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Elasticity of Non-renewable and Renewable Energy towards Electricity Generation for Sustainable Energy in Malaysia

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Abstract
Purpose: To investigate the elasticities of capital, labour, GDP, non-renewable and renewable energy towards electricity generation in Malaysia.
Design/methodology/approach: Using Augmented Cobb- Douglas production function to evaluate the unit root and long-run dynamic relationship. Also, apply trans-log production function to analyze the production elasticities of all determinants, particularly for non-renewable and renewable energy towards electricity generation.
Findings: Labour is traced as having the highest degree of responsiveness. It followed by economic growth to have the second highest degree of responsiveness to generate electricity in Malaysia. Then, the result of production elasticities is larger for non-renewable energy (0.19 percent) and smaller for renewable energy (0.07 percent). However, capital shows the lowest degree of responsiveness, accounting for only 0.054 percent.
Research limitations/implications: This study helps other researcher enhance the analysis, for example, using panel data analysis that related to non-renewable and renewable energy for electricity generation in Malaysia.
Practical implications: This study helps government to design various strategies for Malaysia energy policy in order to highlight the important determinants, particularly for non-renewable and renewable energy.
Originality/value: This study highlights the ridge regression method to analyze production elasticities for all determinants.

Keywords: Non-renewable Energy, Renewable Energy, Electricity Generation, Ridge Regression, Malaysia

Introduction

Energy sustainability and environmental pollution are two main issues examined by many researchers all over the world. The sustainable energy is a form of energy that meet the current demand of energy without putting it in danger of getting expired or depleted and can be used continuously. It should be widely encouraged as it does not cause any harm to the environment (Kardooni et al., 2018; Zafar et al., 2018; Bekhet & Othman, 2018, Bekhet et al., 2014). Thus, energy components are highlighted to stress both of these issues. The significance of energy is recognized universally in the development process and industrialization of nations, as well as in the enhancement of economic activities. Furthermore, the electricity consumption is the major component of energy demand toward economic growth. It indicates that electricity consumption is no longer seen as a fundamental need for a society, but it has become more of a basic right (Oh et al., 2018). Since the electricity demand has increased, this trend is likely to continue increase as well in the future on a global scale. Thus, it shows that total world energy consumption is expanding from 160,896 trillion kilowatt-hours (kWh) in 2012 to 184,342 trillion kWh in 2020 and will be headed to 238,853 trillion kWh in 2040. This means a 48% is expected to increase from 2012 to 2040 (EIA, 2016).

Accordingly, Malaysia shows a continuing increase in electricity consumption and generation by 8.4 and 8.1 percent, respectively, from 1980 to 2017 (see Figure 1). In 2014, the maximum electricity demand in peninsular Malaysia surged by 2.05 percent from 16,562MW in 2013 to 16,901MW in 2014 (Energy Commission, 2016). However, the positive trends of electricity generation, together with electricity consumption, have affected the environment with respect to climate change and global warming due to GHG emissions. It is witnessed that Malaysia is more depending on non-renewable energy sources (coal, oil, and natural gas) and it is increased over the years (Bekhet & Yasmin, 2016). However, the wide use of non-renewable energy has resulted in its depletion (Petinrin & Shaaban, 2015), and it is forecasted to reach continuous exhaustion (IEA, 2015; BP, 2015). In light of these issues, renewable energy prospects have become predictable.

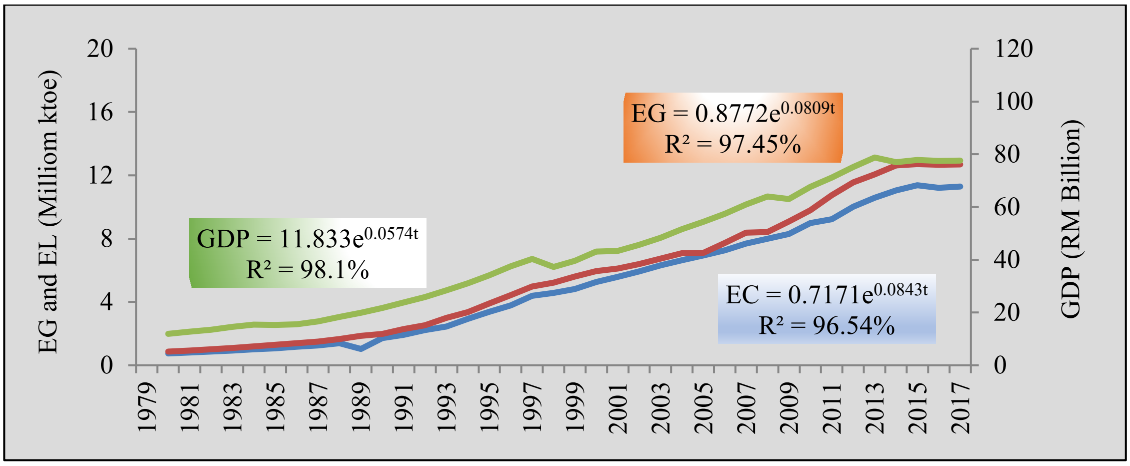

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Figure 1: Trend in Malaysia GDP, EG and EC for 1980-2017.
Source: Energy Commission, Malaysia (2016).

Malaysia is new to renewable energy sources in its domestic electricity generation mix. However, the utilization of renewable energy (Bekhet & Othman, 2018) 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 reducing GHG emission intensity of GDP by targeting 45 percent in 2030 compared with 2005 levels (Economist Corporate Network, 2016). Furthermore, the potential of renewable energy development in Malaysia remains popular due to energy security. For that reason, Malaysia has committed to incorporate renewable energy sources together with non-renewable energy into its electricity generation mix.
Moreover, Malaysia has to achieve the target over 2080 MW (see Figure 2) of energy from renewable energy sources by 2020 for energy security purposes. For that reason, institutions involved with these projections are the Energy Commission, SEDA, and MESTECC. The projection of renewable energy capacity targets up to 2030 is developed by SEDA under a renewable energy plan. Also, it shows that the aim of RE capacity is continuously increasing up to about 4,000 MW by 2030.

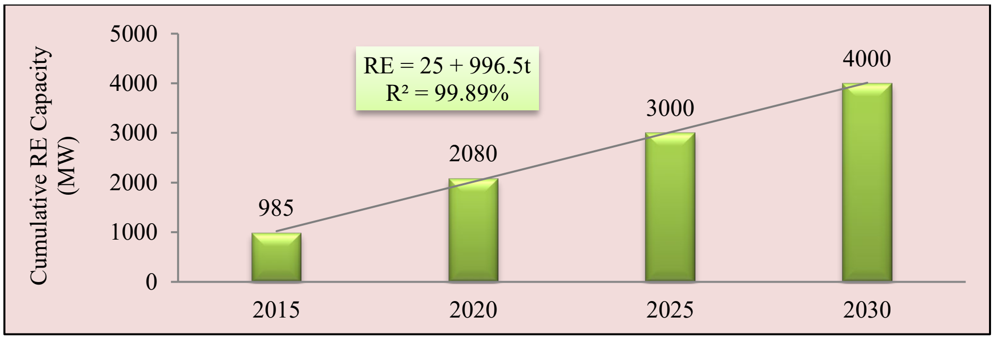

Figure 2: National RE Targets as RE Plan for 2020, 2025, and 2030.
Source: Energy Commission, Malaysia (2016).

Therefore, the potential of renewable energy in Malaysia is highlighted in order to reduce the dependency on the NE for electricity generation. The projected growth in renewable energy can be attributed in part to government policies. Accordingly, it is useful for the government to continuously review its energy policies in order to ensure energy sustainability. Furthermore, improving the implementation of renewable energy in electricity generation will be the most effective way to address the issue of environmental problems and oil price fluctuations.
Consequently, this study is different from previous studies for the several reasons. First, this study stresses electricity generation as a proxy of electricity rather than electricity consumption (Bekhet & Harun, 2018; Dogan, 2015; Ghosh, 2009; Yoo & Kim, 2006). Following the relevant state-of-the-art research, this study proposes electricity generation as a dependent variable, and economic growth should be a component of production function in the same manner as capital and labour. Second, in order to highlight energy as one of the important factors of production, several recent studies discussed this energy and categorized it by sources (renewable and non-renewable energy consumption) in the AC-D for trans-log production function (Lin et al., 2016; Lin & Xie, 2014; Wesseh et al., 2013). The aim is to examine and distinguish the effect of each source on economic activity (Kahia et al., 2017; Apergis & Payne, 2013, 2010). However, this study contributes to the discussion of the effects of both of these categories on electricity generation in Malaysia. Thus, the purpose of this study is to evaluate the production elasticities between all determinants, particularly on non-renewable and renewable energy towards electricity generation. More specifically, the trans-log production function is applied to achieve the objective of this study and to provide more opportunity for drawing policy implications that are specific relevance to Malaysia. Accordingly, the structure of this paper is followed by literature review, model construction and data sources, methodology, findings and finally the discussion and conclusion is explained in order to highlight the objective of this study.

Literature Review

Currently, extensive studies in economics and energy production have sought to address the issue of sustainable energy and environmental protection. One aspect of energy that has received considerable attention is elasticity of non-renewable and renewable energy towards electricity generation. In order to clearly understand the review of past studies, a brief comparison among the findings using ridge regression method in terms of different countries, and different periods of time are discussed. Ridge regression is the specification of the trans-log production model, which includes squared terms of some of the determinants. The concept of production elasticities is similar to the normal production function, yet concerning the multi-collinearity problem. Thus, the aim of this analysis is to highlight the production elasticities by avoiding the multi-collinearity problem. Also, it can be determined the most capable energy determinants in production for various sectors and in various countries. Table 1 is summarized the past studies related to the current paper.

Table 1: Summary of Empirical Studies on Ridge Regression.

Author	Time Period	Country	Sectors	Variables	Findings		
					Production Elasticities	Inputs Substitution	Technology Change
Bello et al. (2018)	1971-2013	Malaysia	Electricity	Y, K, L, Coal, NG, Oil, Hydro	√	√	√
Wesseh & Lin (2018)	1980-2016	Egypt	-	Y, K, L, EL, P, NG	√	√	√
Lin & Atsagli (2017)	1980-2012	Nigeria	Energy	Y, K, L, P, EL	√	√	√
Wesseh & Lin (2017)	1980-2011	12 East African countries	-	Y, K, L, NE, RE	√	√	√
Lin & Liu (2017)	1980-2014	China	Machinery	Y, K, L, E	√	√	X
Lin et al. (2016)	1980-2012	Ghana	-	Y, K, L, P, EL	√	√	√
Wesseh & Lin (2016)	1980-2011	ECOWAS	-	Y, K, L, NE, RE	√	√	√
Lin & Ahmad (2016)	1980-2013	Pakistan	Transport	Y, K, L, E	√	√	√
Lin & Xie (2014)	1980-2010	China	Transport	Y, K, L, E	√	√	X
Wesseh et al. (2013)	1980-2010	Liberia	-	Y, K, L, P, EL	√	√	X
Lin & Wesseh (2013)	1980-2009	China	Chemical	Y, K, L, Coal, Oil, NG, EL	√	√	√
Smyth et al. (2011)	1978-2007	China	Iron and steel	Y, K, L, Coal, Oil, NG, EL	√	√	√

Note: Y: GDP, EG: EL: electricity consumption, K: capital, L: labour, RE: renewable energy, NE: non-renewable energy, NG: natural gas, P: price.
Source: Compiled based on literature survey.

Based on the above studies, most of them highlighted the production elasticities using the GDP as a dependent variable. This study highlights electricity generation as dependent variable to evaluate all determinants, particularly non-renewable and renewable energy using ridge regression method. Hence, this methodology is useful to investigate the highest degree of responsiveness of all determinants to the performance of electricity generation. The finding can help government to design energy policy in Malaysia. Thus, to achieve the objectives of this study, the hypotheses are formulated as follows.

H_{11}: Dynamic relationship exist between electricity generation and its determinants in Malaysia.

H_{12}: Estimation of elasticities exist between electricity generation and its determinants in Malaysia.

Model Construction and Data Sources

In order to highlight the importance and contribution of electricity generation (EG) in Malaysia, this study proposes electricity generation as a dependent variable (Ghosh, 2009; Yoo & Kim, 2006), and economic growth should be a component of production function in the same manner as capital and labour. Furthermore, the sustainable energy source and energy security are widely discussed to meet energy demand for electricity generation in Malaysia. Thus, this energy source is included by classified as non-renewable energy (NE) and renewable energy (RE) for different purpose (Dogan & Ozturk, 2017; Dogan, 2016; 2015; Omri et al., 2015) to find the long dynamic relationship and elasticities of these variables towards the EG. Therefore, the natural log-linear functional form of the AC-D production function is modeled as Equation (1).

$$lEG_t = lA_t + \alpha_K lK_t + \alpha_L lL_t + \alpha_Y lY_t + \alpha_{NE} lNE_t + \alpha_{RE} lRE_t + \varepsilon_t \tag{1}$$

Where *l* symbolizes the natural logarithm of the technology (A), capital (K), labour (L), GDP (Y), non-renewable energy (NE) and renewable energy (RE), respectively. α_js (j=K, L, Y, NE, and RE) indicates the production elasticities of these variables. Also, it shows the positive sign of production factors that specify the positive effect on EG and vice versa, while ε_t specifies the stochastic error terms assumed to be normally distributed along with white noise (Bento & Moutinho, 2016), and t symbolizes the yearly time-series data.

However, the high number of coefficients in Equation (1) might trace the problem of multi-collinearity. Theoretically, the multi-collinearity problem is minimal if only a single production factor is taken into account. However, when OLS regression is applied, it reports inconsistent results due to the value of Variance Inflation Factor (VIF) for each determinant being very high and detecting a multi-collinearity problem. Alternatively, the ridge regression is applied and the results indicate the elasticities of coefficients are reasonable estimations to highlight the production elasticities. Thus, the natural log-linear functional form of the trans-log production function can be developed as in Equation (2).

$$\begin{aligned} lEG_t &= \alpha_0 + \alpha_K lK_t + \alpha_L lL_t + \alpha_Y lY_t + \alpha_{NE} lNE_t + \alpha_{RE} lRE_t \\ &\quad + \gamma_1 t^* + \frac{1}{2}\gamma_2 t^{*2} + \beta_K lK_t t^* + \beta_L lL_t t^* + \beta_Y lY_t t^* + \beta_{NE} lNE_t t^* + \beta_{RE} lRE_t t^* \end{aligned} \tag{2}$$

The production elasticities in trans-log production function (Lin et al., 2016; Lin & Xie, 2014) is the responsiveness of electricity generation due to changes in production determinants, similar to the normal production function. The economic region of a linearly homogenous production function is characterised by strictly positive marginal productivity of all determinants. Thus, the general production elasticities from Equation (2) can be expressed as in Equation (3).

$$\sum_{j=1}^{J} \eta_{jt} = \sum_{j=1}^{J} \frac{\delta lEG_t}{\delta lx_{jt}} = \sum_{j=1}^{J} \left(\alpha_j + \sum_{k=1}^{J} \alpha_{jk} lx_{kt} + \beta_j t^* \right) \tag{3}$$

Where EG is electricity generation, x is production determinants (K, L, Y, NE, RE) and η_{jt} are the production elasticities that vary with the levels of determinants and technology. In order to highlight the role of energy determinants, the production elasticities can be formulated for non-renewable and renewable energy as in Equations (4) and (5).

$$\eta_{NE} = \frac{\delta EG / EG}{\delta NE / NE} = \frac{dlEG_t}{dlNE_t} = \alpha_{NE} + \alpha_{NERE} lRE_t + 2\alpha_{NENE} lNE_t \tag{4}$$

$$\eta_{RE} = \frac{\delta EG / EG}{\delta RE / RE} = \frac{dlEG_t}{dlRE_t} = \alpha_{RE} + \alpha_{RENE} lNE_t + 2\alpha_{RERE} lRE_t \tag{5}$$

Also, above equations can be formulated for capital, labour and GDP as η_K, η_L and η_Y, respectively. Consequently, this study uses annual time-series data from 1975-2017. The option of variables usage and data selection is based on past studies and framework of the above model. The availability and appropriate data used are very important to make sure the analysis of data is significant to the objective of the study. Table 2 summarizes the measurement and proxy of each variable and source of data in this study.

Table 2: Variables and Data Sources.

VARIABLES	MEASUREMENT / PROXY	SOURCES	PAST STUDY
EG	kWh	WDI	Atems & Hotaling (2018), Akber et al. (2017), Bento & Moutinho (2016), Lin et al. (2016), Dogan (2015), Altintas & Kum (2013)
K	GFCF (RM Million)	DOSM	Kahouli (2017), Raza et al. (2015), Robalino-Lopez et al. (2015), Apergis & Payne (2012), Bekhet & Harun (2012).
L	Labour force	WDI	Bekhet and Harun (2017), Rafindadi and Ozturk (2017), Shahbaz et al. (2015), Apergis & Payne (2012), Bekhet & Harun (2012)
Y	GDP (RM Million)	DOSM	Atems and Hotaling (2018), Rafindadi & Ozturk (2016 and 2017), Dogan (2015), Islam et al. (2013), Apergis & Payne (2012).
NE	kWh	WDI	Bélaïd & Youssef (2017), Ulusoy and Demiralay (2017), Afonso et al. (2017), Bento & Moutinho (2016), Marques et al. (2016), Dogan (2015)
RE	kWh	WDI	Praene et al. (2017), Dogan (2016); Jebli & Youseff (2015), Apergis & Payne (2012), Shahbaz et al. (2012)

Source: DOSM (2016) and WDI (2016).

Methodology

Data quality tests are employed to determine the basic features of the data that were acceptable by theory. Then, to confirm the solid results of stationarity of data series, the augmented Dickey–Fuller (ADF, 1979) and Phillips–Perron (P-P, 1988) tests are applied. When these tests are accomplished, the AC-D production function is employed in the determination of the long-run dynamic relationship among the variables by using F-bound test. Also, the AC-D production function [see Equation (1)] can be estimated using the OLS estimation technique.
However, there is greater possibility of high multi-collinearity because of the higher number of explanatory variables. This causes serious problems in estimation by increasing the variance of OLS estimation, thus making it inefficient (Lin & Ahmad, 2016). Therefore, it will slightly modify the OLS by introducing the trans-log production function (see Equation 2) in order to get more efficient estimations. The methodology applied is ridge regression that was introduced by Hoerl and Kennard (1973) and extensively applied in many subsequent studies (Lin et al., 2016; Lin & Xie, 2014; Wesseh et al., 2013; Lin & Wesseh, 2013). The advantages of using it include a lack of rigid principles such as perfect or smooth substitution among production determinants (Klacek et al., 2007). Also, the concept of trans-log production function is the non-linear relationship between the output and production determinants. Thus, it can be used to determine the second-order approximation of a linear-homogenous production.

Findings

Table 3 presents the preliminary results of these six variables, showing that the average range of measurement for these variables is from 8.26 for renewable energy to 15.92 for labour. Furthermore, labour reached its maximum value in 2017, similar to renewable energy, for which the highest peak is observed in 2017. On the other hand, the minimum value for labour and renewable energy is 15.28 and 6.65, respectively. The standard deviations lie in the range of 0.38 and 1.26 of the data series. This highlights that all variables are slightly skewed to the left, meaning that they have longer right tails than for a normal distribution. However, these 43 observations have sufficient distribution because their kurtosis is inferior to a normal distribution. Accordingly, the J-B test strongly accepts the null hypothesis of normality for the aforesaid variables.

Table 3: Descriptive Statistics and Relationship Matrix.

Statistics	*l*EG	*l*K	*l*L	*l*Y	*l*NE	*l*RE
Mean	10.38	11.22	15.92	12.65	10.52	8.26
Median	10.46	11.47	15.96	12.83	10.74	8.49
Maximum	12.32	12.49	16.55	13.86	12.60	9.46
Minimum	8.38	9.90	15.28	11.39	8.36	6.65
Std. Dev.	1.17	0.79	0.38	0.74	1.26	0.79
Skewness	-0.07	-0.16	-0.13	-0.16	-0.06	-0.58
Kurtosis	1.79	1.72	1.79	1.73	1.79	2.12
Jarque-Bera	2.66	3.14	2.76	3.09	2.64	3.76
Probability	0.27	0.21	0.25	0.21	0.27	0.15
Observations	43	43	43	43	43	43
*l*EG	1.00					
*l*K	0.96^{***}	1.00				
*l*L	0.99^{***}	0.96^{***}	1.00			
*l*Y	0.99^{***}	0.97^{***}	0.99^{***}	1.00		
*l*NE	0.99^{***}	0.97^{***}	0.99^{***}	0.99^{***}	1.00	
*l*RE	0.91^{***}	0.90^{***}	0.93^{***}	0.92^{***}	0.91^{***}	1.00

Note: *** denoted a statistically significance at 1%.
Source: Output of the Eviews Package Version 9.0.

Furthermore, the empirical results of this preliminary analysis indicate a high interrelationship between these variables, meaning that a strong positive association is detected between all the variables (see Table 3). Based on the above results, all determinants are acceptable for further analysis in order to achieve the objectives of this study as explain earlier. This means the trans-log production function can be used as in Equation (2).

Then, Table 4 shows the results of stationary properties for each variable. It indicates that all variables are not stationary at level I(0). However, after taking the first difference of all variables, the series is found to be stationary at I(1). Moreover, the above results confirm and validate that all variables are reliable to be applied to the long-run dynamic relationship.

In order to analyze the existence of a long-run dynamic relationship among these variables, the F-Bounds test to the Autoregressive Distributed Lag (ARDL) model is applied with AIC maximum lag length is found to be 3. Hence, the results of F-Bounds test for the long-term dynamic relationships among the variables are shown in Table 5.

Table 4: Unit Root Tests on Each Variables

Variables	ADF		P-P		Decision
	$I(0)$	$I(1)$	$I(0)$	$I(1)$	
lEG	-2.83	-4.18**	-2.07	-4.19**	$I(1)$
lK	-2.95	-4.66***	-2.42	-4.66***	$I(1)$
lL	-1.29	-5.14***	-1.57	-5.19***	$I(1)$
lY	-1.91	-5.16***	-1.98	-5.86***	$I(1)$
lNE	-2.44	-4.84***	-2.28	-4.89***	$I(1)$
lRE	-2.53	-5.40***	-2.24	-6.26***	$I(1)$

Notes: (1) ***, ** and * denotes statistically significance at 1%, 5% and 10% level, respectively.
(2) The unit root test is applied with the trend.
Source: Output of the Eviews Package Version 9.0.

Table 5: Long-run Dynamic Relationships Results.

F-Statistics	Critical Values			Decision
	Sig. level	Lower	Upper	
11.54***	1%	4.05	5.99	Co-integrated
	5%	2.96	4.34	
	10%	2.48	3.71	

Notes: (1) *** as defined in Table 4. (2) Critical values for unrestricted intercept and no trend (k=5, T= 43) as computed by Narayan (2005).
Source: Output of the Eviews Package version 9.0.

Then, the production elasticities are estimated with respect to their determinants toward electricity generation in Malaysia. All the determinants are found to be positive (see Table 6), which indicates the positive trend of these determinants, as electricity generation shows a progressive trend as well. Labour is traced as having the highest degree of responsiveness. Also, the results indicate the responsiveness of electricity generation is 0.69 percent due to 1 percent change in labour. This result show that labour is the most effective determinant for Malaysian electricity generation performance. Thus, it is required to be consistently developing human capital in order to cultivate the electricity generation. In current decade, Malaysia has developed strategies to have more advanced training for labour in order to increase the number of skilled Laboure's, particularly younger people in Malaysia. Furthermore, economic growth is found to have the second highest degree of responsiveness to generate electricity in Malaysia, accounting for 0.32 percent. This result indicates that Malaysia must consistently enhance its economic activity in order to sustain its economic growth. Then, it can be confirmed that electricity generation in Malaysia relies on economic growth as a driving force.

Table 6: Production Elasticities Result.

Variables	Elasticities	Std. Ridge	VIF
lK	0.054	0.036	2.118
lL	0.695	0.225	0.937
lY	0.324	0.204	0.738
lNE	0.196	0.212	0.745
lRE	0.075	0.050	1.106

Source: Output of the Eviews Package Version 9.0.

Also, production elasticities are larger for non-renewable energy (0.19 percent) and smaller for renewable energy (0.07 percent). This is not surprising, since Malaysia is largely dominated by non-renewable energy for generating electricity (EPU, 2016). However, Malaysia faces a shortage of the non-renewable energy sources (Bekhet & Harun, 2017; Lean & Smyth, 2014). Thus, renewable energy has the potential to generate enough electricity to meet consumption requirements (Kadier et al., 2018; Bekhet & Harun, 2018). On the other hand, capital shows the lowest degree of responsiveness, accounting for only 0.054 percent. This indicates that capital is less priority contributor to develop electricity generation in Malaysia for 1975-2017. However, Malaysia focuses on innovation investments for capital, which is categorized as the most important strategy for promoting Malaysian economic growth (EPU, 2016). These innovation investments increase the productivity of capital in the performance of its respective task, since Malaysia is in the industrialization phase. The above results indicate that the hypothesis is supported which is the estimation of elasticities is exist between electricity generation and its determinants in Malaysia.

Discussion and Conclusion

This study investigated the elasticities of capital, labour, GDP, non-renewable and renewable energy towards electricity generation in Malaysia during 1975–2017. Accounting for AC-D production function in unit root and long-run dynamic relationship analysis, also, this study adopted trans-log production function using ridge regression method to evaluate the production elasticities of all determinants to the electricity generation performance. Generally, this study found that all the determinants are stationary at I(1) and long-run dynamic relationship exists among these determinants.

Furthermore, all the determinants are found to be positive (see Table 6), which indicates the positive trend of these determinants, as electricity generation shows a progressive trend as well. Labour is traced as having the highest degree of responsiveness. It followed by GDP is found to have the second highest degree of responsiveness to generate electricity in Malaysia. Then, the result of production elasticities is larger for non-renewable energy (0.19 percent) and smaller for renewable energy (0.07 percent). However, capital shows the lowest degree of responsiveness, accounting for only 0.054 percent. The most responsive determinant for labour indicates that labour trend reflects to the country's labour force, demand, and employment, which are positively adapting to the changing economy. Likewise, it helps to keep unemployment low. In 2013, almost 93,000 jobs were created when approved investments were accepted by the government (DOSM, 2018).

Furthermore, Malaysia is highly dependent on non-renewable energy sources such as coal, oil, and natural gas to generate electricity. However, the continuously dependence on such energy leads to three implications: first, the depletion of non-renewable energy; second, the volatility of world oil prices; and third, environmental pollution (Bello et al., 2018, Dogan, 2016; Hamdi et al., 2014). Recognizing these three problems, alternative renewable energy sources are introduced (Bekhet & Othman, 2016; Dogan et al., 2015; Lean & Smyth, 2014) to secure and sustain energy for electricity generation performance in Malaysia. In more advanced work, a renewable energy source is categorized as a new technology advancement in Malaysia economic development. However, the adoption of sources such as hydroelectricity, solar PV, biomass, and biogas is still in the early stage in Malaysia's electricity generation. Progress on renewable energy installations indicates that the usage of renewable energy has the potential to move forward in the near future. Thus, Malaysia has set the target to achieve the use of renewable energy by 4000 MW in 2030 (see Figure 2). In order to achieve this target, various strategies are implemented by Malaysia's government to enhance the usage of renewable energy sources in various industries, particularly electricity generation.

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