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ANALYZING THE ELASTICITIES OF COAL AND HYDROPOWER TECHNOLOGY TOWARDS MALAYSIAN ELECTRICITY GENERATION

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Abstract

Malaysia is highly dependent on coal in the form of nonrenewable energy (NE) to generate electricity. Then, Malaysia facing with the issues of environmental pollution and depletion of NE. Realizing on these issues, Malaysia applied hydropower technology, as one of the alternative sources in form of renewable energy (RE) for generating electricity. The finding shows that all variables are stationary at *I(1)*. Utilizing the Cobb-Douglas production function and ARDL model, this study indicates the presence of long-run dynamic relationship between capital, labour, GDP, coal, hydropower and electricity generation. Electricity generation is less responsive due to the changes of coal and hydropower, in the long-run and short-run, respectively. However, in the long-run, coal and hydropower have a positive and negative relationship towards the electricity generation, respectively. On the other hand, in the short-run, coal and hydropower have positive relationship to generate electricity. The results of this study will help the policy makers to design energy policy for sustainable energy in electricity generation performance.

Keywords: Cobb-Douglas**,** coal, electricity generation, hydropower, Malaysia.

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1. Introduction

Electricity generation is the essential component for sustainable energy and environmental issues. It is linked to the energy sources for generating electricity. Universally, the significance of this energy is recognized in the development process and industrialization of nations, as well as in the enhancement of economic activities. In Malaysia, coal is categorized as dominant source of non-renewable energy to generate electricity. In 2015, it supplied by 43 percent of generation capacity and it is expected to increase to 53 percent in 2020 (Energy Commission, Malaysia, 2015). However, a rapid growth of coal consumption has caused Malaysia facing the depletion on this source and suffer of environmental pollution. Therefore, greater efforts are needed by government and industry to embrace less polluting and more efficient technologies to ensure that coal becomes a much cleaner source of energy in near future. For the same time, Malaysia concerns an alternative source i.e. renewable energy (RE) to generate electricity in order to meet the individual and industrial electricity demand. The year 2001 has witnessed Malaysia targeting to ensure that renewable energy sources contribute more than 5 percent of its energy mix by 2020 (Economic Planning Unit Malaysia, 2016). Furthermore, Malaysia's government is seeking to intensify the technology development of RE for sustainable energy due to the depletion of non-renewable energy for near future.

Thus, hydropower technology is one of the most important RE source for generating electricity. In 2015, it supplied by 14 percent of generation capacity and it is predicted to increase by 15 percent in year 2020 (Energy Commission, Malaysia, 2015). It shows that Malaysia's hydropower technology is expected to play a more prominent role in the installation of generation capacity. The hydropower technology potential in Malaysia electricity generation is 29,000MW but it is currently utilizing only 2,091MW (Ghafoor et al., 2016), meaning that the available plants can store water during the rainy season and use it according to demand throughout the year. Furthermore, these plants have low generation costs and contribute to maintaining some security in the supply over time. The hydroelectric power plant is built on a dam whose height is used to create potential energy of water for generation of electricity. The largest hydropower generation site is Bakun Power Station, Sarawak with an installed capacity of 2,400 MW. In 2014, the Murum Dam opened to enhance the Bakun Dam for supplying additional electricity to energy-intensive industries such as aluminum and ferro-alloy smelting plants in the Samalaju Industrial Park in Bintulu (The Star, 2013). Its installed capacity is 944 MW. In 2016, Ulu Jelai Hydroelectric Project in Cameron Highlands is completed and its capable to generate electricity by 326 GWh annually (SMEC, Malaysia, 2019). Thus, it shows the contribution to Malaysia's power supply system and helps to meet the surge in demand at peak hours of the day in a country. The hydropower plant will also make the power grid more stable and less prone to frequency fluctuations.

Apart from that, hydroelectric projects also brought socioeconomic development such as flood control, tourism, skills development, and rural electrification. For example, since 1979, the Temenggor Hydro-Electric Project (Temenggor Power Station) has provided water and is an eco-tourism attraction. This dam is located at the Perak River and has the capacity to generate 348MW of electricity. On the other hand, the Kenyir Dam (Sultan Mahmud Power Station) is constructed as a flood mitigation scheme, instead of generating hydroelectric power. This power station generates 400MW of electricity and is located at the Terengganu River.

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The literature has reported that a majority of previous research has thoroughly investigated the relationship between energy consumption and economic growth (Lin and Wang, 2019; Liu et al., 2018; Zhang et al. 2017; Rafindadi & Ozturk, 2017). Then, there a study discussed on the relationship between electricity generation and economic growth (Yoo & Kim, 2006). Realizing the limited of discussion on this variable, this study impresses to analyse the electricity generation and economic growth, by adding other variables using the Cobb-Douglas production function (capital, labour, energy).

The outcome of an elasticity relationship is beneficial in identifying the link between economic growth and energy consumption. A unanimous conclusion revealed by numerous studies is that RE does not exert a positive influence on economic growth (Al-Mulali et al., 2013). This conclusion is inferred due to astronomical expenses to market RE sources which directly contributes to the slow economic development (Marques & Fuinhas, 2012). This contradicts the findings reported in Greece (2004:M08-2014:M02) which proved that RE has a positive impact on economic growth (Marques et al., 2014). France (2010:M01- 2014:M11) reported an inverse result as wind power was revealed to limit economic growth and solar PV encourages economic growth (Marques et al., 2016). These mixed results depict that RE consumption exerts both positive and negative influence on economic growth. Germany (1970:Q1-2013:Q4) determined that economic growth relies on RE development for sustainable energy (Rafindadi & Ozturk, 2016). The variation in the findings can be attributed to the country's rate of development and time period. The highest per capita electricity is consumed by developed nations which offer levied taxes for environmental purposes, while developing industrialised nations are leading in medium per capita consumption and significantly provide subsidy in energy consumption for social purposes (Shaikh et al., 2017; Shahbaz et al., 2015). Thus, this study deduces that previous studies offered minimal discussions on the disaggregation of NE and RE, particularly between coal and hydropower. Thus, this study employs production theory to analyse the relationship between coal and hydropower technology and to highlight the importance of energy (coal and hydropower technology) for electricity generation.

2. Problem Statement

Malaysia is developing country that has significantly transformed itself from a predominantly agriculture-based country to manufacturing and, now, toward modern services and modernization (Economic Planning Unit Malaysia, 2016). Due to the rapid infrastructure development and economic growth, the growing energy demand is continuously effected (Shaikh et al., 2017). Hence, Figure 01 shows the growth rate of Malaysia GDP at 5.9 percent for 1980 to 2016 period and continuously increasing over the years. As the economy activities continue to expand, the positive trends of Malaysia's electricity generation and consumption are shown at 8.4% and 8.7%, respectively. It indicates that the rapid increase in electricity consumption has created the need to evaluate alternative sources of electricity generation.

The growing consumption of energy has resulted in Malaysia becoming increasingly dependent on NE such as coal, oil and gas. Nevertheless, this does not mean that it can consume energy like there is no tomorrow. Instead, these energy sources have to be managed and utilised in the most efficient manner possible. Hence, the NE is becoming depleted over the years and the Malaysia policy must be enhanced to protect the electricity generation by introducing the alternative resources. This NE will become rare and

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the prospect of a serious shortage in the near future has triggered the awareness to find alternative energy as the sustainable energy source (Shaikh et al., 2017).

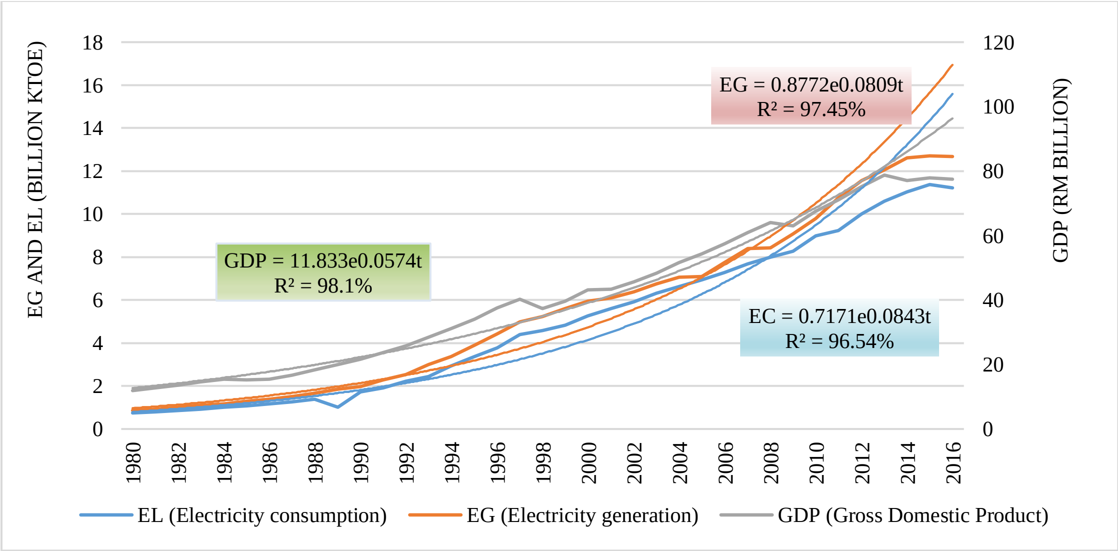

Figure 01. Time trend of GDP, EG and EL in Malaysia (1980-2016)

In order to address these issues, globally the objective has increasingly focused attention on ways to promote RE sources for electricity generation in order to reduce the reliance on NE for environmental protection (Oh et al., 2018). In Malaysia, hydropower is one of the RE source to generate electricity. Then, the energy policy is also continuously reviewed by the government to ensure sustainability of this energy source.

Consequently, this study is different from previous studies for the several reasons. First, this study concerns the electricity generation as dependent variable rather than electricity consumption. It is attempt to highlight the electricity generation component in order to fulfil the demand of electricity in Malaysia. Second, this study considers of RE is the one of the basic indicators of economic and social development and improve the quality of life. Then, it can be regenerative, does not deplete over time, and it ensures to improve energy security all over the world; further, it also reduces carbon emissions. Furthermore, improving the implementation of RE is expected to be the most effective way to address the issue of NE depletion, fluctuating oil prices and environmental pollution.

Thus, the purpose of this study is an empirically to evaluate the nexus between electricity generation and its determinants in Malaysia. Also, it is aimed to analyse the dynamic relationship and elasticities of capital, labour, economic growth, coal and hydropower technology towards the electricity generation. More specifically, the augmented production function is formulated to achieve the objective of this study.

3. Research Questions

1. Do significant long-run relationship between capital, labour, GDP, coal, hydropower and electricity generation in Malaysia exist?
2. Do long-run and short-run elasticities of capital, labour, GDP, coal and hydropower technology towards the Malaysian electricity generation exist?

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4. Purpose of the Study

1. To analyze the existence of significant long-run relationship between capital, labour, GDP, coal, hydropower and electricity generation in Malaysia.
2. To examine the existence of long-run and short-run elasticities of capital, labour, GDP, coal and hydropower technology towards the electricity generation in Malaysia.

5. Research Methods

This part is divided by two main sections. The first section is model construction and data sources while the second section is research methodology.

5.1. Model Construction and Data Sources

Theory is crucial for research as it is the foundation for model development and testing. Thus, this study applies the augmented Cobb–Douglas (AC-D) production function by including capital, labor, GDP and energy (coal and hydropower technology) to examine the relationship among these variables (Dogan & Ozturk, 2017; Shahbaz et al., 2015) by investigating the electricity generation as the dependent variable (Yoo & Kim, 2006). The specific form of AC-D production function is constructed as in Eq. (1).

$$EG = AK^{\propto_1}L^{\propto_2}Y^{\propto_3}C^{\propto_4}H^{\propto_5}e^{u} \quad (1)$$

where EG is electricity generation; α_1, α_2, α_3, α_4 and α_5 are coefficients of capital (K), labour (L), economic growth (Y), coal (C) and hydropower (H), respectively. Then, all the series are converted into natural logarithms to linearize the form of Eq. (1). This transformation will capture the interpretation of elasticities (Bekhet & Harun, 2017; 2018; Shahbaz & Lean, 2012) to the response of EG with respect to the aforesaid variables. The natural log-linear functional form of the AC-D production function is modeled as in Eq. (2).

$$EG_t = \propto_0 + \propto_1 lK_t + \propto_2 lL_t + \propto_3 lY_t + \propto_4 lC_t + \propto_5 lH_t + e_t \quad (2)$$

Subsequently, the Eq. (2) is stretched to Autoregressive Distributed Lag (ARDL) model to assess the short-run and long-run elasticities. So, the ARDL model is derived as in Eq. (3).

$$\Delta lEG_t = \beta_0 + \sum_{s=1}^{p}\beta_1 lEG_{t-s} + \sum_{s=0}^{p}\beta_2 lK_{t-s} + \sum_{s=0}^{p}\beta_3 lL_{t-s} + \sum_{s=0}^{p}\beta_4 lY_{t-s} + \sum_{s=0}^{p}\beta_5 lC_{t-s} + \sum_{s=0}^{p}\beta_1 H_{t-s} + \propto_1 lK_t + \propto_2 lL_t + \propto_3 lY_t + \propto_4 lC_t + \propto_5 lH_t + e_t \quad (3)$$

where *lEG*, *lK*, *lL*, *lY*, *lC*, and *lH* are the natural logarithm of the variables. β_0 is a constant value, $\beta_i s$ and $\propto_i s$ denotes the short-run and long-run elasticities of variables, respectively. *e* specifies the stochastic error terms presumed to be normally distributed, alongside white noise (Bento & Moutinho, 2016), and *t* signifies the yearly time-series data. The data set covers the 1978–2018 period consist of selection for 6 variables. The data of electricity generation (EG), coal (C) and hydro (H) are assembled from Energy Commission, Malaysia and assessed by kilo tonne of equivalent (ktoe). The proxy of capital (K) is Gross Fixed Capital Formation (GFCF) and the proxy of Y is GDP, which were obtained from the Malaysian Department of Statistics. Labor is proxied by labor force which was extracted from World Development Indicator (WDI).

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5.2. Research Methodology

Data quality tests were used to identify the basic features of the data that align with the theory. The augmented Dickey–Fuller (ADF, 1979) and Phillips–Perron (P-P, 1988) assessments were used to validate the stationarity of data series results. When these tests are accomplished, the F-Bound test was employed to determine the long-run dynamic relationship among the variables. This test is advantageous in comparison with other traditional tests (Bekhet & Harun, 2017; Marques et al., 2016). This enables the utilization of a mixture of stationary of *I*(0) and *I*(1) variables. This test is also superior in small samples, $30 \leq t \leq 80$. This test also enables the study to obtain different optimal lags of the variables. Finally, this study eradicates endogeneity issues linked with the Engle–Granger method based on the assumption that all variables are endogeneous variables.

Once the existence of a long-run dynamic relationship is confirmed, the long-run and short-run elasticities of EG responses to the changes of its determinants are examined using the associated ARDL model. Finally, to ensure the error term (e_t) is robust and accurate, the diagnostic and stability tests are applied. The diagnostic tests include the Jarque–Bera tests for normality, the Breusch–Godfrey Lagrange multiplier (LM) for serial correlation test, autoregressive conditional heteroscedasticity (ARCH) for heteroscedasticity test and Ramsey regression equation specification error test (RESET) to correct the functional form. Then, the cumulative sum (CUSUM) test was performed to verify the presence of parameter stability. The suitability of methodologies application is advantageous to accomplish the postulated objectives and the hypotheses are formulated as follows:

H_{11}: Significant dynamic relationship exists between EG and its determinants in Malaysia.

H_{12}: Estimation of long-run and short-run elasticities between EG and its determinants in Malaysia

6. Findings

This part presents the entire findings of the result analysis for this study.

6.1. Preliminary Analysis Results

Table 01 presents the descriptive statistics result of these five variables in this study. It reports that the result of Jarque-Bera test strongly accepts normality of aforesaid variables.

Table 01. Descriptive Statistics

	lEG	***lK***	***lL***	***lY***	***lC***	***lH***
Mean	8.299	11.342	15.979	12.766	7.531	7.158
Median	8.560	11.486	16.019	12.889	7.456	7.180
Maximum	9.729	12.490	16.553	13.862	9.941	8.738
Minimum	6.565	10.082	15.365	11.566	3.135	5.497
Std. Dev.	0.972	0.755	0.358	0.693	1.915	0.714
Skewness	-0.284	-0.229	-0.154	-0.195	-0.610	-0.194
Kurtosis	1.763	1.808	1.840	1.778	2.436	3.384
Jarque-Bera	3.166	2.782	2.462	2.808	3.086	0.511
Probability	0.205	0.248	0.291	0.245	0.213	0.774
Observations	41	41	41	41	41	41

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Furthermore, the result indicates a high correlation between these variables; meaning that a strong positive association is detected between these variables (see Table 02).

Table 02. Correlation Matrix

Variables	*lEG*	*lK*	*lL*	*lY*	*lC*	*lH*
lEG	1.000					
lK	0.966	1.000				
lL	0.996	0.961	1.000			
lY	0.997	0.973	0.996	1.000		
lC	0.968	0.939	0.971	0.970	1.000	
lH	0.869	0.833	0.883	0.869	0.878	1.000

Note: The statistical significant level is at 1%.

6.2. Unit Root Tests Result.

While preliminary test results are detected, the unit root tests are examined. Thus, Table 03 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 are found to be stationary at I(1).

Table 03. Unit Root Tests on Each Variable

Variables	ADF		PP		Decision
	I(0)	*I*(1)	*I*(0)	*I*(1)	
lEG	-0.273	-3.933**	-0.678	-3.993**	*I*(1)
lK	-2.000	-4.512***	-2.000	-4.369***	*I*(1)
lL	-1.207	-5.357***	-1.334	-3.810**	*I*(1)
lY	-1.824	-5.927***	-1.919	-5.525***	*I*(1)
lC	-2.831	-7.838***	-2.763	-8.455***	*I*(1)
lH	-2.385	-3.510*	-2.391	-5.259***	*I*(1)

Notes: (1)***, ** and * denotes statistically significance at 1%, 5% and 10% level, respectively.
(2) The unit root test is applied with the intercept and trend.

6.3. Long-run Dynamic Relationship Result

Despite the fact that all variables are integrated of order one, it is a necessary condition to test a long-run dynamic relationship among the variables in the system. Thus, the F-Bound test is applied, however, it is sensitive to the lag selection; then, we found the appropriate AIC maximum lag length is 3. The outcomes indicate the presence of a long-run dynamic relationship among the variables because the calculated F-statistics (5.301) exceeded the upper critical bound, at 1%, 5%, and 10% levels. Correspondingly, this outcome is permitted to attain long- and short-run elasticities.

6.4. Long-run and Short-run Elasticities Result

Table 04 shows that all the elasticities estimation have positive signs indicating that these determinants have positive contribution to the electricity generation in Malaysia except for labour and hydropower technology. The finding reveals that both determinants, labour and hydropower technology have negative elasticity and inelastic, towards the electricity generation in Malaysia.

Furthermore, the finding indicate that coal has a positive elasticity but inelastic. It shows that 1% increase in coal effecting the electricity generation increased by 7%. But, the increasing of coal is less sensitive to the increasing of electricity generation in Malaysia. On the other hand, the result shows the negative and inelastic elasticity for the hydropower technology. Yet, both these results show that Malaysia's government depending more on the supply of coal rather than hydropower to generate electricity. Alternatively, the hydropower technology is applicable to generate electricity in Malaysia. If the number of hydropower technology is in absolute value, the electricity generation increased by 8.1%, which is 1% higher than coal production (see Table 04).

Table 04. Long-run Elasticities Result

Determinant	Elasticity	*t*-statistics	Conclusions
lK	0.269	0.899	(+) inelastic
lL	-0.884	-0.516	(-) inelastic
lY	1.301	1.387	(+) elastic
lC	0.070	0.756	(+) inelastic
lH	-0.081	-0.839	(-) inelastic

Similar to long-run dynamic elasticities, the short-run dynamic elasticities have a mix sign indicating that all the determinants have positive elasticities except for coal and hydropower (see Table 05). This result reveals that the elasticity of electricity generation with respect to coal is negative inelastic. It is noticeable difference in the long-run analysis, then, the effect of coal to the electricity generation is relatively smaller in the short-run, for the absolute term. Similarly, the elasticity of hydropower is negative inelastic, but the effect of hydropower in the long-run is better rather than in the short-run, for the absolute term.

Table 05. Short-run Elasticities Result

Determinant	Elasticity	*t*-statistics	Sig. Level	Conclusions
d(lK)	0.039	1.275	0.213	(+) inleastic
d(lL)	1.364^{***}	4.073	0.000	(+) elastic
d(lY)	0.347^{**}	2.353	0.026	(+) inelastic
d(lC)	-0.025	-1.653	0.110	(-) inelastic
d(lC(-1))	-0.051^{***}	-3.677	0.001	(-) inelastic
d(lH)	-0.012	-0.829	0.414	(-) inelastic

Note: ***, ** and * as defined in Table 03.

6.5. Diagnostic Test and Stability Test Results

The diagnostic test is essential tool to validate the quality of the estimation for the ARDL model. The result of Jarque-Bera test shows that the error term is normal distributed. Meanwhile, the Breusch-Godfrey Serial Correlation LM test is found that the error term is free from serial correlation. Also, the error term is free from heteroscedasticity problem using Breusch-Pagan-Godfrey Heteroscedasticity and ARCH Heteroscedasticity tests. Furthermore, the Ramsey's RESET indicates that the functional form for the model used is well specified.

Once the model is validated as the best model for goodness of fit and does not violate the condition of OLS assumption, it is necessary to ensure the model is stable. In order to evaluate the stability of the model, the CUSUM statistic plot is applied (Bélaïd & Youssef, 2017; Bekhet & Harun, 2017; Shahbaz et al., 2015). This test capable to detect the stability model by graphically for two statistics are plotted within two straight lines. As a result, the plots of this test are fluctuating within the line and significant at 5 percent for the 1978 to 2018 period. Accordingly, this result suggests that all coefficients in the model [see Eq. (3)] are stable and robust over that sample period.

7. Conclusion

The present study analyzes the dynamic relationship among the capital, labour, economic growth, coal, hydropower and electricity generation variables in Malaysia. It applied the augmented Cobb–Douglas production function in the presence of aforesaid variables over the 1978–2018 period. The F-Bound test approach are utilized, and the result shows the existence of long-run dynamic relationship between the determinants and electricity generation in Malaysia. Using the ARDL model, the results demonstrate the long-run elasticity of coal and hydropower technology on electricity generation, which is positive inelastic and negative inelastic, respectively. Furthermore, the short-run elasticity of coal is negative inelastic on electricity generation. The short-run EG-hydropower elasticity is found negative inelastic, but the effect of hydropower in the long-run is better rather than in the short-run in the absolute term. In addition, the ARDL model is validated by testing the error term. Also, the stability test is checked that ARDL model is confirmed stable and robust over the year.

Yet, the findings above indicate that Malaysia depending on mix sources to generate electricity. In this paper, it highlights the deviations occurred when Malaysia applies coal and hydropower technology for electricity generation. Even though, the coal is dominant energy for generating electricity, the hydropower has potential to implement in Malaysia in order to protect environment. Also, it in line with the government aims to achieve RE target for 20% of energy sources to generate electricity in Malaysia (Ministry of Energy, Science, Technology, Environment and Climate Change, 2019). Therefore, Malaysia needs RM33 billions of investment to enhance the RE implementation by 2025. This investment not come solely from the government, but also from public-private partnerships as well as private financing.

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