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Article

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Renewable Energy Supply and Economic Growth in Malaysia: An Application of Bounds Testing and Causality Analysis

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ABSTRACT

Empirical researches on the nexus between renewable energy supply and economic growth have been neglected. To address this gap, this study aims to examine the relationship between hydropower energy supply (HES) and economic growth within a multivariate model for the 1978-2017 period. This study utilized the auto regressive distributive lag (ARDL) bounds approach to testing for cointegration relationship; and the Granger causality test, based on the vector error correction model (VECM) to test for causality. The bounds F-test for cointegration shows that HES, electricity consumption, capital formation and GDP growth share a long-run relationship. Results show that HES has a significant positive impact on economic growth in the short-run. The causality tests yield evidence of unidirectional long-run and short-run causality running from economic growth to HES, suggesting that economic growth is necessary for providing the essential resources for fostering the HES. The existence of cointegration among HES and GDP growth infers that HES will not drift too far away from economic growth in the long-run. Thus, the government needs to ensure a sufficient supply of hydropower energy in the short-run and the long-run.

Keywords: Renewable Energy Supply, Hydropower Supply, Economic Growth, Malaysia
JEL Classifications: Q21, Q42, O43

1. INTRODUCTION

Energy is an indispensable component to both human extant and economic development. Traditional energy sources such as natural gas, oil, and coal have occurred to be exceptionally potent drivers of economic growth (Ellabban et al., 2014). According to the 2013 International Energy Outlook (IEO) by the Energy Information Administration, global energy consumption is expected to grow by about 56% in the period between 2010 and 2040; where the industrial sector maintains to account for the greatest share of delivered energy consumption. Moreover, the report uncovered that non-renewable sources keep on supplying about 80% of world energy utilization through 2040. However, the world's reliance on these non-renewable sources has triggered a public concern. A major problem is the depletion of these kinds of energy sources. On the other hand, the rise of burning fossil fuels in the last century is accountable for the gradual change in the atmospheric structure (Kampa and Castanas, 2008). Consequently, with a high concentration of greenhouse gas emissions in the atmosphere, a significant change in the world's climate is expected (Hughes, 2000; Haines et al., 2006).

Having said that, the public awareness of renewable energy (RE) sources has increased notably (Apergis and Payne, 2010). RE sources are deemed as clean wellsprings of energy and ideal utilization of these resources limit ecological effects, create least wastes, and it fits the present and future social needs (Panwar et al., 2011). According to the 2018 market report series by the International Energy Agency (IEA), RE share in fulfilling world's energy demand is anticipated to increase by one-fifth in the following 5 years to attain 12.4% in 2023. That is to say, as stated by the report, by 2040, it is predicted that the share of RE sources will meet about 18% of final energy consumption. Similarly, electricity will be the fastest-growing sector of renewables, supplying approximately 30% of energy demand in 2023, up from 24% in 2017. In addition, the report has also stressed that Hydropower persists to be the most significant renewable source, fulfilling 16% of world's energy demand by 2023, coupled by wind (6%), solar photovoltaic (PV) (4%) and bioenergy (3%).

In the context of this study, Malaysia has the highest potential of RE with 4.73 renewable potentials per capita contrasted with four members of the Association of Southeast Asian Nations (ASEAN) as observed from Table 1.

Table 2 presents the breakdown of the potential of renewable sources in Malaysia where Hydropower and Solar PV amounted the highest available potential in Malaysia due to Malaysia's natural geographical terrain (Oh et al., 2010). This is attributed to the abundant rainfall throughout the year in the country. Additionally, Ahmad et al. (2011) manifested that Malaysia has roughly an 18,500 MW electricity generation capacity from hydropower plants.

Although Malaysia has an abundant potential of renewable sources, Kardooni et al. (2015) imply that RE is not yet exploited to its maximum potential. At present, energy generation in Malaysia overly depends on non-renewable sources. Shafie et al. (2011) have pointed out that 94% of electricity generation in Malaysia primarily comes from utilizing fossil fuels such as fuel oil, natural gas, diesel oil, and coal. However, considerations about the volatility of crude oil price, climate change, and energy security are leading to notable changes in how energy and electricity are generated, utilized, and transmitted; and thus, RE sources are turning to be appealing for clean energy development in Malaysia (Shafie et al., 2011).

Regarding energy supply in Malaysia, the primary energy supply in 2017 demonstrated slight expansion of 1.8% (2016: 4.2%) to settle at 98,298 ktoe (Kiloton of oil equivalent) (2016: 96,525 ktoe) as reported by the national energy balance report of 2017 by the Malaysian energy commission through Malaysia Energy Information Hub (MEIH). The increment is driven by growth in hydropower and coal supply. The rate of increase nevertheless, is slower than the previous year, and this is because of a substantial cutback in the supply of petroleum products from 3,627 ktoe to 1,941 ktoe, ascribed to the lower import of motor petrol, fuel oil, Aviation Turbine Fuel and non-energy products. The coal and coke supply registered a growth of 10.8% to record at 20,771 ktoe due to a higher import of coal and coke to meet the growing demand from the power sector. The supply of crude oil continued to be consistent with a small increase to 27,471 ktoe in 2017. Moreover, the total primary energy supply for RE sources, including large-hydro, demonstrated strong growth, recording at 6,947 ktoe, 33.6% higher than in 2016.

Table 1: Total realisable potentials for RE technologies: Shares of ASEAN-6 countries

Country	Renewable potential per capita
Singapore	0.73
Indonesia	1.57
Thailand	1.85
Vietnam	2.18
Malaysia	4.73

Source: Olz and Beerepoot, (2010). RE: Renewable energy

Table 2: RE potential in Malaysia

Renewable energy sources	Potential (MW)
Hydropower	22,000
Mini-hydro	500
Biomass/Biogas	1,300
Municipal solid waste	400
Solar PV	6,500

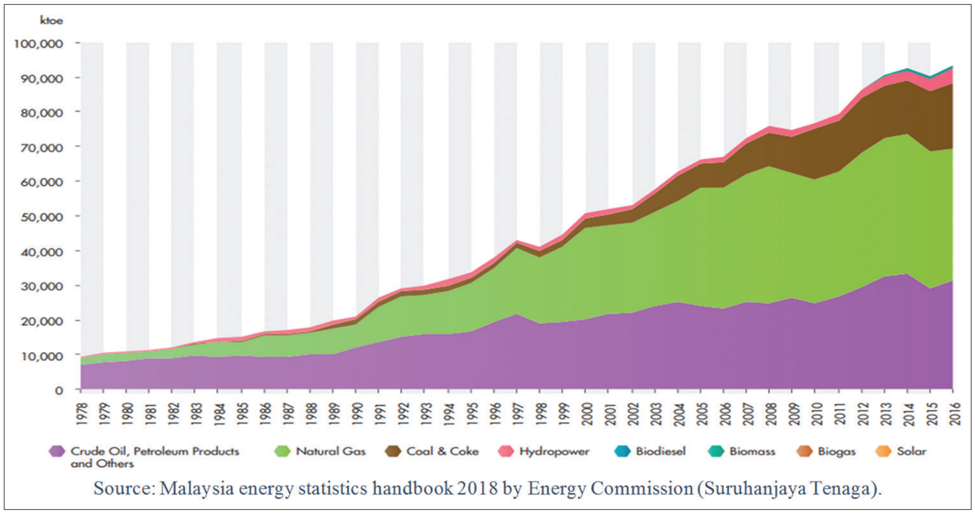
Source: Oh et al. (2010). RE: Renewable energy

Figure 1 shows the primary energy supply by fuel type trends in Malaysia. The primary energy supply of natural gas remained as dominant in Malaysia which represented 41.9% (2016: 42.7%) of total primary energy supply, albeit the small reduction in its share. This was followed by crude oil and petroleum products with a share of 29.9% (2016: 32.5%), coal and coke with 21.1% (2016:19.4%) and hydropower and other RE sources with 7.1% (2016: 5.4%). The increase in the share of renewables indicates the government's efforts in fostering RE in the country. Currently, the government is aiming to increase the RE generation to 20% in the next 6 years (Malay Mail, 2019; Sustainable Energy Development Authority Malaysia (SEDA), 2019). This plan is for a progressively competitive and diversified mix of electricity generation that is more transparent for the industry and consumers. Additionally, The 2016 energy balance report by the energy commission notes that that the implementation of support initiative in the power sector for RE sources through the Feed-in-Tariff (FiT) initiative has raised the consumption of renewables in the country. The FiT initiative (under Renewable Energy act 2011) managed by SEDA is a policy tool to encourage investment in RE technologies which basically involves lower charges to RE producers compared to conventional energy producers.

Consequently, as of January 2017, installed capacity of small hydropower under the FiT scheme is 30 MW, with plants in progress representing more than 200 MW, the largest share of all renewables (International Hydropower Association, 2017). In addition, the IHA points out that as well as adding to a more balanced energy mix, hydropower development is essential to the government's efforts to lessen its greenhouse gas emissions intensity of GDP by 45 percent by 2030 compared to 2005 levels. Currently, Sarawak Bakun hydropower project is the largest hydroelectric plant in Malaysia with a capacity of 2,400 MW which was completed in the year of 2011.

Despite the abundant RE sources and the continuous efforts of the government, RE capacities are under-utilized. Mustapa et al. (2010) draw attention to some issues and challenges that affect the development of RE in Malaysia, including financial and technical barriers. The study emphasizes that new technologies bear a certain degree of uncertainty. Hence it forms a barrier for its development. This uncertainty arises in high financing costs for advancement, arrangement and research. Further, there is also

Figure 1: Primary energy supply by fuel type in Malaysia for the 1978-2016 period



Source: Malaysia energy statistics handbook 2018 by Energy Commission (Suruhanjaya Tenaga)

a technical difficulty that includes a lack of local field expertise with efficient skills and equipment handling. Apart from these two main factors, another issue could be the lack of awareness of the importance of RE in addressing the climate change and energy security as the fossil fuels that the country is currently dependent on are depleting by the increasing exploitation.

This paper is organized as follows. The next section discusses the previous studies on the nexus between economic growth and energy supply and between RE consumption and economic growth, while section 3 explains the methodology adopted. Section 4 discusses the empirical findings of the study. Section 5 presents the conclusion coupled with policy implications.

2. LITERATURE REVIEW

The energy-growth nexus has received increasing attention from developed and developing countries after the oil shocks and energy crises of the last three decades (Samawi et al., 2017). Although the research that assesses the relationship between RE consumption and economic growth have been carried-out extensively (e.g. Apergis and Payne, 2010; Menegaki, 2011; Ocal and Aslan, 2013; Ozcan and Ozturk, 2019), studies examining the relationship between renewable energy supply (RES) and economic growth, to the best of researchers knowledge, have not been investigated. However, few studies have generally linked energy supply to economic growth (e.g. Nnaji et al., 2013; Samawi et al., 2017; Bass, 2018).

Nnaji et al. (2013) analyzed the causal relationship between electricity supply, fossil fuel consumption, Carbon dioxide emissions (CO_2) and GDP growth in Nigeria and found that economic growth is associated with increased CO_2 emissions while electricity supply and CO_2 emissions are positively related. The causality tests of this study also show that electricity supply has not impacted economic growth significantly because of the electricity crisis in the country. In contrast to the conclusion of this study, Bass (2018) pointed out that electricity supply is essential for fostering the Russian economic growth in the long-run. Likewise, Samawi et al. (2017) explored the relationship between energy supply and economic growth in oil-exporting countries. The findings of the study indicate that energy supply is strongly correlated with economic growth. Moreover, this study outlines that although ensuring a sustainable energy supply is a crucial factor, and other mediating effects are also important to consider when measuring the direct and indirect effects on economic growth; hence, the study concluded that changes in energy suppliers appear to reflect changes in the political economy of the country rather than shifts in energy consumption.

Many studies have also scrutinized the causal effects between energy consumption and economic growth (e.g. Ghosh, 2002; Bartleet and Gounder, 2010; Dagher and Yacoubian, 2012; Shahbaz and Feridun, 2012; Pao and Fu, 2013; Pao et al., 2014; Shahbaz et al., 2015; Alper and Oguz, 2016; Tang et al., 2016; Zakaria and Shamsuddin, 2016; Kahia et al., 2017; Rafindadi and Ozturk, 2017; Sultan and Alkhateeb, 2019), which can be categorized into four hypotheses, each of which has an essential implication for energy policy (Al-Mulali et al., 2013). These hypotheses are identified as growth, conservation, feedback and neutral hypotheses; where these hypotheses are essential to be studied to reach a relevant theoretical, empirical and policy implications (Odhiambo, 2009). The growth hypothesis advocates that unidirectional causality runs from energy consumption to economic growth. It infers that increase in energy consumption has a positive impact on economic growth. Hence, energy consumption has a crucial role in productivity and decreases in energy consumption may restrain economic growth. In the case where causality is running from economic growth to energy consumption is identified as conservation hypothesis. This hypothesis implies that a country is not entirely dependent on energy for its economic growth, and a reduction in energy will have a little or no impact on economic growth. A bi-directional causality between energy consumption and economic growth is called the feedback hypothesis. It demonstrates that both energy consumption and economic growth complement each other. In other words, there exists a negative impact between them, which suggests that decreasing energy harms GDP growth and vice versa. No causality is noted as neutrality hypothesis. Under this hypothesis, a decrease or increase in energy consumption does not affect economic growth and vice versa.

For instance, analyzing a sample of European countries, Alper and Oguz (2016) found that growth hypothesis is valid for Bulgaria while the conservation hypothesis is supported for the Czech Republic. Moreover, the study manifested that the neutrality hypothesis is present for Cyprus, Estonia, Hungary, Poland and Slovenia. That means energy conservation policies may harm GDP growth in Bulgaria while the opposite holds for the Czech Republic. For the other countries where the neutrality hypothesis is stable, energy use does not influence economic growth and vice versa. In another context, Pao and Fu (2013) reported the existence of bi-directional causality between energy economic growth and total renewable energy consumption (TREC) which confirms the feedback hypothesis. This indicates that in Brazil, TREC is fundamental for GDP growth and vice versa. Additionally, the study shows the existence of unidirectional causality running from economic growth to non-RE consumption which suggests the conservation hypothesis. The findings of this study imply that Brazil is a non-renewable-energy-independent economy.

Overall, although the majority of the studies in the literature complement the relationship between RE consumption and economic growth, the supply side or the demand side of RE and economic growth has not been yet investigated. Consequently, to fill such a gap, this study intends to examine whether the supply of Hydropower energy adds to the Malaysian economic growth. Moreover, the causal effects of the variables are also studied.

3. RESEARCH METHODOLOGY

3.1. Data and Variables

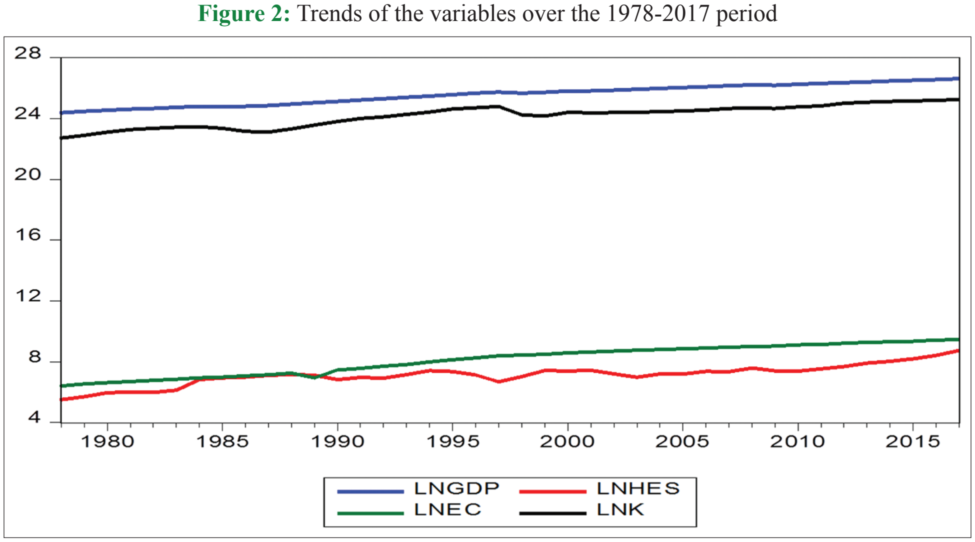
Annual data covering the period from 1978 to 2017 were obtained from world development indicators (WDI) and Malaysia energy information hub (MEIH). The study period was chosen based on data availability. The real gross domestic product (GDP) has been used as an indicator of economic growth. The real GDP is in billions of constant 2010 US $. Kiloton of Oil Equivalent measures data on hydropower energy supply (HES) and total electricity consumption (EC). The total EC consists of residential, commercial, industrial, transport and agricultural electricity consumption. Besides, real gross fixed capital formation (K) is in billions of constant 2010 US $. The data for Hydropower supply and electricity consumption is collected from MEIH while the data of the other two variables are detached from WDI. Figure 2 illustrates the trends of these variables in natural logarithms in the Malaysian economy.

3.2. Econometric Approach

This study aims to explore the association between hydropower energy supply (HES) and economic growth in Malaysia. This study adopts the auto regressive distributive lag (ARDL) bounds test approach introduced by Pesaran and Shin (1999) and later developed by Pesaran et al. (2001). One advantage of this test is that it can be utilized whether the regressors are stationary at the first differences $I(1)$, $I(0)$ or a combination of both. This helps to avoid the uncertainties created by unit root testing. Moreover, the ARDL method can viably fix potential endogeneity issues of the variables (Lin and Moubarak, 2014). Another advantage of the ARDL bounds method, including that the ARDL procedure is more statistically significant in examining the cointegration relation in small data samples, while the Johansen cointegration techniques require large data samples for validity. Furthermore, the ARDL method permits the variables to have different optimal lags, while it is impossible with other cointegration methods (Ozturk and Acaravci, 2010). Therefore, based on these justifications, the following multivariate unrestricted error correction model (UECM) of the ARDL bounds approach is as follows:

$$\Delta GDP_t = \alpha + \gamma_1 GDP_{t-1} + \gamma_2 HES_{t-1} + \gamma_3 E_{t-1} + \gamma_4 K_{t-1} + \sum_{i=1}^{n} \phi_i \Delta GDP_{t-i} + \sum_{j=0}^{n1} \delta_i \Delta HES_{t-j} + \sum_{l=1}^{n2} \acute{\eta}_i \Delta EC_{t-l} + \sum_{m=1}^{n3} \theta_i \Delta K_{t-m} + \mu_t \quad (1)$$

Figure 2: Trends of the variables over the 1978-2017 period



Where Δ the difference operator, γ_t are the long-run multipliers and μ_t is the white noise error term. All variables in Eq. (1) are transformed into natural logarithms. Transforming variables into the logarithmic form helps in reducing heteroscedasticity and to obtain the growth rate of the relevant variables by their differenced logarithms (Ozturk and Acaravsi, 2010).

The bounds test is based on the joint F-statistics (Wald statistics) for cointegration procedure. This procedure involves three critical steps. The first step involves testing the joint significance of the coefficients of the lagged levels in Eq. (1) using Ordinary Least Squares (OLS) for a possible long-run relationship among the series. The null hypothesis of no cointegration is given as H_0: $\gamma_1 = \gamma_2 = \gamma_3 = \gamma_4 = 0$ while the alternative hypothesis is H_1: $\gamma_1 \neq \gamma_2 \neq \gamma_3 \neq \gamma_4 \neq 0$. The bounds test provides two critical values that indicate critical value bounds for the regressors that are I (1), only I (0), or a mixed order of integration. If the computed F-statistics falls below the lower critical bounds value, then the null hypothesis of no cointegration cannot be rejected. However, If the computed F-statistics exceeds the upper critical bounds value, the null hypothesis of no cointegration is rejected, showing cointegration or a long-run relationship. Finally, if the computed F-statistics falls between the bounds, the test is inconclusive.

If there is cointegration among the variables, the next step incorporates in estimating the long-run coefficients of the ARDL model as follows:

$$GDP_t = \begin{array}{l}\alpha + \sum_{i=1}^{n} \beta_1 GDP_{t-i} + \sum_{j=0}^{n1} \beta_2 HES_{t-j} \\ + \sum_{l=0}^{n2} \beta_3 EC_{t-l} + \sum_{m=0}^{n3} \beta_4 K_{t-m} + \mu_t\end{array} \quad (2)$$

The last step is to estimate the short-run dynamic coefficients by running the error correction model presented in Eq. (3):

$$\begin{aligned}\Delta GDP_t = {} & \alpha + \sum_{i=1}^{n} \phi \Delta GDP_{t-i} + \sum_{j=1}^{n1} \delta_j \Delta HES_{t-j} \\ & + \sum_{l=1}^{n2} \acute{\eta}_l \Delta EC_{t-l} + \sum_{m=1}^{n3} \theta_m \Delta K_{t-m} + \\ & \psi ECT_{t-1} + \mu_t\end{aligned} \quad (3)$$

Where ϕ, δ, $\acute{\eta}$ and θ are the short-run coefficients and ψ is the error correction term (ECT). The ECT indicates the extent of disequilibrium that can be adjusted at each period, and it should be a statistically significant coefficient with a negative sign. The significance of the ECT confirms further evidence of a stable long-run relationship (Banerjee et al., 1998).

After estimating the bounds test for cointegration, the causal relationship among the variables can be investigated. Theoretically, cointegration suggests the existence of causality between the variables, but it does not report the direction of the causal relationship (Eddrief-Cherfi and Kourbali, 2012). Granger (1988) suggests that if the variables are cointegrated, a VECM should be applied rather than a standard VAR for testing the causal effects. Hence, following Granger (1988), this study estimates a VEC modelling and uses it to conduct a Granger causality test with the variables in first differences and incorporating the long-run relationships as error correction terms into the model. Thus, the following 4-equation VECM is modelled as follows:

$$\begin{aligned}\Delta GDP_t = {} & \lambda_{10} + \xi_1 ECT_{t-1} + \sum_{i=1}^{m1} \lambda_{11i} \Delta GDP_{t-i} + \\ & \sum_{i=1}^{n1} \lambda_{12i} \Delta HES_{t-i} + \sum_{i=1}^{p1} \lambda_{13i} \Delta EC_{t-i} + \\ & \sum_{i=1}^{q1} \lambda_{14i} \Delta k_{t-i} + \mu_{1t}\end{aligned} \quad (4)$$

$$\begin{aligned}\Delta HES_t = {} & \lambda_{20} + \xi_2 ECT_{t-1} + \sum_{i=1}^{m4} \lambda_{21i} \Delta GDP_{t-i} + \\ & \sum_{i=1}^{n4} \lambda_{22i} \Delta HES_{t-i} + \sum_{i=1}^{p4} \lambda_{23i} \Delta EC_{t-i} + \\ & \sum_{i=1}^{q4} \lambda_{24i} \Delta k_{t-i} + \mu_2\end{aligned} \quad (5)$$

$$\begin{aligned}\Delta EC_t = {} & \lambda_{30} + \xi_3 ECT_{t-1} + \sum_{i=1}^{m3} \lambda_{31i} \Delta GDP_{t-i} + \\ & \sum_{i=1}^{n3} \lambda_{32i} \Delta HES_{t-i} + \sum_{i=1}^{p3} \lambda_{33i} \Delta EC_{t-i} + \\ & \sum_{i=1}^{q3} \lambda_{34i} \Delta k_{t-i} + \mu_{3t}\end{aligned} \quad (6)$$

$$\begin{aligned}\Delta K_t = {} & \lambda_{40} + \xi_4 ECT_{t-1} + \sum_{i=1}^{m2} \lambda_{41i} \Delta GDP_{t-i} + \\ & \sum_{i=1}^{n2} \lambda_{42i} \Delta HES_{t-i} + \sum_{i=1}^{p2} \lambda_{43i} \Delta EC_{t-i} + \\ & \sum_{i=1}^{q2} \lambda_{44i} \Delta k_{t-i} + \mu_{4t}\end{aligned} \quad (7)$$

Where the lagged error correction term (ECT_{-1}) is obtained from the long-run equilibrium relationship, ξ_i are the coefficients of the respective ECTs which indicate the deviation of the dependent variable from the long-run equilibrium, and m_i, n_i, p_i and q_i are the optimum lag lengths that are usually determined based on Akaike Information Criterion (AIC), Schwarz Bayesian Criterion (SBC) and Hannan-Quinn information criterion.

The VECM can capture the long-run causality based on the significance of the coefficient(s) of lagged error correction term and the short-run causality based on the F-statistic or Wald test. While the coefficient of the lagged error correction term denotes the long-run causal relationship which shows how fast any disequilibrium is adjusted between variables, the Wald test can be utilized to examine the significance of all lagged dynamic terms to estimate the short-run causal effects (see also Odhiambo, 2009; Ozturk and Acaravsi, 2010). The joint test of short-run dynamics gives a sign of which variables bear the burden of short-run adjustment to restore long-run equilibrium, as a result of a shock to the system (Asafu-Adjaye, 2000). Moreover, The long-run causality is observed by testing H_0: ξ_i = 0 while the short-run causality is found by testing H_0: $\lambda_i = 0$. For instance, the significance of $\lambda_{12i} \neq 0$ suggests that hydropower energy supply Granger causes economic growth, and it outlines that the past values of HES are useful in predicting the level of GDP growth and vice versa. On the other hand, causality running from economic growth to hydropower supply can be demonstrated by the significance of $\lambda_{21i} \neq 0$.

4. EMPIRICAL FINDINGS

4.1. Unit Root Test

The augmented Dickey-Fuller (ADF) (Dickey and Fuller, 1979) and the Phillips-Perron (PP) (Philips and Perron, 1989) are utilized to identify the level of integration among the variables. Although the bounds test for cointegration does not require that all variables be integrated of order 1 [*I* (1)], it is rational to perform unit root tests to ensure the variables are not 2 [*I* (2)] because the F-statistics of bounds test computed by Pesaran et al. (2001) are based on the assumption that the series is either *I* (0) or *I* (1). If a variable exceeds order one (e.g. *I* [(2)]), the regression results could be spurious. The results of unit root tests with the inclusion of an intercept and linear trend are shown in Table 3.

The results reported in Table 3 indicate that all variables were confirmed to be stationary. The null hypotheses of unit root problem cannot be rejected at the level because the variables are not significant at the 1, 5 and 10% levels of significance. However, when they are converted to a different first form, they are stationary at the 1% significance level. Thus, since no variables are stationary at *I* (2), the ARDL cointegration approach is valid.

Table 3: Unit root test (ADF and PP)

Series	Levels		1st differences	
	ADF	PP	ADF	PP
lnGDP	−1.355807	−1.288632	−4.868967***	−4.873955***
lnHES	−2.131113	−2.255824	−3.565471**	−5.254726***
lnEC	−0.667452	−1.148113	−9.011846***	−9.105210***
lnK	−1.447447	−1.447447	−4.144599***	−4.014189***

***and** shows significance at the 1% and 5% levels, respectively

Table 4: F-bounds test for cointegration relationship

$GDP_t = f(HES_t, EC_t, K)$				
F-statistics	Sig. level (%)	Bounds critical values		Outcome
		I (0)	*I* (1)	
6.7309***	10	3.38	4.02	Cointegration
Lag length	5	3.88	4.61	
(1,2,2,2)	1	4.99	5.85	

***Indicates significance at the 1% level. Appropriate lag selection is based on the Akaike information criterion. The critical values for the lower *I* (0) and the upper *I* (1) bounds are taken from Pesaran et al. (2001, Table CI (iv) Case IV)

4.2. Cointegration Test

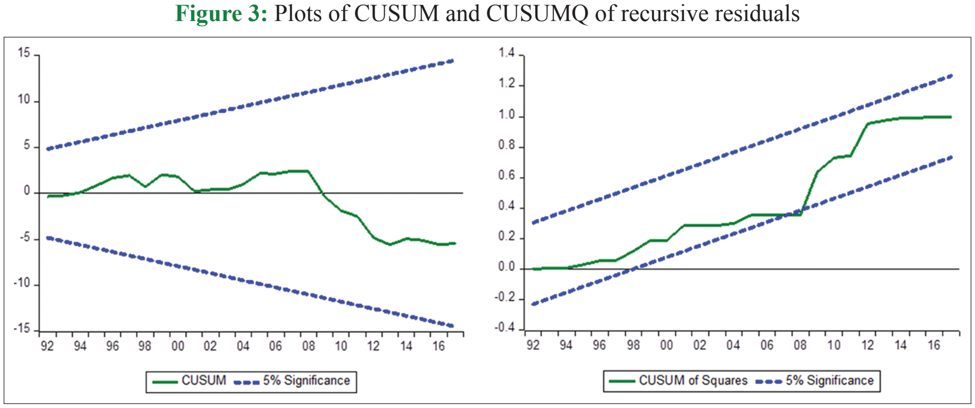
After estimating the order of integration, the next step is to examine whether a long-run relationship between the variables exists by estimating equation (1). The results of the bounds test are reported in Table 4. The F-statistic results in Table 4 demonstrate the existence of long-run relationship among the variables. The calculated F-statistics (6.7309) falls above the critical value at the 1% level of significance. Thus, the null hypothesis of $\gamma_1 = \gamma_2 = \gamma_3 = \gamma_4 = 0$ is rejected, and the alternative is accepted. The F-bounds test for cointegration suggests a long-run relationship between economic growth, hydropower energy supply, electricity consumption and capital formation in Malaysia. To confirm the goodness fit of the bounds model, the stability of the short-run and long-run coefficients, cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) test proposed by Brown et al. (1975) are performed. Both test statistics are applied to the residuals of the estimated model. As seen from Figure 3, both tests fall within critical bounds of 5% significance level, and they indicate the stability of the estimated parameters over the study period.

4.3. Long-run Coefficients, Short-run Dynamics and Error Correction Mechanism

After ensuring the existence of cointegration between HES, EC, K and GDP growth, the next step is to estimate the long-run coefficients of equation (2). The model was estimated and presented in Table 5. The long-run results suggest that primary supply of hydropower energy has an insignificant positive effect on economic growth in Malaysia. That demonstrates, HES has not reached the level where it significantly contributes to economic growth in the country. This result can be since the share of hydropower supply remains very small compared to the other energy sources such as natural gas, crude oil, petroleum products, coal and coke. For instance, in the year of 2016, the share of all renewables including hydropower was just 7.1% of aggregate energy supply contrasted with the supply share of 41.9%, 29.2% and 21.1% of natural gas, crude oil plus petroleum products and coal plus coke, respectively.

Moreover, the estimate of electricity consumption is positively related to economic growth in Malaysia and significant at the 1% level, showing that a 1 unit increase of electricity consumption is expected to lead economic growth roughly by 0.29%. This

Figure 3: Plots of CUSUM and CUSUMQ of recursive residuals



positive long-run relationship is also reported by (Long et al., 2018). Furthermore, a 1% increase of capital formation leads to a 0.24% increase in economic growth, and it is significant at the 1% level, a similar result is also found by Kahia et al. (2017).

Correspondingly, the results of the short-run model were estimated from equation (3) and presented in Table 5. In the short-run, hydropower energy supply has a significant positive impact on economic growth. Hence, a one-unit increase in HES leads to a small rise of 0.026% in economic growth. The results also suggest that the prior period's hydropower energy supply had a significant negative impact on economic growth where a one-unit increase in HES led to a small decrease in economic growth by 0.04%. Furthermore, electricity consumption has an insignificant positive impact on economic growth. That shows an increase of electricity consumption does not affect the economic growth in the short-run. It is also documented that electricity consumption in the last year had a significant negative impact on economic growth, where a one-unit use of electricity led to a marginal decline of 0.05%.

Considering the capital formation in the current period, a 1% increase of capital formation drives the economic growth of almost 0.27%. However, capital formation affected the economic growth negatively in the last period, where a 1% increase in capital formation led to GDP growth to decline slightly by 0.05%.

Table 5: Estimated long and short-run coefficients

Dependent variables is $lnGDP_t$		
Variables	**Coefficients**	**T-ratio (P-values)**
Long-run results		
lnHES	0.0299	1.3926 (0.1756)
lnEC	0.2879	6.5430 (0.0000)***
lnK	0.2370	5.6708 (0.0000)***
Constant	6.9486	5.8918 (0.0000)***
Short-run results		
ΔHES	0.0260	2.8898 (0.0068)**
ΔHES_{t-1}	−0.0430	−4.5660 (0.0001)***
ΔEC	0.0222	1.1480 (0.2443)
ΔEC_{t-1}	−0.0596	−2.3669 (0.0235**
ΔK	0.2674	18.1463 (0.0000)***
ΔK_{t-1}	−0.0508	−3.6546 (0.0009)***
ECT_{t-1}	−0.4076	−5.8506 (0.0000)***
Diagnostic tests	**F-statistics**	**P-values**
x^2SC	0.0793	0.9241
x^2HET	0.1187	0.7325
x^2N	0.4453	0.8004
x^2FF	1.5171	0.2295

***and **denote 1% and 5% level of significance, respectively. x^2SC, x^2HET, x^2N and x^2FF present the Breusch-Godfrey serial correlation LM test, the ARCH: Autoregressive conditional heteroskedasticity test, the Jarque-Bera normality test and Ramsey Reset test for functional form misspecification, respectively

Furthermore, the lagged error correction term (ECT_{t-1}) in Table 6 is negative and significant at the 1% level, which provides further evidence of cointegration. The negative sign shows the speed of adjustment towards equilibrium. The error correction term is roughly −41% with the expected sign, indicating that a deviation from the long-run equilibrium level of economic growth in 1 year is corrected by almost 41% over the following year. The diagnostic tests in the lower part of Table 6 imply the acceptable fit of the model.

4.4. Causality Test

Since there is cointegration among the variables, a causality analysis through a vector error correction model can be estimated. The results of the Granger causality of both short-run and long-run are presented in Table 6. From equation 4, the empirical results do not confirm either a short-run or a long-run causality between HES, EC and K to economic growth when the dependent variable is the real GDP. However, concerning equation 5, when the dependent variable is HES, the error correction term (ECT) is negative and significant at 1% level showing a long-run unidirectional causality running from GDP, EC, K to hydropower energy supply without any feedback effect. The statistical significance of the ECT implies that hydropower energy supply responds to deviations from long-run equilibrium with an adjustment of −0.46% each period so that variables converge towards their equilibrium path. Also, in the short-run, economic growth and capital formation Granger causes hydropower energy supply and not vice versa. In other words, GDP growth and capital formation lead to more supply of hydropower energy and not vice versa.

Further, in terms of equation 6, there is evidence of long-run causality running from economic growth, hydropower energy supply and capital formation to electricity consumption at the 10% level of significance without any feedback effect. The findings of this study support the conservation hypothesis, which suggests that electricity conservation policies do not harm economic growth in Malaysia. This manifests that rising economic activities in the country leads to more electricity use as an essential input to the residential, commercial, industrial, transport and agricultural activities. This unidirectional causality is in line with the findings of Ghosh (2002) for India, Shahbaz and Feridun, (2012) for Pakistan and Zakaria and Shamsuddin (2016) for Malaysia.

Table 6: Granger causality test results

Variables	Short-run causality				Long-run causality
	ΔGDP	**ΔHES**	**ΔEC**	**ΔK**	ECT_{-1}
ΔGDP	-----	0.086 (0.9577)	0.1995 (0.9051)	0.9810 (0.6123)	0.0733 [0.6978]
ΔHES	11.6444 (0.0030)**	-----	2.8559 (0.2398)	13.1820 (0.0014)**	−0.4637 [0.0000]***
ΔEC	0.6156 (0.7351)	0.4357 (0.8042)	-----	2.5432 (0.2804)	−0.0646 [0.0754]*
ΔK	0.7779 (0.3778)	2.9610 (0.0848)*	0.3108 (0.5772)	-----	−0.2461 [0.0643]*

Values in parentheses are P values of Wald tests of the short-run lagged coefficients. ECT indicates the coefficient of the error correction term. P values of the respective ECT's are given in the brackets. ***,**and *show 1%, 5% and 10% significance levels, respectively

Moreover, regarding equation 7, a unidirectional long-run causality running from economic growth, Hydropower energy supply, electricity consumption to capital formation is present and significant at the 10% significance levels and not vice versa. This unidirectional causality is also reported by Mehrara and Musai, (2013). A short-run unidirectional causality running from hydropower energy supply to capital formation is also detected, and it is significant at the 10% level.

5. CONCLUSION AND POLICY IMPLICATIONS

The relationship between renewable energy supply and economic growth has not been discussed in the previous literature. Therefore, the main objective of this study is to examine the influence of hydropower energy supply on economic growth in Malaysia over the period from 1978 to 2017. The study analyzed the hydropower energy supply, electricity consumption, gross fixed capital formation and economic growth using the ARDL bounds approach and VECM (in the Granger sense) to test for the cointegration relationship and causal effects among the variables, respectively. The cointegration test results yield evidence that the variables are cointegrated. In the long-run, hydropower energy supply has an insignificant positive impact on economic growth. However, it has a significant positive impact on economic growth in the short-run. The existence of cointegration among hydropower energy supply and economic growth, nevertheless infers that the supply of hydropower energy will not drift too far away from economic growth in the long-run. Thus, it is vastly important for the government to ensure a sufficient supply of hydropower energy in the long-run. Furthermore, capital formation has a significant positive impact on GDP growth in both the short-run and the long-run. This study also finds that electricity consumption has a significant positive impact on economic growth in the long-run.

The causality tests show a unidirectional causality running from economic growth to hydropower energy supply, both in the short-run and long-run and not vice versa. These results suggest that economic growth is necessary for providing the essential resources for fostering the supply of hydropower energy. Empirical findings also report a unidirectional long-run causality running from economic growth to electricity consumption and not the other way around. In this regard, our results support the conservation hypothesis, which implies that electricity conservation policies can be implemented without restraining economic growth in the country. Additionally, in the long-run, capital formation Granger causes hydropower energy supply, while in the short-run, they Granger causes each other, which suggest the feedback effect.

Although the government of Malaysia initiated many policies to increase the use RE such as the Small Renewable Energy Program (SREP), the utilization of conventional energy sources is still predominant despite the high capacities of clean energy sources. However, continued efforts are promising as the government is aiming to increase the RE generation to 20% in the next 6 years, which will hopefully lead to downward costs of RE. In relation to this effort, electricity generation from hydropower sources could be one of the viable options for the policymakers to pursue to reach their target. On the other hand, even though Malaysia has had the proficiency and capability in mini-hydro systems since the 1970s, these have not been utilized for added benefit to the country as reported by SEDA. The SEDA also states that data on mini-hydro potential sites and their respective power generation potentials are not effectively accessible because rivers are under the control of the state authorities. Therefore, it is of utmost importance to establish a central regulatory body to manage the streams and rivers that are flowing from highlands and have a potential of hydropower energy generation. Moreover, a typical issue in mini-hydro development is their remote locations. Despite the fact that the potential can be very high, realizable projects should be those within feasible distance of around 10 km or less from the closest points of interconnection. Consequently the shortage of accessible data implies there is a need to gather adequate data to undertake an assessment of the potential.

Thus, to perpetuate a green economy and to reduce the carbonic emissions in the country, RE sources are regarded as a significant contributor. Additionally, with its interior mountains and hills, hydropower is a fundamental component of the country's energy mix and feasible alternative to conventional electricity generation to ascertain a clean energy supply for sustainable-social economic development. It is proven that hydropower is one of the most abundant renewables in the country which has the potential to be exploited. This study has implications for the policymakers to ensure a sustainable supply of hydropower energy, encourage its consumption and raise public awareness on the importance of RE sources. It is also essential to resolve the issues impeding the development of RE, such as financial and technical barriers. Government ought to engage in investing and subsidising the sustainable renewable technologies to minimize the uncertainties related to investing in RE, and encourage the private sector participation. The technical barriers could also be overcome by conducting and funding training to gain the required knowledge and technical skills related to hydropower plants designing. It is also recommended that the government offer extra incentives under the Feed-in-Tariff (FiT) scheme, which is shown to stimulate RE consumption in other developed countries.

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