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Article

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Elasticity and Causality among Electricity Generation from Renewable Energy and Its Determinants in Malaysia

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ABSTRACT

Renewable energy (RE) is a significant issue in attaining low-carbon emissions for Malaysia's economic development path. Therefore, this study investigates the determinants (capital, labor, economic growth, and financial development [FD]), which has an influence on RE generation, using time-series data from 1982 to 2015 period. The augmented Cobb–Douglas production function, F-bound test, and vector error correction model are employed to achieve the objectives of the study. The result of the analysis indicates a dynamic relationship among these variables. The long-run elasticity of capital and labor promotes RE generation, while the responsiveness of economic growth and FD undermine electricity generation from RE. Furthermore, there is long-run bidirectional causal relationship between capital and RE generation. Similarly, the feedback effect is found between labor and electricity generation from RE. Economic growth and FD are found to influence RE generation. Accordingly, the Malaysian government should pursue policies to enhance the utilization of RE sources toward national electricity supply security and sustainable socio-economic development.

Keywords: Malaysia, Renewable Energy, Financial Development, Sustainable Energy, Elasticity, Causality
JEL Classifications: E44, Q4, Q43

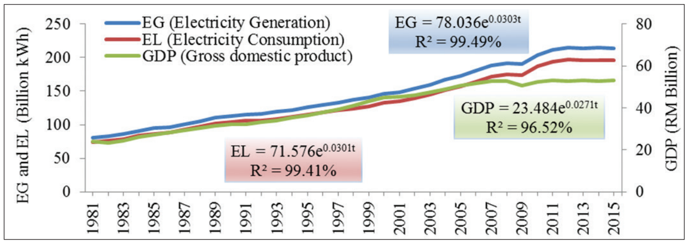
1. INTRODUCTION

Energy has been an important element of economic growth for many decades. Thus, many researchers have discussed energy issues and their significant effects on economic growth (Dogan, 2016; Dogan, 2015; Hamdi et al., 2014; Shahbaz et al., 2014; Karanfil and Li, 2015; Islam et al., 2013; Apergis and Payne, 2012; Shahbaz and Lean, 2012; Lorde et al., 2010; Jumbe, 2004). This shows that a secure, sufficient, and accessible supply of energy is a crucial requirement for the sustainability of modern societies and their economic well-being (Rafindadi and Ozturk, 2016b). This is regardless or contingent on the level of economic growth attained. Thus, an impressive economic performance has resulted in increased electricity consumption. While electricity demand is increased, the trend is likely to continue in the future on a global scale. In 2014, worldwide electricity generation was 23,636 TWh (Enerdata, 2015). Accordingly, world generation and consumption of electricity are moving together, and both have a significant relationship with economic growth. Figure 1 shows the world gross domestic product (GDP), electricity generation, and electricity consumption growth rate during the 1981-2015 period at 2.71%, 3.03%, and 3.01%, respectively. As the world energy consumption continues to increase significantly, there is growing concern regarding energy security (Ivy-Yap and Bekhet, 2016).

However, increasing electricity consumption has affected the environment in regards to climate change and global warming due to CO_2 emissions. There is broad consensus among scientists that accumulated CO_2 emitted from the burning of fossil fuels, along with contributions from other human-induced greenhouse gas (GHG) emissions, is warming the atmosphere and the oceans (IPCC, 2007), These climate changes, in turn, can have significant impacts on the functioning of ecosystems, the viability of wildlife, and the well-being of humans (Boutabba, 2014). In 2020, CO_2 emissions in developing countries are anticipated to be 127% higher than in developed countries (EIA, 2013). Due to these environmental concerns, the world has been forced to consider appropriate alternative electricity resources for sustainable energy.

Renewable energy (RE) sources are seen as essential contributors to sustainable energy, as they generally contribute to world energy security, reduce dependence on fossil fuels, and provide

Figure 1: Time trends of world gross domestic product, electricity generation and electricity consumption for 1981-2015 period



Source: EIA (2015)

opportunities for mitigating GHG. For example, in France, the major player in electricity generation is nuclear energy (Mbarek et al., 2015). However, the country also is committed to the challenging European Union (EU) targets of incorporating RE sources into the electricity mix (Marques et al., 2016b). The EU should keep on increasing its share of RE for lower levels of CO_2 emissions (Dogan and Seker, 2016). On the other hand, Brazil utilizes hydropower as the backbone of its electricity generation sector. This resource offers advantages in terms of fewer GHG emissions in the country (da Silva et al., 2016). Furthermore, Asian countries such as China, India, and Japan show that they are likewise interested in RE potential, as they also have noted the depletion of fossil fuels. In addition, the projection of increased or decreased RE should be linked to the adverse effect of RE on GHG. Furthermore, in India, many people believe that solar photovoltaic (PV) energy can provide more energy in the future compared with other types of RE (Sahoo, 2016). Generally, feed in tariff (FiT) is one of the regulatory policies that also plays a central role in attempts to increase generation from renewables in developing countries (Romano et al., 2017).

Malaysia is new at obliging an RE source within its domestic electricity generation mix. However, the utilization of RE shows promising prospects for Malaysia's power sector. This prospect is determined by the recent rapid development of sustainable energy technologies and increasing demand for low CO_2 emissions by targeting a 45% reduction in 2030 (SEDA, 2016). Furthermore, the potential of RE development in Malaysia remains popular due to energy security. For that reason, Malaysia has committed to incorporate RE sources into the electricity generation mix. In 1978, Malaysia introduced hydropower as its first RE source (Energy Commission, 2015). The electricity generated from hydropower is relatively cheaper compared with oil and natural gas over the long term. The cost will not be affected by changing fuel prices, which are currently determined by the international market. Additionally, the Malaysia government initiated other potential RE, which consists of biomass, biogas, and solar PV. These RE sources were introduced starting in 2012 due to environmental concerns and energy security. Therefore, the originality of this study compared with the previous works in the field of energy economics is that we consider the variables of electricity generation from RE as dependent variables. The presence of the relationship has been tested for utilizing the augmented production function by including capital (*K*) and labor (*L*) and other variables such as economic growth (*Y*) and financial development (*FD*). Furthermore, the individual country characteristics such as culture, wealth, income level, RE endowment, technology advancement, and amount of CO_2 emissions are important factors in RE (Lin et al., 2016; Vachon and Menz, 2006). Due to these factors, our analysis emphasizes Malaysia as being an individual country in order to achieve the objectives of the study. Then, this attempt may be important for policy- and decision-makers to better capture the determinants of RE generation in Malaysia.

Thus, the remainder of this paper is organized as follows. Section 2 highlights the Malaysian energy sector with economic performance. Section 3 reviews the past studies related to energy issues. Section 4 describes the model construction, data sources, and methodology. The findings and discussions are presented in Section 5. Conclusions and policy implications are discussed in Section 6.

2. OVERVIEW OF THE ENERGY SECTOR PERFORMANCE

Nowadays, 97.6% of the Malaysian people have access to electricity in sectors such as housing, transportation, manufacturing, construction, etc. (EPU, 2016). The dependency of people on electricity consumption for all the activities must be highlighted for sustainable electricity generation. From 1981 to 2015, the growth rates of electricity consumption and generation are 8.7% and 8.4%, respectively (Figure 2). These growth rates are increasing exponentially with the GDP growth at 5.9%. It has been revealed that the electricity supply is needed for enhancement to meet the electricity of demand.

Electricity is produced in power stations, which are normally situated away from urban and industrials areas where power is required by consumers (Bekhet and Harun, 2010). In Malaysia, the electricity supply industry is vertically integrated in a monopolistic market, where a utility company handles all the generation, transmission, and distribution of electricity in a region. The main utility companies are Tenaga Nasional Berhad (TNB), Sabah Electricity Sdn. Bhd., and Sarawak Energy Berhad, with each covering the regions of the Peninsular Malaysia, Sabah, and Sarawak, respectively. Figure 3 displays the performance of electricity generation in the above companies for the 2010-2015 period. It reveals the electricity generation by these companies and shows that TNB is the major contributor.

Realizing the increase in electricity consumption, the government continuously reviews its energy policy to ensure long-term reliability and security of energy resources. To fulfill electricity demand, Malaysia has resorted to use the viability of energy sources for generating electricity to increase its installed capacity. The efficient use of an energy source is one of the principal requirements for sustainable energy. The optimization of fuel mix and exploration of a RE source is given priority to reduce the nation's dependency on fossil fuels for electricity generation. Furthermore, higher energy consumption has led policymakers to build the potential of an RE source (Romano et al., 2017). Since 2001, Malaysia has aimed to generate more than 5% of its energy mix coming from RE sources by the year 2020 (EPU, 2016;

SEDA, 2015). Currently, Malaysia's government is seeking to intensify technology development of RE sources for sustainable energy. Technologies that promote sustainable energy include RE sources such as hydroelectricity, solar energy, biogas, biomass, geothermal energy, and technologies designed to improve energy efficiency. The continuous discussion of the importance of RE source development in Malaysia has been verified by the Malaysia Plans since 2001 (Lean and Smyth, 2014).

Figure 4 displays the installed capacity of electricity generation by total and different sources of RE from 2012 to 2015. Total RE installations have increased from 167.46 to 395.17 MWh, for 2012 and 2013, respectively. Thus, the graph shows the continuous increase of total installations to 553.17 and 605.57 MWh, for 2014 and 2015, respectively (SEDA, 2016), Since the development of RE source in the early stage, this information has created a clear picture of the available potential and current status of different RE sources in Malaysia.

Among all RE sources, Malaysia is blessed with significant hydropower energy potential. Since 1978, hydroelectric power plants have shown remarkable benefit to the Malaysia electricity industry. However, the development of a hydropower dam is complex, and the issues are not confined to the design, construction, and operation of the dams themselves; environmental and social concerns play a role as well. Furthermore, Malaysia also is blessed with the huge potential of solar PV being another source of clean energy supply. Due to the ideal weather conditions in Malaysia, solar energy is appropriate and would be an easily available RE source. Likewise, solar energy can be used for electricity generation or producing thermal energy, and solar electricity can be produced using off-grid or on-grid systems. It can be used for lighting applications and operating electrical appliances or machines in residential, commercial, and industrial sectors. For the time being, bio-mass and bio-gas power plants have been considered due to the significant potential of these sources in Malaysia (EPU, 2016), Moreover, among the various sources of RE, bio-energy seems to be the most prevalent source in Malaysia. This is because the Malaysia Fuel Diversification Policy (2001) determined bio-mass to be the "fifth fuel" resource. In 2006, the National Bio-fuel Policy was launched and encouraged the use of environmentally friendly, sustainable, and viable sources of bio-mass energy (Bujang et al., 2016; Petinrin and Shaaban, 2015).

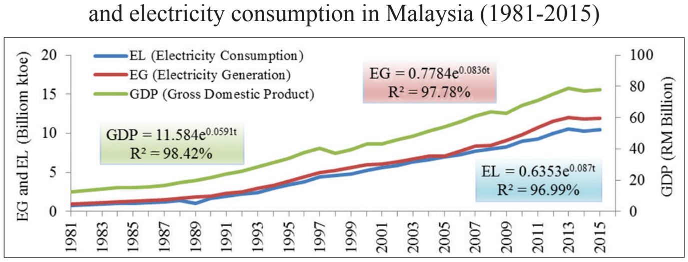
The development of utilization on the RE source is significantly taken to improve the share of this RE in Malaysia's energy mix. Therefore, government incentives and national policies have been designed to encourage RE usage of power generation in Malaysia. In order to fulfill the RE policy, action plans and strategies are needed to encourage the growth of RE installation, such as solar energy. Thus, Malaysia introduced FiT and utility scale solar in order to generate power and reduce electricity bills, focusing on households and industries. For the purpose of energy security, Malaysia has to achieve a target of 2080, 3000, and 4000 MW (Figure 5) of energy resulting from RE sources by 2020, 2025, and 2030, respectively. Currently, Malaysia is facing the challenge of awareness and development of RE targets, similar to other countries in the global community (Lean and Smyth, 2014; Klessmann et al., 2011; Tolón-Becerra et al., 2011).

Hence, the importance of electricity generation from RE is highlighted in order to protect environmental issues and also for the energy security, in the case of Malaysia.

3. LITERATURE REVIEW

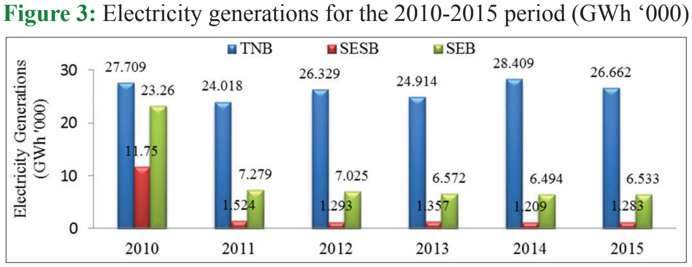
Traditionally, most previous studies have examined the relationship between energy consumption and economic growth (Raza et al., 2015; Alshehry and Belloumi, 2015; Kivyiro and Arminen, 2014; Islam et al., 2013; Shahbaz and Lean, 2012; Belloumi, 2009; Ghali and El-Sakka, 2004; Soytas and Sari, 2003; Yang, 2000;

Figure 2: Time trend of gross domestic product, electricity generation and electricity consumption in Malaysia (1981-2015)



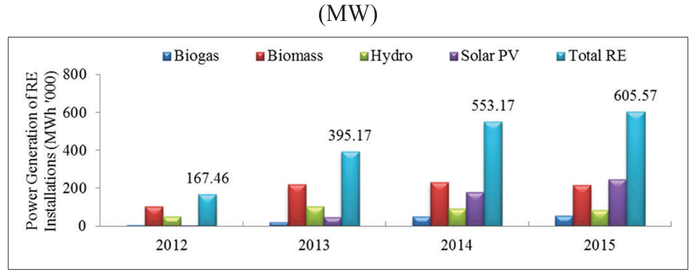
Source: Energy Commission, Malaysia (2015)

Figure 3: Electricity generations for the 2010-2015 period (GWh '000)



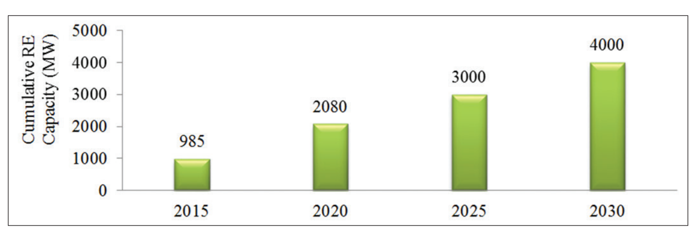
Source: Energy Commission, Malaysia (2015)

Figure 4: Installations of renewable energy for the 2012-2015 period (MW)



Source: SEDA, Malaysia (2016)

Figure 5: National renewable energy targets, for year 2015, 2020, 2025 and 2030



Source: Energy Commission, Malaysia (2016)

Asafu-Adjaye, 2000; Kraft and Kraft, 1978). It was conducted using bi-variate and multivariate models in different methodologies, time periods, sectors, and countries. Different variables customizing energy consumption and explaining economic growth also were used. The majority of energy-growth nexus comes from aggregate energy consumption, and some of them use electricity consumption (Rafindadi and Ozturk, 2016a; Khatun and Ahmad, 2015; Matar and Bekhet; 2015; Husaini and Lean, 2015; Karanfil and Li, 2015; Wolde-Rufael, 2014; Lorde et al., 2010; Jamil and Ahmad, 2010; Chandran et al., 2010; Narayan et al., 2009; Mozumder and Marathe, 2007; Soytas and Sari, 2007; Squally and Wilson, 2006; Shiu and Lam, 2004; Jumbe, 2004), Nowadays, many researchers are more concerned with alternative energy issues in the literature, which has investigated the relationship between economic growth and RE consumption (Rafindadi and Ozturk, 2016b; Dogan, 2016; Marques et al., 2016b; Bento and Moutinho, 2016; Lin et al., 2016; Shahbaz et al., 2015; Caraini et al., 2015; Bloch et al., 2015; Jebli and Youseff, 2015; Jebli et al., 2016; Bhattacharya et al., 2016; Jebli et al., 2015; Marques et al., 2014; Ohler and Fetters, 2014; Al-Mulali et al., 2013; Shahbaz et al., 2012). Therefore, it is important in the methodology process to concentrate on the elasticities and the direction of causalities in the literature.

The result of an elasticity relationship is useful in determining the response between economic growth and energy consumption. A common result of some studies is that the RE does not have a positive response on economic growth (Al-Mulali et al., 2013; Apergis and Payne, 2012; Lean and Smyth, 2010). The authors claimed that the high cost of promoting RE sources is the reason that their use does not have a positive response on economic growth (Marques and Fuinhas, 2012). This violates the result in Greece (2004:M08-2014:M02), whereby the RE has a positive response to the economic growth (Marques et al., 2014). In France (2010:M01-2014:M11), wind power constrains economic growth and solar PV stimulates economic growth (Marques et al., 2016a). It means that RE consumption has a positive and negative response to economic growth. In Germany (1970:Q1-2013:Q4), economic growth is depends on RE development for sustainable energy (Rafindadi and Ozturk, 2016b). The clear reason for this situation is due to the level of a country's development; developed and developing countries and also the period of time. Developed countries have been consuming highest per capita electricity consumption in buildings and tend to levy taxes for environmental reasons on electricity, whereas developing industrialized countries are taking the lead in medium per capita consumption and heavily subsidize energy consumption for social reasons (Shaikh et al., 2016; Shahbaz et al., 2015).

On the other hand, the result of a causal relationship can be categorized based on the direction of the causality test in three ways—bidirectional, unidirectional, and neutrality relationship—then it can decide on the possible policy outcomes. For example, Rafindadi and Ozturk (2016a) and Shahbaz and Lean (2012) found that the energy and economic growth are jointly determined and affect each other. This implies that energy exploration policies should be encouraged to sustain economic growth in Japan (1970-2008) and Tunisia (1971-2008). These results also offer significant contributions in energy economics and opens a new direction for policymakers to explore new and alternative sources of energy. Therefore, some studies (Rafindadi and Ozturk, 2016b; Bloch et al., 2015; Ohler and Fetter, 2014; Al-Mulali et al., 2013) revealed that an RE source is among the alternative elements to support enhancing the sustainability for further economic growth in countries such as Germany, China, and OECD countries. In addition, some studies have revealed a unidirectional causal relationship from economic growth to energy consumption (Charfeddine and Khediri, 2016; Husaini and Lean, 2015; Jamil and Ahmad, 2010; Soytas and Sari, 2003), This indicates that a reduced policy of energy demand may not have much impact on economic growth in the UAE (1975-2011), Malaysia (1978-2011), Pakistan (1960-2008), Italy (1950-1992), and Korea (1953-1991). The energy-saving policies that protect the environment can be utilized without reducing economic growth. Some researchers have examined the opposite type of causality, known as a unidirectional causal relationship, running from energy consumption to economic growth (Alshehry and Belloumi, 2015; Ziramba, 2015; Khatun and Ahamad, 2015; Shahbaz et al., 2013). In this type of causality, energy conservation policies usually have had a negative effect on growth in Saudi Arabia (1971-2010), South Africa (1990-2008), Bangladesh (1972-2010), and China (1971-2011), The same inference is drawn for Tunisia (1980-2009) and Hungary (1980-2013) by using a RE source, which showed the validity of the conservation hypothesis, which are economic growth Granger cause RE (Jebli and Youssef, 2015; Caraini et al., 2015), But Shahbaz et al. (2012) in the case of Pakistan (1972-2011) supported the unidirectional running from RE to economic growth. Moreover, the results and details of a bidirectional and unidirectional causal relationship are presented in Table 1, Part A and Part B, respectively.

On the other hand, the neutral relationship holds when energy conservation programmes do not have an effect on growth. A few studies have resulted in evidence of no causal relationship between energy consumption and economic growth (Karanfil and Li, 2015; Wolde-Rufael, 2014; Kivyiro and Arminen, 2014) in North America (1980-2010), Poland (1975-2010), and Zimbabwe (1971-2009), Similar results also have been found in European countries with advanced analysis on energy by including RE sources (Menegaki, 2011), This means that the consumption of RE plays a minor role in the determination of GDP in Europe. The details of neutral relationship results are shown in Table 1, Part C. Given that there are numerous studies in existing literature, which have discussed economic growth as a dependent variable and include energy consumption as their determinant in the various countries in the world. Our study, therefore, attempts to fill the gap by considering the electricity generation from RE as a dependent variable and the relationship with its determinants (*K*, *L*, *Y*, and *FD*) is examined by utilizing an augmented production function (more details see Section 4). Also, this analysis focuses on Malaysia as an individual country. To achieve the objectives of this study, the hypotheses are formulated as follows.

H_{11}: There is a short- and long-run dynamic relationship between electricity generation from RE and its determinants (*K*, *L*, *Y*, and *FD*) in Malaysia.

H_{12}: There are short- and long-run elasticities between electricity generation from RE and it determinants (*K*, *L*, *Y*, and *FD*) in Malaysia.

Table 1: Summary of empirical studies on energy-growth nexus literature

Author	Time period	Country	Econometric technique	Variables	Finding
A: Bidirectional causal relationship					
Rafindadi and Ozturk (2016a)	1970-2012	Japan	Multivariate	Y_{pc}, EL_{pc}, FD_{pc}, EX_{pc}, IM_{pc}, K_{pc}	EL↔Y
Rafindadi and Ozturk (2016b)	1971-2013(Q)	German	Multivariate	Y_{pc}, RE_{pc}, K_{pc}, L_{pc}	RE↔Y
Bloch et al. (2015)	1977-2013	China	Multivariate	I, EC, ECco, ECcr, RE	EC↔I, ECco↔Y, ECcr↔Y, RE↔Y
Karanfil and Li (2015)	1980-2010	160 countries	Bivariate	Y_{pc}, EL_{pc}	EL↔Y
Raza et al. (2015)	1973-2013	Pakistan	Multivariate	Y, EC, EX, IM	EC↔Y
Hamdi et al. (2014)	1975-2011(Q)	Bahrain	Multivariate	Y_{pc}, EL_{pc}, K_{pc}, FDI_{pc}	EL↔Y
Wolde-Rufael (2014)	1975-2010	Ukraine	Bivariate	Y, EL	Y↔EL
Shahbaz et al. (2014)	1972-2012(Q)	Pakistan	Multivariate	Y_{pc}, $EGng_{pc}$, K_{pc}, L_{pc}	EGng↔Y
Islam et al. (2013)	1971-2009	Malaysia	Multivariate	Y, EU, FD, POP	EU↔Y
Shahbaz and Lean (2012)	1971-2008	Tunisia	Multivariate	Y_{pc}, EC_{pc}, FD_{pc}, IND_{pc}, URB_{pc}	EC↔Y
Apergis and Payne (2012)	1990-2007	80 countries	Multivariate	Y, RE, NRE, K, L	RE↔Y, NRE↔Y
Lorde et al. (2010)	1960-2004	Barbados	Multivariate	Y, EL, K, L, T	EL↔Y
Narayan et al. (2009)	1974-2002	Middle East	Multivariate	Y, EL, EX	EL↔Y
He et al. (2008)	1978-2006	China	Bivariate	Y, EC	EC↔Y
Squalli and Wilson (2006)	1980-2003	Bahrain, Qatar, Saudi Arabia	Bivariate	I, EL	EL↔I
Yoo and Kim (2006)	1971-2002	Indonesia	Bivariate	Y, EG	Y↔EG
Ghali and El-Sakka (2004)	1961-1997	Canada	Multivariate	Y, EU, K, L	EU↔Y
Jumbe (2004)	1970-1999	Malawi	Multivariate	Y, EL, AY, NY	EL↔Y
Soytas and Sari (2003)	1950-1990	Argentina	Bivariate	Y, EC	EC↔Y
Yang (2000)	1954-1997	Taiwan	Bivariate	Y, EC	EC↔Y
Asafu-Adjye (2000)	1971-1995	Thailand and Philippines	Multivariate	I, EC, P	EC↔I
B: Unidirectional causal relationship					
Dogan, 2016	1988-2012	Turkey	Multivariate	Y_{pc}, RE_{pc}, NRE_{pc}, K_{pc}, L_{pc}	RE→Y
Charfeddine and Khediri (2016)	1975-2011	UAE	Multivariate	CO_{2pc}, I_{pc}, EL_{pc}, FD, TR, URB	I↔EL
Matar and Bekhet (2015)	1976-2011	Jordan	Multivariate	Y, EL, FD, EX	Y→EL
Alshehry and Belloumi (2015)	1971-2010	Saudi Arabia	Multivariate	CO_{2pc}, Y_{pc}, EC_{pc}, P	EC→Y
Khatun and Ahmad (2015)	1972-2010	Bangladesh	Multivariate	Y, EL, FDI	EL→Y
Ziramba (2015)	1990-2008	South Africa	Multivariate	Y, ECcr, K	ECcr→Y
Caraini et al. (2015)	1980-2013	Poland	Multivariate	Y, EC, ECco, ECcr, ECng, RE	Y→ECng, ECco→Y, EC→Y
Caraini et al. (2015)	1980-2013	Turkey	Multivariate	Y, EC, ECco, ECcr, ECng, RE	Y→ECco
Caraini et al. (2015)	1980-2013	Romania	Multivariate	Y, EC, ECco, ECcr, ECng, RE	ECco→Y
Jebli and Youssef (2015)	1980-2009	Tunisia	Multivariate	CO_{2pc}, Y_{pc}, RE_{pc}, NRE_{pc}, TR_{pc}	Y_{pc}→RE
Caraini et al. (2015)	1980-2013	Hungary	Multivariate	Y, EC, ECco, ECcr, ECng, RE	Y→RE
Husaini and Lean (2015)	1978-2011	Malaysia	Multivariate	Yva, EL, P	Yva→EL
Wolde-Rufael (2014)	1975-2010	Belarus, Bulgaria	Bivariate	Y, EL	EL→Y
Wolde-Rufael (2014)	1975-2010	Czech Republic, Latvia, Lithuania, Russian Federation	Bivariate	Y, EL	Y→EL
Shahbaz et al. (2013)	1971-2011	China	Multivariate	Y_{pc}, EU_{pc}, FD_{pc}, TR_{pc}, K_{pc}, $L_{,}$	EU→Y
Bekhet and Harun (2012)	1978-2009	Malaysia	Multivariate	Ygo, EU, K, L	EU→Y
Shahbaz et al. (2012)	1972-2011	Pakistan	Multivariate	Y_{pc}, RE_{pc}, NRE_{pc}, K_{pc}, L_{pc}	RE→Y, NRE→Y
Chandran et al. (2010)	1971-2003	Malaysia	Bivariate	Y, EL	EL→Y
Jamil and Ahmad (2010)	1960-2008	Pakistan	Multivariate	Y, EL, P	Y→EL
Lean and Smyth (2010)	1970-2008	Malaysia	Multivariate	Y_{pc}, $Ecng_{pc}$, EX_{pc}, P	Y→ECng
Belloumi (2009)	1971-2004	Tunisia	Bivariate	Y_{pc}, EC_{pc}	EC_{pc}→Y_{pc}

(Cond...)

Table 1: (*Continued*)

Author	Time period	Country	Econometric technique	Variables	Finding
Mozumder and Marathe (2007)	1971-1999	Bangladesh	Bivariate	Y_{pc}, EL_{pc}	Y_{pc}→EL_{pc}
Soytas and Sari (2007)	1968-2002	Turkey	Multivariate	Yva, EL, K, L	EL→Yva
Squalli and Wilson (2006)	1980-2003	Kuwait	Bivariate	I, EL	I→EL
Shiu and Lam (2004)	1971-2000	China	Bivariate	Y, EL	EL→Y
Soytas and Sari (2003)	1950-1992	Turkey, France, Germany, Japan	Bivariate	Y, EC	EC→Y
Soytas and Sari (2003)	1950-1992	Italy	Bivariate	Y, EC	Y→EC
Soytas and Sari (2003)	1953-1991	Korea	Bivariate	Y, EC	Y→EC
Asafu-Adjye (2000)	1973-1995	India, Indonesia	Multivariate	I, EC, P	EC→I
C: Neutral relationship					
Karanfil and Li (2015)	1980-2010	North American	Bivariate	Y_{pc}, EL_{pc}	EL≠Y
Karanfil and Li (2015)	1980-2010	Sub-Saharan African	Bivariate	Y_{pc}, EL_{pc}	EL≠Y
Wolde-Rufael (2014)	1975-2010	Albania, Moldova, Poland, Romania, Slovak Republic, Serbia, Slovenia	Bivariate	Y, EL	Y≠EL
Kivyiro and Arminen (2014)	1971-2009	Zimbabwe	Multivariate	CO_{2pc}, EC_{pc}, Y_{pc}, FDI	Y≠EC
Menegaki (2011)	1997-2007	European countries	Multivariate	Y, RE, EC, CO_2, EMP	Y≠RE
Eden and Jin (1992)	1974-1990	USA	Bivariate	Y, EC	Y≠EC
Yu and Choi (1985)	1950-1976	USA, UK, Poland	Bivariate	Y, EC	Y≠EC
Eden and Hwang (1984)	1947-1979	USA	Bivariate	Y, EC	Y≠EC
Akarca and Long (1980)	1950-1968	USA	Bivariate	Y, EC	Y≠EC

Y: GDP, Ygo: Gross output, Yva: Value added, I: Income, EC: Energy consumption, EL: Electricity consumption, EG: Electricity generation, EU: Energy use, EGng: Natural gas consumption, ECco: Coal consumption, ECcr: Crude oil consumption, NRE: Non-renewable energy consumption, RE: Renewable energy consumption, K: Capital, L: Labor, EMP: Employment, CO_2: Carbon dioxide/greenhouse gas emissions, FD: Financial development, FDI: Foreign direct investment, TR: Trade openness, EX: Export, IM: Import, POP: Population, IND: Industrialization, URB: Urbanization, P: Energy price, AY: Agricultural GDP, NY: Non-agricultural GDP, Q: Quarterly time period. The notation →, ↔ and ≠ represents uni-directional causality, bi-directional causality and no causality, respectively. The suffix *pc* means that series are expressed in per capita, GDP: Gross domestic product

H_{13}: There is a short- and long-run causality between electricity generation from RE and its determinants (*K*, *L*, *Y*, and *FD*) in Malaysia.

4. DATA SOURCES AND METHODOLOGY

4.1. Model Constructions and Data Sources

Theories play an important role in any empirical study in order to show the strength of the model specification. Therefore, the theory of production shows the relationship between inputs toward the output. The Cobb–Douglas (C-D) production function is the most universal form in theoretical and empirical analyses of growth and productivity (Felipe and Adams, 2005). Stern (1993) highlighted the importance of energy and used the augmented C-D production function (Equation 1) to examine the relationship between economic growth (*Y*), capital (*K*), labour (*L*), and energy (*E*),

$$Y = AK^{\alpha_1} L^{\alpha_2} E^{\alpha_3} \tag{1}$$

This approach was applied by many researchers (Stern, 2000; Ghali and El-Sakka, 2004; Oh and Lee, 2004; Soytas and Sari, 2007; Yuan et al., 2009) to find the relationship among the above variables. Thus, it has become a standard technique in the new empirical growth literature. Bloch et al. (2015) included coal, oil, and RE as inputs in the production function framework. Furthermore, there are some studies (Apergis and Payne, 2012; Arbex and Perobelli, 2010) used the disaggregation of energy consumption, namely, RE and non RE (NRE) as the determinants in their framework. As noted earlier, the alternative source, namely, RE has become an important issue nowadays, especially since this issue has been debated in regards to economic growth and environmental concerns. Thus, RE sources are able for implementation of electricity generation in Malaysian economic growth. Due to this issue, an advanced discussion on development of RE is included in the augmented production function (Equation 2),

$$Y = AK^{\alpha_1} L^{\alpha_2} RE^{\alpha_3} \tag{2}$$

Originally, most of the studies labeled *A* as a constant value. However, Shahbaz et al. (2013) defined *A* as a *FD*. The authors revealed that FD enhances domestic production through investment activities and boosts economic growth via a well-developed and growing financial market, as in the case of China. Furthermore, Sadorsky (2010) indicated that FD markets enhance confidence of local as well as foreign investors. Therefore, the identification of (*A*) could be constructed as in Equation 3. If substitute it into Equation 2, then the extended production function can be simplified as in Equation 4.

$$A = \alpha_0 FD^{\alpha_4} \tag{3}$$

$$Y = \alpha_0 K^{\alpha_1} L^{\alpha_2} RE^{\alpha_3} FD^{\alpha_4} \tag{4}$$

Because the issue of electricity consumption is kept growing with economic growth (*Y*), it also will affect electricity generation and energy sources (Figures 1 and 2), Therefore, these dynamic relationships, elasticities, and causality issues require more in-depth investigation, and it becomes an interesting discussion related to the RE element with economic growth in a developing country such as Malaysia. For that reason and following (Rafindadi and Ozturk, 2016b; Dogan, 2016; Shahbaz et al., 2015; Marques et al., 2014; Yoo and Kim, 2006), we use electricity generation from RE as a dependent variable and *Y* as independent variable with the other factors (*K*, *L*, and *FD*). Thus, the model can be rewritten as in Equation (5):

$$RE_t = \alpha_0 K_t^{\alpha_1} L_t^{\alpha_2} Y_t^{\alpha_3} FD_t^{\alpha_4} \quad (5)$$

To linearize this function, all the variables are transformed to the natural logarithms (*l*) form (as in Equation 6), It will reduce heteroscedasticity problems and obtain more consistent and efficient results (Ertugrul et al., 2016; Bekhet and Al-Smadi, 2016; Hamdi et al., 2014; Boutabba, 2014; Shahbaz and Lean, 2012), Also, it is useful to interpret the coefficient estimates as the elasticities (Dogan and Seker, 2016; Bekhet and Harun, 2012) of the response variables (RE) with respect to the independent variables (*K*, *L*, *Y*, and *FD*),

$$lRE_t = \alpha_0 + \alpha_1 lK_t + \alpha_2 lL_t + \alpha_3 lY_t + \alpha_4 lFD_t + \varepsilon_t \quad (6)$$

Where α_0, α_2, α_3 and α_4 represent the partial coefficients of the *K*, *L*, *Y*, and *FD* variables, respectively. t symbolizes the time-series data in years, and ε indicates the stochastic error terms assumed to be normally distributed, along with white noise (Bento and Moutinho, 2016), The data on RE generation sources are obtained from Energy Commissions, Malaysia, and measured by kg of oil equivalent (ktoe), While the data on *K*, *L*, and *Y* variables are collected from Department of Statistics Malaysia (DOSM, 2015), The proxy of *K* is gross fixed capital formation, *L* is labor force in Malaysia, and *Y* is GDP. The series of *K* and *Y* are transformed to the real value (2005 = 100) to avoid the inflation issue. Additionally, the FD is taken from the World Development Indicator. It is measured by domestic credit to private sector as a share of GDP. The data is annual observations for the period 1982-2015. In addition, Table 2 summarizes these variables sources, and past empirical studies have used them.

4.2. Methodology

Data quality tests are employed to determine the basic features of the data that were acceptable by theory. To confirm the solid results of stationarity of data series, the augmented Dickey and Fuller (1979), Phillips and Perron (1988), Kwiatkowski et al. (1992), and Ng and Perron (2001) tests are applied. Therefore, the F-bound test is used to identify the dynamic relationship among the variables (Pesaran et al., 2001). It has many advantages compared with other conventional methods (Bento and Moutinho, 2016; Marques et al., 2016b; Matar and Bekhet, 2015; Boutabba, 2014; Hamdi et al., 2014; Shahbaz et al., 2013; Shahbaz et al., 2012). First, it allows us to use a mixture stationary of I(0) and I(1) variables. Second, it performs better in small samples, $30 \leq t \leq 80$. Third, it allows us to have different optimal lags of the variables. Fourth, assuming all the variables as endogenous eliminates the endogeneity problems associated with the Engle–Granger method (Al-Mulali et al., 2015), Therefore, Equation 7 is formulated to analyze the dynamic relationship among the variables.

$$\Delta\begin{bmatrix} lRE \\ lK \\ lL \\ lY \\ lFD \end{bmatrix}_t = \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_4 \\ \alpha_5 \end{bmatrix} + \begin{bmatrix} \varphi_{11} & \varphi_{12} & \varphi_{13} & \varphi_{14} & \varphi_{15} \\ \varphi_{21} & \varphi_{22} & \phi_{23} & \varphi_{24} & \varphi_{25} \\ \varphi_{31} & \varphi_{32} & \varphi_{33} & \varphi_{34} & \varphi_{35} \\ \varphi_{41} & \varphi_{42} & \varphi_{43} & \varphi_{44} & \varphi_{45} \\ \varphi_{51} & \varphi_{52} & \varphi_{53} & \varphi_{54} & \varphi_{55} \end{bmatrix} \begin{bmatrix} lRE \\ lK \\ lL \\ lY \\ lFD \end{bmatrix}_{t-1} + \sum_{s=0}^{n} \Delta \begin{bmatrix} \delta_{11} & \delta_{12} & \delta_{13} & \delta_{14} & \delta_{15} \\ \delta_{21} & \delta_{22} & \delta_{23} & \delta_{24} & \delta_{25} \\ \delta_{31} & \delta_{32} & \delta_{33} & \delta_{34} & \delta_{35} \\ \delta_{41} & \delta_{42} & \delta_{43} & \delta_{44} & \delta_{45} \\ \delta_{51} & \delta_{52} & \delta_{53} & \delta_{54} & \delta_{55} \end{bmatrix}_s \begin{bmatrix} lRE \\ lK \\ lL \\ lY \\ lFD \end{bmatrix}_{t-s} + \begin{bmatrix} \mu_1 \\ \mu_2 \\ \mu_3 \\ \mu_4 \\ \mu_5 \end{bmatrix}_t \quad (7)$$

Where, Δ is the first difference operator, $\alpha_i s$ represent the intercepts; $\varphi_{it}s$ and $\delta_{it}s$ denote the long- and short-run coefficients, respectively. $\mu_{it}s$ symbolize the error terms, *n* indicates the optimal lag length, *t* represent time period, and *s* is the lag order selection. The selection of the lags is based on the Akaike information criteria (AIC), Schwarz Bayesian information criterion, and Hannan-Quinn (HQ) criterion. The autoregressive distributed lag (ARDL) model is used to examine the relationship among variables (Equation 7), It is useful to determine the dynamic relationship between electricity generation and its determinants, the long- and short-run relationships (H_{11}), For the long-run relationship, the joint significance of the F-statistics on the lagged level explanatory variables (lRE_{t-1}, lK_{t-1}, lL_{t-1}, lY_{t-1}, lFD_{t-1}) is applied, which compares with upper critical bound I(1) and lower critical bound I(0) generated by Narayan (2005), because the sample size of observation is small (T = 34). The null hypothesis (H_{01}: $\varphi_{it} = 0$) of no long-run relationship is tested against the alternative hypothesis

Table 2: Variables and data sources

Variables	Proxy	Sources	Past study
RE	Ktoe	Energy commissions	Jebli and Youseff (2015), Apergis and Payne (2012), Shahbaz et al. (2012), Arbex and Perobelli (2010)
K	GFCF (RM million)	DOSM	Raza et al. (2015), Robalino-Lopez (2015), Apergis and Payne (2012), Bekhet and Harun (2012)
L	Labour force	DOSM	Shahbaz et al. (2014), Apergis and Payne (2012), Bekhet and Harun (2012), Lorde et al. (2010), Arbex and Perobelli (2010)
Y	GDP (RM million)	DOSM	Rafindadi and Ozturk (2016), Dogan (2015), Islam et al. (2013), Apergis and Payne (2012)
FD	Domestic credit to private sector as the share of GDP	WDI	Lin et al. (2016), Rafindadi and Ozturk (2016), Boutabba (2014), Shahbaz et al. (2013), Beck et al. (2010)

RE: Renewable energy consumption, K: Capital, L: Labour, Y: GDP, FD: Financial development, GDP: Gross domestic product

(H_{11}: $\varphi_{it} \neq 0$) of a long-run relationship. The decision rule is to reject the null of no long-run relationship if the F-statistic values exceed the I(1) critical value and vice versa if the F-statistics values are below the I(0). However, if the F-statistic values are between the I(0) and I(1), no exact conclusion can be made or the test is uncertain. In this case, the result may refer to the past literature, which has or has not confirmed the existence of the long-run relationship. Alternatively, some of the studies have suggested that the error correction term will be a useful way to establish a dynamic relationship (Ivy-Yap and Bekhet, 2016; Matar and Bekhet, 2015; Boutabba, 2014; Banerjee et al., 1998; Kremers et al., 1992). On the other hand, the short-run relationship could be determined if the null hypothesis (H_{01}: $\delta_{it} = 0$) of no short-run relationship is rejected.

Because the dynamic relationship is obtained, the next step is to examine the elasticities of RE generation toward its determinants (Ivy-Yap and Bekhet, 2016; Ivy-Yap and Bekhet, 2015; Asteriou and Hall, 2007). These elasticities consider that the use of electricity generation from RE can provoke various responses on the other determinants as well as economic growth. The computation of both short- and long-run elasticities by using the ARDL approach ensures the measurement of these response (Narayan and Narayan, 2005). The result of these elasticities would achieve the second hypothesis (H_{12}) for short- and long-run elasticities between the RE generation and its determinants. Although the finding of dynamic relationships and elasticities among the variables are included in the model, the direction of causality is not identified. Thus, we employ a vector error correction model (VECM) to detect the direction and nature of causality (Equation 8), The results of this method are important to Malaysia policymakers for constructing and applying energy policies.

$$\Delta\begin{bmatrix} lRE \\ lK \\ lL \\ lY \\ lFD \end{bmatrix}_t = \begin{bmatrix} b_1 \\ b_2 \\ b_3 \\ b_4 \\ b_5 \end{bmatrix} + \sum_{j=1}^{k} \Delta \begin{bmatrix} \beta_{11} & \beta_{12} & \beta_{13} & \beta_{14} & \beta_{15} \\ \beta_{21} & \beta_{22} & \beta_{23} & \beta_{24} & \beta_{25} \\ \beta_{31} & \beta_{32} & \beta_{33} & \beta_{34} & \beta_{35} \\ \beta_{41} & \beta_{42} & \beta_{43} & \beta_{44} & \beta_{45} \\ \beta_{51} & \beta_{52} & \beta_{53} & \beta_{54} & \beta_{55} \end{bmatrix}_j \begin{bmatrix} lRE \\ lK \\ lL \\ lY \\ lFD \end{bmatrix}_{t-j} + \begin{bmatrix} \gamma_1 \\ \gamma_2 \\ \gamma_3 \\ \gamma_4 \\ \gamma_5 \end{bmatrix} \left[ECT_{t-1}\right] + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \\ \varepsilon_4 \\ \varepsilon_5 \end{bmatrix}_t \tag{8}$$

Where, Δ is the first difference operator, $b_i s$ symbolize the constant values; $\beta_{it}s$ denote the short-run causal relationships. $\varepsilon_{it}s$ represent serially uncorrelated random error terms with a zero mean, k indicates the optimal lag length, j is the lag length criteria based on likelihood ratio test, and t represents the time period. ECT_{t-1} is the one period lagged error-correction term, generated from the long-run association (Equation 7) and ε_{it} are the serially uncorrelated random error terms. The statistical significance of ECT_{t-1} coefficients using a t-statistic further validates the established long-run relationship between the variables with the negative sign. The estimates of ECT_{t-1} also show the speed of adjustment rate from a short-run toward the equilibrium path in all models, while the short-run causality is determined by the joint χ^2 statistical significance of the estimates of the first difference lagged independent variables (lRE_{t-j}, lK_{t-j}, lL_{t-j}, lY_{t-j}, lFD_{t-j}). Therefore, the result of a short- and long-run causal relationship is useful to achieve the third hypothesis (H_{13}) for a causal relationship between electricity generation from RE and its determinants.

The normality, serial correlation, and heteroscedasticity tests are used to confirm the robustness of error terms generated by the ARDL model. It includes Ramsey's reset test by using the square of the fitted values to correct the functional form (Bento and Moutinho, 2016); then, cumulative sum (CUSUM) and CUSUM squared tests are applied to verify the stability of long- and short-run relationships (Brown et al., 1975), Additionally, the variance decomposition (VD) for RE generation and its determinants are estimated, which determines what percentage of the forecast error variance of the dependent variable can be explained by exogenous shocks to the independent variable. Furthermore, the impulse response function (IRF) is employed to investigate how the selected variable under consideration reacts to the exogenous shocks in the others.

5. FINDINGS AND DISCUSSIONS

Table 3 reveals the data quality tests and inter-relationship matrix results, which confirm that the distribution of the data variables is normal. As noted, electricity generation from RE has a strong significant and positive relationship with each of *K*, *L*, *Y*, and *FD* variables and within an acceptance range of relationship coefficients. Generally, these results are consistent with the existing literature (Matar and Bekhet, 2015; Islam et al., 2013; Lai et al., 2011; Narayan and Smith, 2009).

Furthermore, *RE*, *K*, *L*, *Y*, and *FD* variables contain a unit root at their I(0), which becomes stationary at their I(1) at a 5% level of significance (Table 4). Again, these results are in line with the existing literature (Lin et al., 2016; Bento and Moutinho, 2016; Rafindadi and Ozturk, 2016b; Shahbaz et al., 2015; Bloch et al., 2015).

The unique order of integration of these variables leads us to test the existence of a dynamic relationship among them. In doing so, we performed the F-bound test because the number of observations (T = 34) is small. As noted, the lag selection is important in the case of the ARDL approach. The results of optimal lag order (LR, FPE, AIC, SC, and HQ criterions) are at lag 2. These criterions are useful in choosing a suitable lag length that helps us in capturing the dynamic relationship to select the best ARDL model to estimate the elasticities. Hence, results of an F-bound test for the dynamic relationship among the variables are shown in Table 5, which indicates that *RE*, *K*, *Y*, and *FD* models are co-integrated at a 5% significance level. This result is similar to that found in the existing literature (Dogan, 2016; Shahbaz et al., 2015; Marques et al., 2014), However, these results detect four vectors of a dynamic relationship: The EGRE, *K*, *Y*, and *FD* models. In this paper, we use only the first model (RE) to achieve the objectives of the current study. Also, the result of the RE model is allowed to employ the ARDL model simultaneously in order to obtain the long- and short-run elasticities.

Based on the dynamic relationship among the above variables (Table 5), the long- and short-run elasticities of these variables are investigated. These results are shown in Figure 6 and Appendices A. In the long-run elasticity, the capital has a positive response and is inelastic on RE. It is noted, a 1% increase in capital leads electricity generation from RE increases by 0.55%. Labor was equally found to have a positive response but remains elastic in the Malaysia RE generation. This study discovered that a 4.58% increase in RE generation is due to 1% increase in labor. Contrarily, the responsiveness of GDP is negative and elastic on RE, which means that a 1% increase in GDP reduces electricity generation from RE by 1.64% in the long-run. Our finding is a bit misleading with most of previous empirical result, where we found that increase in GDP will reduce RE generation for Malaysia. Typically, it is not consistent with recent studies by Lin et al. (2016), Marques et al. (2014) and Rafiq et al. (2014), where increases in GDP boosts the RE. However, in the short-run, the GDP has a positive response and elastic on RE. A 1% increase in GDP leads to increase in RE generation by 3.51%. In Malaysia, industrial and manufacturing production contributes to the GDP growth and these sectors are highly related to RE generation which highly sensitive to economic growth in the short-run only.

Besides, the responsiveness of FD is negative and inelastic in the long-run. A 1% increase in FD will reduce electricity generation from RE by 0.29%. This result is not consistent in some countries, such as China, whereby FD promotes the RE consumption even in the small portion (Lin et al., 2016; Pfeiffer and Mulder, 2013; Brunnschweiler, 2010). In Malaysia, the changes of FD cannot remain predictable for the changes of RE generation due to the lower awareness of the importance of RE in Malaysia. If several fiscal incentives had been launched by the government, the development of RE would be rather slow and still in the infancy stage (Mekhilef et al., 2014), The reason is that the RE developers faced difficulty in getting financing because the financial institutions still worry about such business ventures due to the perceived high risks (Shamsuddin, 2012), However, to confirm the long-run relationship still existed among the variables, the ECT_{t-1} verified the negative sign and remained statistically significant at 1%. This shows the speed of convergence in RE generation from the short-run toward its long-run equilibrium path. The short-run variations are corrected by 65.5% every year. The value of ECT shows that the short-run adjustment would require nearly 7 years and 9 months for converging to its long-run equilibrium.

According to the diagnostic test results, the error term is normally distributed, and it is free from serial correlation and heteroscedasticity problems. The functional form of a model is well specified. These results have confirmed that the short- and long-run findings are robust. Also, it can be proven that the model is relatively stable over time (Figure 7).

Table 3: Descriptive statistics and relationship matrix

Statistics	*lRE*	*lK*	*lL*	*lY*	*lFD*
Mean	7.20	11.38	9.09	12.80	12.86
Median	7.19	11.49	9.11	12.89	13.25
Maximum	8.13	12.34	9.54	13.58	13.79
Minimum	5.98	10.17	8.60	11.81	11.35
SD	0.46	0.64	0.28	0.57	0.74
Skewness	−0.35	−0.41	−0.04	−0.31	−0.63
Kurtosis	4.11	2.05	1.86	1.78	1.97
Jarque-Bera	2.46	2.20	1.86	2.66	3.79
P	0.29	0.33	0.39	0.27	0.15
Number of observations	34	34	34	34	34
lRE	1.00				
lK	0.72	1.00			
lL	0.81	0.93	1.00		
lY	0.78	0.96	0.99	1.00	
lFD	0.77	0.93	0.95	0.97	1.00

The statistical significant level is at 1%. Source: Output of Eviews package version 9.0. SD: Standard deviation, RE: Renewable energy, FD: Financial development

Table 4: Unit root tests on each variable

Variables	ADF		PP		KPSS		Ng-Perron		Conclusion
	I (0)	I (1)	I (0)	I (1)	I (0)	I (1)	I (0)	I (1)	
lRE	−2.319	−5.045***	−2.297	−5.419***	0.717**	0.186	−0.588	−15.827***	I (1)
lK	−0.697	−4.098***	−0.792	−3.975***	0.612**	0.060	0.618	−14.755***	I (1)
lL	−3.075	−6.274***	−0.819	−5.823***	0.684**	0.060	−3.31	−50.155***	I (1)
lY	−1.847	−4.232***	−1.847	−4.198***	0.666**	0.333	0.367	−14.964***	I (1)
lFD	−1.668	−4.891***	−2.003	−4.88***	0.634**	0.270	0.406	−15.234***	I (1)

***,** and * denotes statistically significance at 1%, 5% and 10% level, respectively. Source: Output of the Eviews version 9.0. RE: Renewable energy, FD: Financial development, ADF: Augmented Dickey–Fuller, PP: Phillips–Perron, KPSS: Kwiatkowski, Phillips, Schmidt and Shin

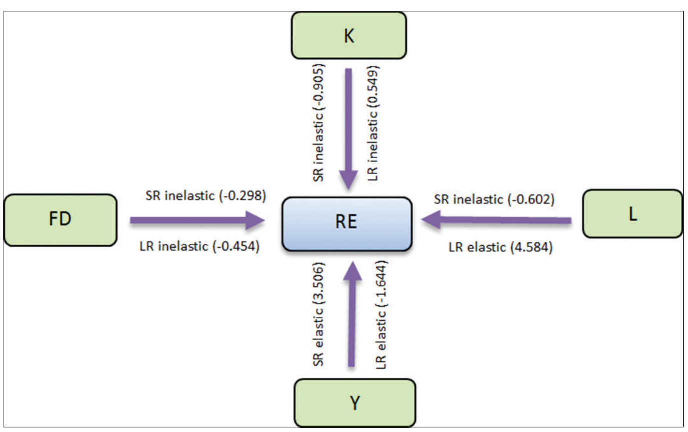
Table 5: Dynamic relationships results

Model	F-statistics	Critical values						Decision
		1%		5%		10%		
		I (0)	I (1)	I (0)	I (1)	I (0)	I (1)	
lRE	4.49**	4.77	6.67	3.35	4.77	2.75	3.99	Co-integrated
lK	6.96***							Co-integrated
lL	1.21							Not co-integrated
lY	5.53**							Co-integrated
lFD	4.97**							Co-integrated

***,** and * as defined in Table 4. Critical values for unrestricted intercept and no trend (k=4, T=34) as computed by Narayan (2005). Source: Output of the Eviews software version 9.0. RE: Renewable energy, FD: Financial development

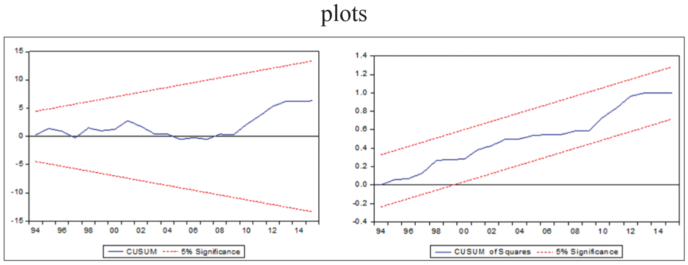
In determining the causal relationship between the variables, the study proceeds to apply VECM Granger causality framework. This test will enable us to test the direction of causality among the variables of the model. The direction of the causal relationship between the variables is helpful in designing comprehensive EGRE, capital, labor, GDP, and FD policies in Malaysia. This will greatly help in monitoring economic growth toward associating the country's RE prospects. The results are reported in Figure 8 and Appendices B. which shows long- and short-run causality. In that analysis, the long-run causality results of the study discovered the existence of a bidirectional causal relationship between capital and RE generation for the case of Malaysia. Also, the feedback effect is found between labor and electricity generation from RE. Additionally, GDP was found to Granger cause RE generation. This result is in contrast with the findings in Greece and other European countries (Marques et al., 2016; Menegaki, 2011), in that there is no causal relationship between GDP and RE generation. But our result is consistent with Tunisia and Hungary (Jebli and Youssef, 2015; Caraini et al., 2015), Likewise, the FD was found to Granger cause electricity generation from RE in the long-run causality. Conversely, the results of the Granger causality tests show neutral relationships for all models in the short-run except in the FD model, which detects that high skills in labor are significant, which demonstrate that this labor Granger cause FD in the short-run. Also, it indicates that high skills in labor influence the development of FD for the short-term period only.

Figure 6: Magnitude of renewable energy elasticities.
(1) SR = Short-run elasticity, LR = Long-run elasticity. (2) Diagnostic tests: Normality = 2.189 (0.335), serial correlation = 2.676 (0.262), heteroscedasticity = 9.304 (0.41), Ramsey reset test = 2.817 (0.108), adjusted R^2 = 84%, F-statistics = 12.938 (0.000)



Source: Appendix A

Figure 7: Cumulative sum (CUSUM) and CUSUM squared statistics plots

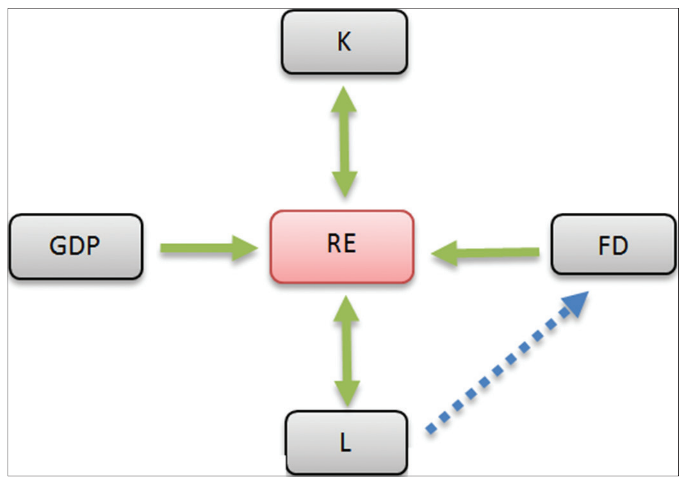


Source: Output of the Eviews software version 9.0

Furthermore, the VD approach is used to highlight the magnitude of the predicted error variance accounted by innovations from each variable (Ivy-Yap and Bekhet, 2016; Shahbaz et al., 2015). The results of VD are presented in Table 6 until 10 horizon periods, which show that the variation in RE generation is largely accounted by itself (46.8%); then, the rest of its variation is explained due to capital (22.41%), labor (16.09%), and GDP (13.82%). The contribution of FD is minimal, which explains RE by 0.88%. This implies that all the determinants play quite significant roles in explaining electricity generation from RE except FD. Also, it verified that capital is the most trusted determinant in the development of RE generation for the near future. It is followed by labor and GDP. However, FD is not a reliable determinant to support this development due to the reduction in its portion of contribution over time.

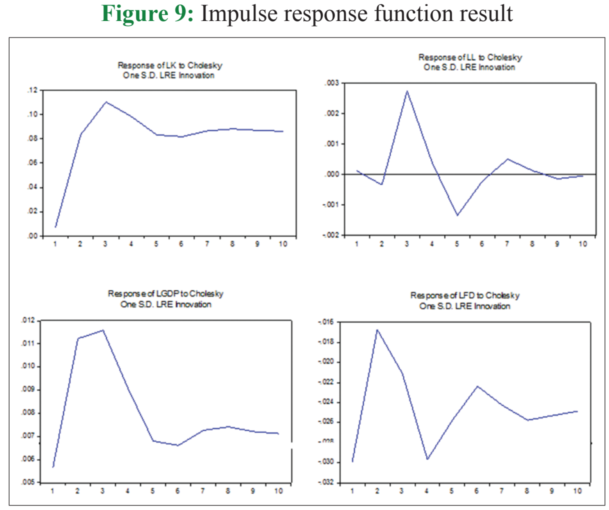
Finally, Figure 9 provides line plots of the IRF between RE and its determinants. It is computed by fixing an initial shock size that is equal to the time-series average of the stochastic volatility level

Figure 8: The short-run and long-run causalities.
Note: (1) ⟷ and ⟶ denotes the long-run bi-directional and uni-directional causal relationships, respectively. (2) - - ➔ denote the short-run uni-directional causal relationship



Source: Appendix B

Figure 9: Impulse response function result



Source: Output of the Eviews software version 9.0

Table 6: VD result

Time horizon	*lRE*	*lK*	*lL*	*lY*	*lFD*
1	100	0	0	0	0
2	93.387	0.004	0.384	3.684	2.542
3	79.727	1.642	5.013	10.823	2.794
4	66.967	7.065	9.915	13.823	2.230
5	59.881	12.676	11.853	13.833	1.756
6	55.917	16.085	12.919	13.626	1.452
7	52.777	18.225	14.029	13.717	1.253
8	50.228	19.909	14.952	13.814	1.098
9	48.291	21.305	15.599	13.830	0.975
10	46.799	22.414	16.089	13.821	0.877

Source: Output of the Eviews software version 9.0. VD: Variance decomposition, RE: Renewable energy, FD: Financial development

for each series over the sample period (Nakajima, 2011). Also, it shows the reaction of RE generation to one standard deviation shock of each variable in this model. The most effective power of one standard deviation shock on RE generation is capital. As noted, the electricity generation from RE is positive due to the standard deviation shock, which occurs in capital, GDP, and FD. This fact is well-matched with the primary role played by capital and GDP in that they are reliable determinants toward the development of RE generation. Also, RE responds positively due to the shocks in labor but depletes after the third time horizon. Overall, the capital, GDP, and FD perform a significant role with the changes of time toward electricity generation from RE. But the role of labor for RE generation is not performed consistency due to the time-dependency.

6. CONCLUSIONS AND POLICY IMPLICATIONS

The augmented C-D production function and F-bound test approach are applied to examine the dynamic relationship and elasticities among electricity generation from RE, capital, labor, and FD in Malaysia. Also, the VECM is employed in order to analyze the causal relationship between these variables from 1982 to 2015 period. We find that a dynamic relationship exists among the variables. The responsiveness of capital and labor are positive for RE generation. However, economic growth and FD have a negative response in the long-run. But in the short-run, the opposite result of economic growth was found, which had a positive response on RE generation. In addition, a long-run bidirectional causal relationship was found between capital and RE generation. The same inference was discovered between labor and electricity generation from RE. The unidirectional running from economic growth to RE generation also was detected in this study, which indicates that the contribution of Malaysia economic activities support the development of electricity generation from RE. Also, the finding shows that there is a unidirectional causality running from FD to RE generation, which contributes a minimal value to RE generation.

To date, total electricity generation comes from fossil fuels, thus raising concerns about energy security and CO_2 emissions. The electricity generated from RE source is among the main strategies to reduce the country's dependence on fossil fuels, improve energy supply security, and achieve CO_2 emissions savings (Bento and Moutinho, 2016), Also, energy efficient and RE have been identified as the vital instruments to be highlighted due to their ability to mitigate CO_2 emissions (Bekhet and Othman, 2016), Indeed, we can see that the electricity generated in Malaysia can be part of the nation's economic generation indicator. Now the country is aiming 4000 MW of RE capacity by 2030 (Energy Commission, 2016). Therefore, the development of electricity generation remain an indicator if such alternative sources are able to end energy poverty, stimulate economic growth, and maintain the environment. Accordingly, the policies were designed to enhance the utilization of RE sources toward national electricity supply security and sustainable socio-economic development (EPU, 2016; MEC, 2005). However, Malaysia faces the need to rationalize the mechanisms used for supporting electricity generation from RE. Hence, the country has implemented a series of legal and regulatory changes (Energy Commission, 2016), most of which are related to energy efficiency and introduction of FiT. RE FiT has been used as a tool to support changes in technology and the infrastructure costs of RE production plants. In such situations, Malaysia has moved to enhance the operation of solar energy (EPU, 2016) because it is environment friendly and also to meet rising energy demands. Indeed, Malaysia initiated to set an annual new FiT fund quota of 20 MW for biomass and 15 MW for biogas for the year 2025 (SEDA, 2015). On the other hand, other programs and strategies have been introduced by the government to enhance electricity generation using RE sources. These aspects need to be further improved using renewable research and development (Energy Commission, 2015).

This study clearly indicates that the largest electricity generation from RE is related to capital, labor, economic growth, and FD. The contribution of capital, labor, and economic growth has dynamic linkages with RE generation. The Malaysian government should focus more attention on seeking appropriate technology innovations by emphasizing advanced green and clean technologies for the sustainable energy. Therefore, it would improve the country's ability to provide RE generation for economic development purposes in the near future. The interesting insights drawn from this study leads us to reinvestigate the relationship between electricity generation from RE, capital, labour, economic growth, and FD by including other variables such as NRE and foreign direct investment. The role of RE can be determined as complement or substitute sources against NRE for electricity generation. Malaysia's energy sector has been continuously progressing in generation capacity through NRE sources such as natural gas, coal, and crude oil (Bekhet and Harun, 2016). Furthermore, the importance of foreign direct investment would be highlighted for the development of electricity generation from RE, which may help policymakers to formulate comprehensive RE for electricity generation in the case of Malaysia.

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APPENDICES

Appendix A: Long-run and short-run elasticities of RE towards its determinants

	Long-run elasticity			Short-run elasticity		
Determinant	**Elasticity**	**t-statistics**	**Conclusion**	**Elasticity**	**t-statistics**	**Conclusion**
lK_t	0.549*	1.737	(+) inelastic	−0.905*	−1.736	(−) inelastic
lL_t	4.584***	3.295	(+) elastic	−0.602	−0.400	(−) inelastic
$lGDP_t$	−1.644*	−1.792	(−) elastic	3.506*	1.789	(+) elastic
lFD_t	−0.454	−1.081	(−) inelastic	−0.298	−1.248	(−) inelastic

***,** and * as defined in Table 4. Source: Output of the Eviews software version 9.0. RE: Renewable energy, FD: Financial development, GDP: Gross domestic product

Appendix B: The VECM Granger causality analysis

Model	Short-run causality (Wald F-test)					Long-run causality	
	ΔlRE	**ΔlK**	**ΔlL**	**$\Delta lGDP$**	**ΔlFD**	**γ**	**t-statistics**
ΔlRE	-	0.928	0.352	0.422	2.045	−0.595***	−4.674
ΔlK	0.599	-	0.075	0.968	0.033	−0.227**	2.44
ΔlL	0.319	1.154	-	0.052	1.257	−0.031**	2.291
$\Delta lGDP$	0.017	0.652	0.176	-	0.751	0.042	1.498
ΔlFD	0.669	0.781	16.749***	0.004	-	−0.095	−1.163

***,** and * as defined in Table 4. Source: Output of the Eviews software version 9.0. RE: Renewable energy, FD: Financial development, GDP: Gross domestic product