliyu, 2015). Second, although Malaysia is a country that is blessed with an abundance of natural resources including oil and natural gas, there is an increased concern over the reserves of these resources as the demand for non-renewable energy sources keeps rising over the years. For example, Malaysia's average annual growth rate for total energy demand was recorded as 6.6% over the period from 1980 to 2010 (Kardooni, Yusof, & Kari, 2016). To overcome the issue of rising demand on energy, it is expected that power sector in Malaysia will need to be more dependent on imported coal. The problems concerning the use of foreign coal is that it exposes Malaysia to the risks of supply interruption and price fluctuations.

As non-renewable energy sources have adverse effects on both the environment and national power security as mentioned above, efforts are required to encourage the development and consumption of renewable energy sources in Malaysia. In particular, Malaysia needs to tap into green energy potentials to reduce the reliance of its power plants on fossil fuels, particularly coal. Indeed, various policy measures, such as the Five Fuel Diversification in 1999 and Renewable Energy Act in 2011 have been developed to promote the use of renewable energy in Malaysia. The most recent initiative in promoting green technology can be seen in the 11th Malaysia Plan (2016-2020) where 'pursuing green growth for sustainability and resilience' has been included as one of the strategic thrusts of the Plan. However, the contribution of renewables for electricity generation over the years remains low in Malaysia. Renewable energy sources (excludes hydro that takes up 7%) such as biomass/biogas, solar PV, mini hydro, and municipal solid waste, accounted for merely 0.2% of the total electricity generated in 2012 (Basri et al., 2015). This situation leads to a question regarding what motivates and hinders renewable electricity consumption in Malaysia. Although there is a vast literature on the factors affecting renewable energy consumption (for example, Omri & Nguyen, 2014; Saidi & Ben Mbarek, 2016; Vachon & Menz, 2006), the literature on the determinants for renewable electricity consumption remains scarce. So far, Lin, Omoju, and Okonkwo (2016) have studied the factors leading to renewable electricity consumption in China. Other studies on the drivers of renewable electricity consumption are still absent from the literature. Despite the fact that an investigation on the determinants for renewable electricity consumption is vital in Malaysia, the current literature on the issue tends to focus merely on reviewing and describing the current scenario of renewable energy consumption in the country. Many of the existing studies (such as, Basri et al., 2015; Bujang, Bern, & Brumm, 2016; Mekhilef et al., 2014; Petinrin & Shaaban, 2015) have been discussing on the current energy policies and the potential renewable resources in Malaysia. As far as we are aware, the literature has yet to investigate the determinants for the consumption of renewable electricity in Malaysia.

Our study contributes to the literature in several important ways. First, we consider renewable electricity consumption as the dependent variable, instead of renewable energy consumption as adopted in most of the existing studies. It is because the burning of fossil fuels particularly coal to generate electricity has been identified as the main human activity that has led to climate change according to the scientists. In Malaysia, the power plants have been depending on fossil-based energy sources, such as coal and oil for electricity production. In terms of CO_2 emissions from electricity production, it is predicted that the pollution intensity of CO_2 will increase by almost threefold from 1999 to 2020 (Basri et al., 2015). Second, most of current literature about renewable energy development emphasize on developed countries, such as Sovacool (2009) for United States and Popp, Hascic, and Medhi (2011) for OECD countries. On the contrary, our study focuses on the factors affecting renewable electricity consumption in an emerging economy. Third, compared to past studies on renewable energy consumption in Malaysia that provide mostly current situation of renewables development, this study attempts to extend the literature by examining the determinants for renewable electricity consumption in the country which is of great importance to the policy makers. Thus, our study generally aims to investigate the determinants of renewable electricity consumption in Malaysia using Autoregressive Distributed Lag (ARDL) and Granger causality test for the period from 1980 to 2015. There are two specific objectives of the study. First, it is to examine the long-run relationship among renewable electricity consumption, economic growth, CO_2 emissions, foreign direct investment and trade openness in Malaysia. Second, the results of the study would serve as a reference for policy makers to design energy, environmental and economic policies that can eventually contribute to higher consumption of renewable electricity in Malaysia.

The rest of the paper is organized as follows. Section 2 presents the literature review. Section 3 describes the methodology used. Section 4 provides a discussion on the empirical results obtained while Section 5 concludes the paper with the inclusion of policy implications.

2. LITERATURE REVIEW

Numerous researches have analyzed the energy-growth nexus for different countries or regions using different econometric methods to show whether energy consumption has an impact on economic growth, and vice versa (Al-Iriani, 2006; Belloumi, 2009; Borozan, 2013; Dagher & Yacoubian, 2012; Ghali & El-Sakka, 2004; Hossien, Yazdan, & Ehsan, 2012; Lee, Chang, & Chen, 2008). There are four well-established hypotheses related to energy-growth nexus. The first hypothesis is growth hypothesis which suggests that economic growth is energy dependent. Conversely, the second hypothesis is conservation hypothesis which claims that economic growth is not energy dependent. Next, the neutrality hypothesis argues that economic growth and energy are independent. Lastly, the feedback hypothesis suggests an interdependent connection between economic growth and energy. The more recent studies on the link between energy consumption and economic growth have noticed the decomposition of energy variable into renewable and nonrenewable energy sources (Al-mulali, 2011; Apergis & Payne, 2010; Kum, Ocal, & Aslan, 2012; Payne & Taylor, 2008; Yang, 2000). Among these studies, some have been focusing on factors affecting renewable energy consumption or production. Studies on investigating the determinants for renewable energy can be further grouped into a single country or a panel of countries, various econometric techniques, developed or developing countries, and different types of renewable energy.

By utilizing a dynamic system-GMM panel model, Omri and Nguyen (2014) discover that CO_2 emissions and trade openness do play an important role in contributing to higher renewable energy consumption in 64 countries for the period 1990 to 2011. However, a rise in oil price is found to have a negative impact on renewable energy consumption in the middle-income countries as well as the global panel. In addition, Sebri and Ben-Salha (2014) reveal a bidirectional causality between renewable energy consumption and economic growth in BRICS countries. A unidirectional causality is found to run from output to renewable energy in the case of OECD countries in the study by Ben Jebli, Youssef, and Ozturk (2015). Similarly, Apergis and Payne (2010) examine the energy-growth nexus in OECD countries over the period of 1985-2005 using heterogeneous techniques. The results suggest that there is a bi-directional causality between economic growth and renewable energy consumption. Another study on OECD countries by Kula (2014) concludes that economic development has a significant effect on renewable energy consumption. Focusing on Baltic region, Furuoka (2017) discovers that there is a unidirectional causality from economic growth to renewable electricity consumption. Furthermore, the outcomes of a study by Sadorsky (2009) show that income and pollution have a long-run positive effect on per capita renewable energy consumption in G7 countries using panel cointegration techniques. However, an increase in oil price is found to have impacted renewable energy consumption negatively. Marques and Fuinhas (2011) discover that public awareness about climate change mitigation and CO_2 reduction targets fail to be the motivators for renewable energy consumption in European countries using data from 1999 to 2006. It is also found that GDP and prices of fossil fuels do not influence the development of renewables, concluding that the market does not play an important role in promoting renewable energy in the 24 countries concerned. Furthermore, by using data of 112 developing and developed countries from 1998 to 2009, Stadelmann and Castro (2014) suggest that domestic factors like population and wealth do have a positive impact on the adoption of renewable energy policies.

A study by Ben Jebli and Ben Youssef (2015) reveals that there is a unidirectional causality relationship running from GDP, carbon emissions, nonrenewable energy and trade openness to renewable energy in Tunisia. Sovacool (2009) reveals that the share of fossil fuels plays an important role in explaining the consumption of renewable energy in the United States. Most recently, Lin et al. (2016) employ the Johansen cointegration technique and vector error correction model to identify the determinants of the share of renewable electricity in total electricity consumption in China for the years 1980-2011. The results indicate that economic growth and financial development tend to encourage renewable electricity consumption. However, foreign direct investment, traditional energy sources and trade openness reduce the consumption on renewable energy. A unidirectional causality is also found running from financial development to renewable electricity consumption. The results imply that the government policies should gear towards the use of renewable energy sources to ensure reduced CO_2 emissions and sustainable economic growth in China.

In the context of Malaysia, none of the existing literature has studied the factors affecting renewable energy consumption in the country. Much of the literature about Malaysia has been focusing on presenting the descriptive analysis and surveys, which show a review on the current situation of renewable energy consumption. For example, Petinrin and Shaaban (2015) attempt to figure out what are the most prospective renewable energy sources in Malaysia. They conclude that biomass and solar energy are the most potential types of renewable energy in the country. The study also looks into the effectiveness of the existing renewable strategies implemented in

Malaysia. Similarly, Mekhilef et al. (2014) give a detailed description on Malaysian energy policies and renewable energy programs in their study. The study further concludes that enhanced collaboration between the public and private sectors is needed to fully utilize the renewable energy sources. In addition, Bujang et al. (2016) also provide a discussion on the renewable energy initiatives in Malaysia. The study further suggests that more efforts need to be taken in developing the potential of renewable resources to reduce the consumption of fossil fuel in the country. In an earlier study by Ahmad, Kadir, and Shafie (2011), the primary sources of renewable energy in Malaysia, such as solar, mini-hydro, and biomass as well as their potentials are discussed. It is also highlighted in the study that meeting future energy demand and cutting carbon emissions are the two main reasons for the country to switch from non-renewable to renewable energy sources. Likewise, Ahmad and Tahar (2014) study the potential of four different types of renewable resources (hydropower, solar, wind and biomass) in Malaysia for electricity generation using analytical hierarchy process (AHP) methodology. The results indicate that solar is the most potential renewable resource followed by biomass, hydro, and wind respectively. Basri et al. (2015) go a step further by discussing both energy policies and potential renewable energy sources in their study. The study also stresses the importance of strategies, such as inclusion of renewable energy into energy mix, adoption of more effective energy policies and power expansion plan to achieve sustainability in Malaysia. Most recently, Kardooni et al. (2016) study factors that determine renewable energy technology acceptance in Peninsular Malaysia. It is revealed that cost of renewable energy does have an indirect effect on public's attitude towards the use of renewables via the associated impact on the perceived ease of use and perceived usefulness.

3. METHODOLOGY

The study uses annual time series data for the period from 1980 to 2015 in Malaysia. The data is derived from International Energy Statistics, World Development Indicators (WDI) and Emissions Database for Global Atmospheric Research (EDGAR). The dependent variable in the model refers to renewable electricity consumption which is measured using renewable electricity net consumption in billion kWh. Meanwhile, the explanatory variables included are economic growth, carbon dioxide (CO_2) emissions, trade openness, FDI which are denoted by GDP per capita (US$), CO_2 emissions in metric tons per capita, share of import and export in GDP, ratio of foreign investment to GDP respectively. To reduce the variation and induce stationarity in the variance-covariance matrix, the natural logarithmic form (ln) is applied to all the variables.

The analysis is started by determining the order of integration of the variables using unit root test. Augmented Dickey Fuller (ADF) is one of the best known unit root tests based on the model of the first-order autoregressive process (Box & Jenkins, 1970). In addition, Phillips and Perron (PP) test allows for milder assumptions on the error distribution and controls for higher order serial correlation in the series as well as heteroscedasticity. After deciding the order of integration, the existence of long-run relationship between the variables is tested. The autoregressive distributed lag (ARDL) method (Pesaran et al., 2001) is proposed due to its effective applications for small sample sizes compared to Johansen (1988) and Engle and Granger (1987) tests. ARDL is also applicable irrespective of the variables are integrated of order zero or one or mutually cointegrated as long as not order two. Moreover, Banerjee et al. (1998) claimed that ARDL does not convert the short run coefficients into residuals. In essence, ARDL procedure involves the estimation of unrestricted error correction model (UECM) in first difference form, augmented with one period lagged of all variables in the model. The UECM model is shown as follows:

$$\Delta lnREC_t = \alpha_0 + \beta_1 lnREC_{t-1} + \beta_2 lnGDP_{t-1} + \beta_3 lnCO2_{t-1} + \beta_4 lnTRADE_{t-1} + \beta_5 lnFDI_{t-1} + \sum_{i=1}^{p} \beta_i \Delta lnREC_{t-i} + \sum_{j=0}^{q} \beta_j \Delta lnGDP_{t-j} + \sum_{k=0}^{r} \beta_k \Delta lnCO2_{t-k} + \sum_{l=0}^{s} \beta_l \Delta lnTRADE_{t-l} + \sum_{m=0}^{t} \beta_m \Delta lnFDI_{t-m} + \mu_t \quad (1)$$

where REC is renewable electricity consumption, GDP is economic growth, CO_2 is carbon dioxide emissions, TRADE is trade openness and FDI is foreign direct investment, Δ is the first difference operator andμ_t is error term respectively. The optimal lag length is selected based on Akaike's Information Criterion (AIC). The F-statistics derived from Wald tests is used to determine the joint significance of the coefficients of the lagged level of the variables (Pesaran et al., 2001). The null hypothesis of no cointegration is established as $H_O: \beta_1 + \beta_2 + \beta_3 + \beta_4 + \beta_5 = 0$. The upper bound critical value (UCB) assumes that all the regressors are I(1) while I(0) for lower bound critical value (LCB). Given that the sample size of this study is relatively small (T=36), the rejection of null hypothesis refers to the critical value simulated by Narayan (2005). It was proved that the cointegration existed between the variables if F-statistics is greater than UCB. Otherwise, the null hypothesis cannot be rejected if F-statistics is lower than LCB which indicates that the variables are not cointegrated. According to Bardsen (1989), the long-run coefficients are estimated using the ratio of coefficients of each independent variable to dependent variable's coefficient respectively.

This is followed by Granger causality test to investigate the causal relationship between the variables in short run. If the variables are not cointegrated, the vector autoregressive (VAR) in first difference form is employed. In contrast, if the cointegration is found between the variables, the study estimates the direction of causality using vector error correction models (VECM).

$$\Delta lnREC_t = v_1 + \sum_{i=1}^{k} \gamma_{1i} \Delta lnREC_{t-i} + \sum_{i=0}^{k} \delta_{1i} \Delta lnGDP_{t-i} + \sum_{i=0}^{k} \theta_{1i} \Delta lnCO2_{t-i} + \sum_{i=0}^{k} \sigma_{1i} \Delta lnTRADE_{t-i} + \sum_{i=0}^{k} \lambda_{1i} \Delta lnFDI_{t-i} + \zeta_{1t} \quad (2)$$

where Δ is the first difference operator, k is the optimal lag order based on AIC and ζ_{1t} is error term.

Nevertheless, VECM Granger causality is unable to provide reliable estimation on the strength of causal relationship between variables beyond the selected sample period. In addition, Granger causality only looks into the direction of causal relationship, but not focusing on the sign of relationship. The cholesky impulse response function (IRF) is believed as not sensitive to the order of VECM. This enables the IRF to determine the positive or negative effect in the long run or short run from a shock on the current and future values of all the endogenous variables. The IRF is restricted in providing the magnitude of the relevant effect. Therefore, variance decomposition is employed to measure the percentage contribution of each innovation to h-step ahead forecasting error variance of the dependent variable. It also identifies the relative importance of shocks by explaining the variation in the dependent variable.

4. RESULTS

4.1. Descriptive Analysis

Table 1 shows the descriptive statistics of the variables used in our study. The mean of renewable electricity consumption is amounted to 5.960 billion kilowatthours with standard deviation of 3.075 billion kilowatthours over the period of 1980-2015. The consumption of renewable electricity can achieve as high as 14.806 billion kilowatthours or as low as 1.29 billion kilowatthours throughout these 36 years. Besides, the average of CO_2 emissions is recorded as 4.881 metric tons per capita with the standard deviation of 2.148 metric tons per capita. The maximum and minimum values are amounted to 8.141 and 1.953 metric tons per capita respectively. Moreover, GDP, trade and FDI deliver the mean of US$ 6,478.374, 159.897 and 3.965% respectively. The standard deviations are amounted to US$ 2,294.132, 37.295 and 1.869 respectively. The statistic of skewness reveals that renewable electricity consumption, GDP, CO_2 emissions and FDI are skewed to right while TRADE has the left side skewness. Furthermore, the natural logarithmic form (ln) is applied to all the variables to reduce the variation and induce stationarity in the variance-covariance matrix.

Table 1: Descriptive statistics

	Renewable electricity consumption (billion kilowatthours)	**GDP per capita (constant 2010 US$)**	**CO_2 emissions (metric tons per capita)**	**Trade (Share of import and export in GDP in current US)**	**FDI (net inflows, % of GDP)**
Mean	5.960	6,478.374	4.881	159.897	3.965
Max	14.806	10,876.73	8.141	220.407	8.761
Min	1.290	3,308.772	1.953	105.057	0.056
Std. Dev.	3.075	2,294.132	2.148	37.295	1.869
Skewness	1.114	0.210	0.062	-0.018	0.416
Kurtosis	4.569	1.866	1.546	1.690	3.566

4.2. Unit Root Test

Table 2 presents the results of the ADF and PP unit root tests for the five variables both at level and first difference of the natural log values. Interestingly, all the variables in ADF test are non-stationarity at level except for FDI. The variables turn into stationary when they are first differenced at 1% significance level while trade is the only variable significant at 5% level. Besides, PP test produces results similar to ADF test. Only FDI achieves stationarity at level while other variables such as renewable electricity consumption (REC), GDP, CO_2 emissions and trade become stationary at first difference with 5% significance level. As all the variables are found to have the order of I(0) and I(1), we choose to employ ARDL bound test in order to determine the long-run cointegration between GDP, CO_2 emissions, trade and FDI with REC in Malaysia. Furthermore, it is also applicable in VECM Granger causality with the integration of I(0) and I(1) (Sinha & Sinha, 1998).

Table 2: Unit root test

	ADF		PP	
	Level	**Difference**	**Level**	**Difference**
REC	-3.1020(1)	-5.3638(1)***	-2.2602	-4.7036***
GDP	-1.7677(0)	-4.8434(0)***	-1.9633	-4.8434***
CO_2	-0.8178(0)	-4.5520(8)***	-1.0483	-4.8662***
TRADE	-0.4222(1)	-4.0373(0)**	0.0900	-3.8114**
FDI	-5.0415(0)***	-6.4872(1)***	-5.0448***	-23.6103***

Notes: Both intercept and deterministic trendare included in the test equation for the variable in level and first difference. The ADF and PP are estimated with t-Statistic. The optimal lag length in ADF equation is reported in ( ) and based on AIC. ***, ** and * denote significance at 1%, 5% and 10%, respectively.

4.3. ARDL Bound Test

Table 3 presents the results of the bounds test based on REC and its determinants. The ARDL (1, 4, 0, 2, 3) model is selected to fit the data of value added per capita in service sector. The optimal lag selected is one based on AIC tests. The computed F-statistic of 13.591 in ARDL bound test is greater than the upper critical bound value of 6.250 at 1% significance level based on Narayan (2005). The rejection of null hypothesis of no cointegration suggests that the existence of steady-state long-run relationship among GDP, CO_2 emissions, trade, FDI and renewable electricity consumption in Malaysia. This is in line with the studies conducted by Sardorsky (2009) and Sebri and Ben-Salha (2014) who reveal a long-run relationship among the variables.

Table 3: ARDL bound test

Model	**F-statistic**	**Conclusion**
REC = f (GDP, CO_2, TRADE, FDI)	13.591***	Cointegrated
Optimal lag	[1,4, 0, 2, 3]	
Critical value	***I(0)***	***I(1)***
1% significance level	4.428	6.250
5% significance level	3.202	4.544
10% significance level	2.660	3.838
Diagnostic test		
Breusch-Godfrey LM test	0.4654 (0.6366)	
Heteroskedasticity test	0.0300 (0.8636)	
Ramsey RESET	0.0493 (0.9613)	

Notes: Critical values: case III: unrestricted intercept and no trend (k=4, T=40). ( ) refers to p-values.

The robustness of the model is confirmed by the diagnostic tests, such as Breusch-Godfrey serial correlation Lagrange multiplier (LM), autoregressive conditional heteroskedasticity (ARCH) and Ramsey RESET. The Breusch-Godfrey serial correlation LM test indicates that the model is free from serial correlation problem. There is no heteroskedasticity problem found from ARCH test..

In addition, Ramsey RESET test indicates that there is no functional form misspecification. Furthermore, plots of cumulative sum (CUSUM) and CUSUM of squares tests in Figure 1 point out that no misspecification and structural instability of long-run and short-run estimated parameters appeared in the sample period. This implies that the estimated parameters of the model produce a reliable estimation.

Figure 1: Plot of cumulative sum (CUSUM) and CUSUM of squares tests for the equation of renewable electricity consumption

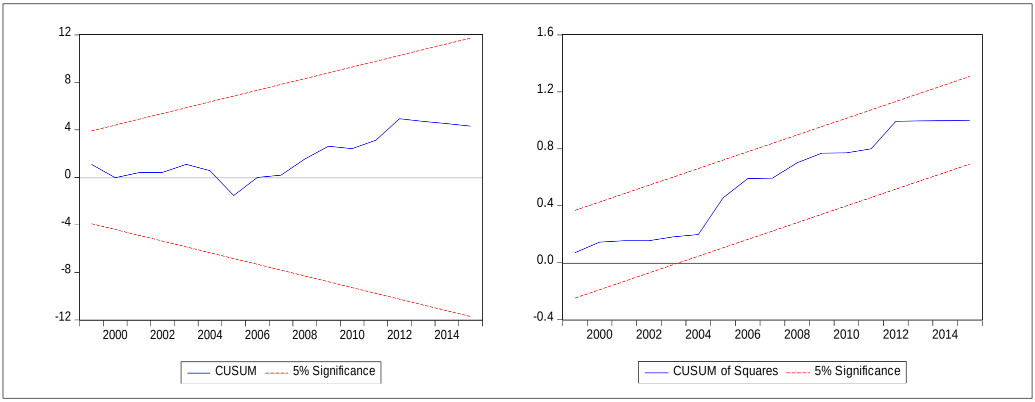


Table 4 indicates the results of long-run elasticities of explanatory variables on renewable electricity consumption. Interestingly, all the explanatory variables are found to be significant in explaining the renewable electricity consumption in the long run for Malaysia except CO_2 emissions. It is evident that GDP possesses a positive and significant coefficient throughout the long run at 10% significance level, indicating that 1% increase of GDP would increase the renewable electricity consumption by 1.189%. The estimated income elasticity of renewable electricity consumption or demand is positively greater than 1, indicating that it can be considered as a superior good in Malaysia. The result is within our expectation as higher economic growth would allow the economy to have more resources to promote the use of greener energy sources that include renewable electricity. In the meantime, better economic performance enables people in the country to have more income to be spent on environmental protection and to demand more of renewable energy. The positive impact of GDP on renewable electricity consumption is verified by previous studies, such as Marques and Fuinhas (2011). In addition, the finding further implies the importance of economic growth in boosting renewable electricity consumption by increasing its ability to develop technologies related to renewable electricity in Malaysia.

This positive coefficient also implies that Malaysian government has been concentrating on the sustainable energy in line with the strategic thrust 4 of the eleventh Malaysia Plan. One of the focus areas in the strategic thrust is to adopt the sustainable consumption and production concept that aims to provide at least 2,080 MW in renewable energy installed capacity. Meanwhile, the government also allocates RM5 billion to implement the Green Technology Financing Scheme in Malaysian Budget 2018 to ensure a sustainable green development.

Besides, an additional percentage increase in FDI also significantly raises renewable electricity consumption by 0.299%. This suggests that technological transfer through FDI has successfully enhanced the consumption of renewable electricity. Our finding agrees with the popular belief that FDI is essential in improving renewable electricity consumption. Nonetheless, the result does not support the findings of previous studies, such as Peterson (2007) who finds no evidence of a positive relationship between FDI and renewable energy consumption. This is due to the change in the global perception of renewable energy particularly in the electricity sector compared to a decade ago. Nowadays, renewable energy technologies are not only used for the enhancement of energy security and mitigation of climate change, but also an important factor contributing to the nation's economic development either directly or indirectly.

Trade openness is found to be negatively related to renewable electricity consumption in the long run. The renewable electricity consumption is diminished by 1.352% with one percent increase in trade openness. The result indicates that foreign trade is not able to encourage the exchange of renewable technologies in electricity generation via technological transfer. In other words, it does not promote the consumption of renewable electricity in Malaysia. This finding is in line with the result reported by Lin et al. (2016). However, it contradicts with conclusions documented in literature such as Ben Jebli and Ben Youssef (2015) and Omri and Nguyen (2014) who claim that trade openness leads to an increase in the use of renewable energy.

On the other hand, our results show that CO_2 emissions do not have a significant impact on renewable electricity consumption. The value of the coefficient is positive though not significant. This indicates that our finding is not in line with previous studies such as Marques, Fuinhas, and Manso (2010) who suggest that the deterioration of environmental quality tends to reduce renewable electricity consumption. The positive relationship between CO_2 emissions and renewable electricity consumption, however, is consistent with Omri and Nguyen (2014) and Sadorsky (2009) who claim that a rise in CO_2 emissions is the major driver for renewable electricity consumption. In the case of Malaysia, a positive but yet insignificant relationship between the two variables can be explained by the fact that public awareness on the importance of utilizing renewable electricity is still weak among Malaysians.

Table 4: Long-run coefficient of renewable electricity consumption

Variable	Coefficient	Standard Error	t-Statistic
C	-2.482	5.914	-0.419
GDP	1.189*	0.666	1.783
CO_2	0.429	0.596	0.719
TRADE	-1.352***	0.275	-4.908
FDI	0.299***	0.097	3.056

Notes: ***, ** and * denote significance at 1%, 5% and 10%, respectively

4.4. VECM Granger Causality test

The results of Granger causality as shown in Table 5 indicates that GDP does Granger-cause renewable electricity consumption in a unidirectional way at 10% significance level. This result confirms the importance of economic development of Malaysia in promoting renewable electricity consumption. Similar to findings obtained by Furuoka (2017) and Kula (2014), a unidirectional

causality is also found from GDP to renewable electricity consumption. However, our finding differs from studies by Farhani and Shahbaz (2014) and Al-mulali, Fereidouni, and Lee (2014) who found no causality and a bidirectional relationship between economic growth and renewable electricity consumption respectively.
In addition, a unidirectional causal relationship is found from trade openness to CO_2 emissions at 1% significance level indicating that trade liberalisation does contribute to the deterioration of environmental quality in Malaysia. It is consistent with the findings of Kasman and Duman (2015) who also discover a unidirectional causality from trade openness to CO_2 emissions in the case of new EU member countries. Our result, however, is contradictory with the finding by Ohlan (2015) who suggests that there is no causality between the two variables.

Last but not least, with the expected negative sign, the speed of adjustment on the lagged ECT for renewable electricity consumption represents a significant long-run causal effect which is consistent with the results of ARDL. The ECT indicates that renewable electricity consumption will converge its equilibrium within 22.08 years after the shocks with the adjustment of 4.53% per annum.

Table 5: VECM granger causality

Dependent variables	D(REC)	D(GDP)	D(CO_2)	D(TRADE)	D(FDI)	ECT(-1)
D(REC)	-	3.5041*	1.7657	0.0285	0.1219	-0.0453***
D(GDP)	0.0299	-	0.0441	1.2022	0.0007	0.0016
D(CO_2)	1.1187	1.2484	-	7.1720***	0.0042	0.0058
D(TRADE)	1.2587	0.4189	0.8548	-	0.0029	0.0011
D(FDI)	0.6351	0.0371	0.1555	0.2362	-	0.2469***

Notes: ***, ** and * denote significance at 1%, 5% and 10%, respectively

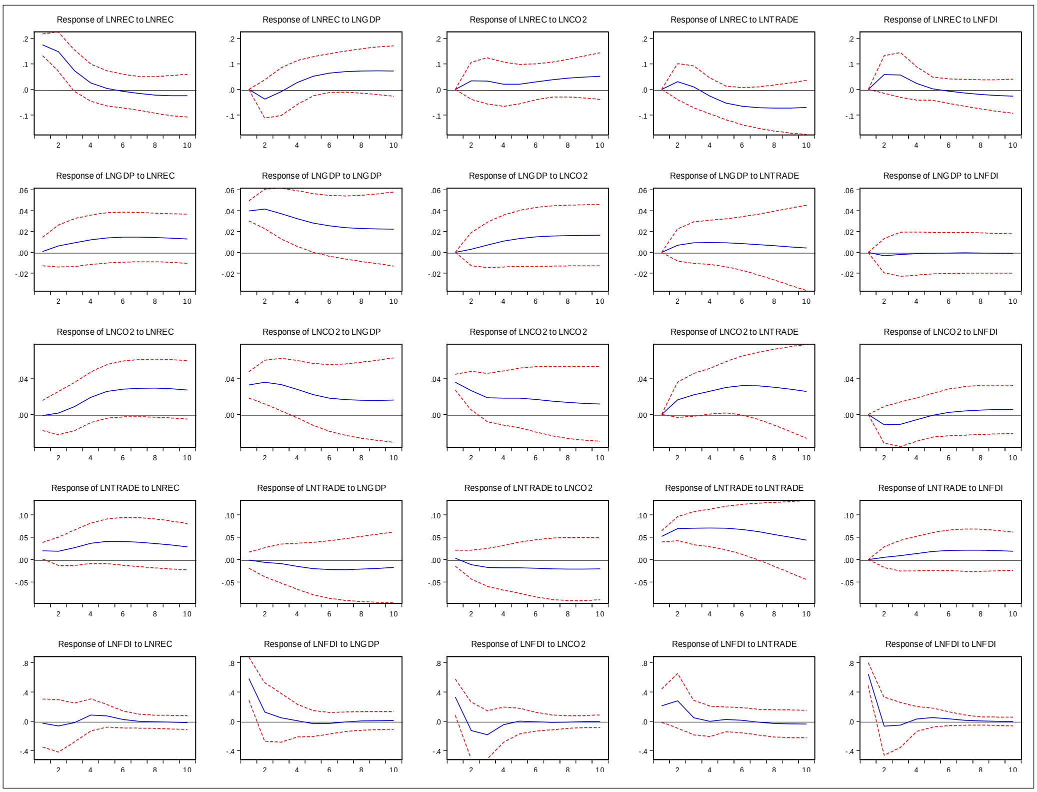
4.5. Impulse Response Function

Figure 2 indicates the results of impulse response function that visualize the destabilization experienced by the endogenous variables (REC, GDP, CO_2 emissions, TRADE and FDI) in response to one external standard deviation (SD) shock within other variables. Renewable electricity consumption is found to be significantly responsive to its own shock in the second period with the continuing negative effect. Besides, the response of REC to one SD shock of GDP reveals the positive trend from the second year to tenth year. This supports the long-run positive relationship between GDP and renewable electricity consumption in Malaysia. Moreover, the REC would be increased in the first year, then slightly decreasing to fourth year when there is one SD shock given to CO_2 emissions. Subsequently, the impact on REC from the shock of CO_2 emissions continues to increase until tenth year.

In addition, the response of REC is found to be negative after the first year when there is an occurrence of a shock in trade. This is in line with the findings of negative coefficient in TRADE towards renewable electricity consumption. Similarly, the response of REC from the shock of FDI indicates a drop for REC after the first year. Furthermore, the shocks of all the variables (GDP, CO_2, TRADE and FDI) on the response of REC are found to make a turning change at the first year before following the trend throughout the remaining periods. This indicates the actual responses are only found after the first year in order to determine the adjustment towards the shock of REC.

On the other hand, the response of GDP to its own shocks is significant and negative in the fifth period. TRADE possesses the significant response to its own shocks in the sixth period with marginal movement. For the response of CO_2 emissions, it is significant and negative to its own shock in the second period while the third period from the shock of GDP. Last but not least, the significant and negative responses to FDI are found from the shocks of GDP and FDI in the first period.

Figure 2: Impulse response functions



4.6. Variance decomposition analysis

Table 6 shows the results of variance decomposition analysis (VDC) that separate the variation for each endogenous variable into the component shocks to the VECM. The VDC of renewable electricity consumption (REC) clearly indicates that TRADE and GDP are vitally explaining the innovation to renewable electricity consumption. The shocks to REC in response to a one standard deviation innovation in TRADE and GDP highly range from 0% to 20.96% and 20.93% respectively. Similar to the findings of ARDL and IRF, these VDC findings confirm the dynamic effect of shocks from TRADE and GDP towards REC. This implies that the growth and development of Malaysian economy is important to enhance the consumption of renewable electricity. On the other hand, the shocks of CO_2 (8.77%) and FDI (6.46%) are found to contribute the minor effect on the shocks of REC in the discrete time periods.

Moreover, the VDC of GDP indicates the most significant shocks effect of CO_2 emissions (12.53%) towards the shocks of GDP compared to REC (11.15%), TRADE (4.02%) and FDI (0.15%) respectively. In addition, the VDC of CO_2 finds that the shocks effect of TRADE highly responds to one standard deviation innovation in CO_2 emissions. This is in line with the findings of VECM Granger causality that TRADE granger causes CO_2 emissions. Meanwhile, one standard deviation shock in GDP explains CO_2 emissions by 27.25%. The existence of inverted U-shaped relationship between GDP and CO_2 emissions in Malaysia is proved as GDP increases at the initial stage and begins to decline after reaching the peak point. The contributions of REC, GDP, CO_2 and FDI to TRADE are amounted to 18.65%, 4.88%, 5.50% and 4.62% respectively. Furthermore, the changes of FDI are explained by one standard deviation shock in REC, GDP, CO_2 and TRADE with the percentage of 1.73%, 32.82%, 14.66% and 11.87% respectively.

Table 6: Variance decomposition analysis of renewable electricity consumption (%)

Variance Decomposition of LNREC						
Period	**S.E.**	**LNREC**	**LNGDP**	**LNCO$_2$**	**LNTRADE**	**LNFDI**
1	0.1743	100.0000	0.0000	0.0000	0.0000	0.0000
2	0.2428	88.4018	2.3773	1.9064	1.5413	5.7730
3	0.2622	83.5519	2.1632	3.2115	1.4686	9.6045
4	0.2678	80.9656	3.0808	3.6432	2.3404	9.9698
5	0.2786	74.8663	6.2389	3.9047	5.7648	9.2252
6	0.2949	66.8649	10.2367	4.4874	10.1230	8.2877
7	0.3142	59.1724	13.9009	5.4189	14.0152	7.4924
8	0.3347	52.5682	16.8844	6.4938	17.1079	6.9454
9	0.3552	47.1674	19.1898	7.6186	19.3989	6.6251
10	0.3745	42.8606	20.9396	8.7702	20.9693	6.4601
Variance Decomposition of LNGDP						
Period	**S.E.**	**LNREC**	**LNGDP**	**LNCO$_2$**	**LNTRADE**	**LNFDI**
1	0.0397	0.0346	99.9653	0.0000	0.0000	0.0000
2	0.0584	1.1093	96.9300	0.2706	1.3843	0.3056
3	0.0708	2.4516	93.4367	1.1670	2.6567	0.2878
4	0.0800	4.1732	89.3736	2.7206	3.4839	0.2485
5	0.0874	5.9885	85.2044	4.5827	4.0066	0.2176
6	0.0937	7.6111	81.4389	6.4744	4.2821	0.1933
7	0.0993	8.9265	78.2830	8.2464	4.3687	0.1752
8	0.1043	9.9280	75.7396	9.8442	4.3254	0.1626
9	0.1090	10.6547	73.7215	11.2680	4.2003	0.1552
10	0.1133	11.1580	72.1206	12.5387	4.0293	0.1532

Variance Decomposition of $LNCO_2$						
Period	**S.E.**	**LNREC**	**LNGDP**	**$LNCO_2$**	**LNTRADE**	**LNFDI**
1	0.0484	0.0533	45.5687	54.3779	0.0000	0.0000
2	0.0686	0.0817	49.7092	41.8845	5.6003	2.7241
3	0.0825	1.2289	50.3528	34.0343	10.7745	3.6094
4	0.0947	4.9786	46.8631	29.5074	15.5598	3.0909
5	0.1065	9.6699	41.3706	26.2685	20.2391	2.4517
6	0.1173	13.7105	36.4817	23.6732	24.0754	2.0589
7	0.1270	16.9428	32.8279	21.5953	26.7753	1.8585
8	0.1354	19.5213	30.2222	19.9730	28.5127	1.7705
9	0.1426	21.5462	28.4221	18.7385	29.5483	1.7447
10	0.1488	23.1019	27.2505	17.8223	30.0795	1.7457
Variance Decomposition of LNTRADE						
Period	**S.E.**	**LNREC**	**LNGDP**	**$LNCO_2$**	**LNTRADE**	**LNFDI**
1	0.0554	12.7151	0.0384	0.3441	86.9022	0.0000
2	0.0915	8.7578	0.4428	1.6003	88.8624	0.3365
3	0.1201	10.0469	0.7980	2.9989	85.4322	0.7238
4	0.1464	12.9015	1.5578	3.5288	80.6826	1.3292
5	0.1704	15.1659	2.5008	3.7398	76.4875	2.1058
6	0.1911	16.5804	3.3189	3.9918	73.2823	2.8263
7	0.2079	17.4696	3.9284	4.3384	70.8467	3.4166
8	0.2214	18.0534	4.3611	4.7305	68.9548	3.8999
9	0.2319	18.4306	4.6666	5.1273	67.4749	4.3004
10	0.2399	18.6587	4.8831	5.5099	66.3185	4.6295
Variance Decomposition of LNFDI						
Period	**S.E.**	**LNREC**	**LNGDP**	**$LNCO_2$**	**LNTRADE**	**LNFDI**
1	0.9515	0.0663	37.3594	11.9953	4.9250	45.6537
2	1.0118	0.4476	34.6022	12.1572	11.9923	40.8005
3	1.0317	0.4547	33.4844	14.8239	11.7656	39.4712
4	1.0368	1.1424	33.1649	14.8722	11.6508	39.1694
5	1.0415	1.6389	32.9601	14.7392	11.6093	39.0523
6	1.0429	1.6916	32.9413	14.7040	11.5987	39.0641
7	1.0432	1.6907	32.9268	14.7154	11.6063	39.0607
8	1.0437	1.6933	32.8973	14.7127	11.6707	39.0257
9	1.0444	1.7047	32.8619	14.6946	11.7647	38.9738
10	1.0453	1.7309	32.8201	14.6696	11.8712	38.9081

Cholesky Ordering: LNREC LNGDP $LNCO_2$ LNTRADE LNFDI

5. CONCLUSION AND POLICY IMPLICATION

Identifying the determinants for renewable electricity consumption is important for Malaysia to design appropriate policies and strategies that can help to combat environmental problems. In this study, we analyze the drivers and barriers to the consumption of renewable electricity in Malaysia using annual data from 1980 to 2015. To be more specific, our study intends to investigate the long-run and causal relationship among renewable electricity consumption, economic growth, CO_2 emissions, foreign direct investment and trade openness using autoregressive distributed lag (ARDL) bounds testing cointegration approach and VECM Granger causality test respectively.

Results obtained from autoregressive distributed lag (ARDL) bounds testing cointegration approach reveal that economic growth and FDI are the main drivers for renewable electricity consumption in Malaysia. This implies that renewable electricity consumption could be further enhanced via an increase in GDP and FDI. On the other hand, trade openness is discovered to have a negative effect on renewable electricity consumption in the long run, indicating that exchanges of goods and services among countries tend to hinder the consumption of renewable electricity. It is found that CO_2 emissions insignificantly affect renewable electricity consumption. Furthermore, a unidirectional causality relationship is found running from GDP to renewable electricity consumption, suggesting that conservation hypothesis is valid for Malaysia. It is also confirmed that a unidirectional Granger causality is running from trade openness to CO_2 emissions, but not vice versa.

Several important policy implications can be drawn based on the results obtained. In relation to this, the policy makers should continue to implement sound fiscal and monetary policies that can ensure robust growth while encouraging the development of renewable energy in the country. We also find that FDI has a positive impact on renewable electricity consumption. This result is indicative of the fact that FDI can be utilized as a tool to promote the use of renewables. While attracting more FDI, the Malaysian government needs to ensure that only those foreign investors who develop and adopt renewable energy are welcome to the country.

In recent years, awareness on environmental issues has increased among Malaysians. However, a lot more efforts need to be done to increase awareness.[1] Thus, Malaysia must relook into the effectiveness of current measures aimed at creating greater public awareness on the importance of adopting renewable electricity in combating environmental problems. Adding to the existing policies that geared towards improving environmental quality, the government should consider adopting more effective ways of developing environmental awareness among Malaysians. For example, government agencies can make use of media (print, broadcast or Internet) to enhance education and awareness of people on environmental protection. Besides, incorporating environmental education into the current science classes in schools can be another effective way to create a sense of responsibility to the environment among children and young adults. By enhancing public awareness, it is hoped that renewable electricity consumption can be enhanced in Malaysia.

As trade openness hinders the consumption of renewable electricity, it is suggested that the policy makers have to ensure that trade between Malaysia and trading partners involves the transfer or use of technologies related to renewables. In this context, for example, the government can encourage the use of renewables among local exporters by providing them incentives, such as tax exemption.

Our finding of a unidirectional causality running from GDP to renewable electricity but not vice versa is in line with the 'conservation hypothesis'. The 'conservation hypothesis' implies that

[1]Despite various strategies and efforts taken to curb pollution, Malaysia remains as one of the top 30 CO_2 emitters in the world.

Malaysia may implement energy conservation policies without affecting its economic performance. In other words, a reduction in renewable electricity consumption would not retard the GDP growth. On the other hand, as economic growth helps to stimulate the use of renewable electricity as our finding suggested, it is vital therefore for Malaysia to come up with economic policies that would lead to robust growth.

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