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Article

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Macroeconomic Indicators for Electrical Consumption Demand Model in Malaysia

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ABSTRACT

Malaysia has pledged to reduce carbon emissions by 45% in year 2030 and to attain a completely carbon neutral status by year 2050. For those purposes, substantial measures and policies have been implemented geared towards green growth and sustainability, as stipulated in the 9th, 10th, and 11th Malaysia Plans commencing from 2006 until 2020. Nevertheless, it is indeed a challenge in striking to achieve these targets due to reported increment in the total final energy consumption by 30% from 2010 until 2014. Demand for electricity in Malaysia has been expected to surge between 5% and 6% within these couple of years in line with nation urbanisation and economic progression. As such, a number of macroeconomic indicators that might have influenced Malaysia's electrical consumption had been analysed for the 1970-2016 period by estimating electricity consumption per capita demand function linked with economic growth, foreign direct investment inflows, trade liberalisation, population growth, urbanisation population growth, financial development, industrialisation, inflation, and household consumption expenditure. The analysis was conducted by using the Autoregressive Distributed Lag model. The estimation outcomes revealed the roles of economic progression and urbanization that led to increment in electrical consumption, whereas financial deepening and higher inflation linked to reduction. Such results enlighten significant insights for policymakers. For instance, since electricity consumption rises with urbanisation, it is essential that energy-efficient appliances are made relatively affordable and readily available for urbanites. The central bank also should play its part by lowering the lending rates so as to allow the financial institutions across the nation to offer attractive loans with lower financing cost to firms associated to renewable energy. With more companies being involved in cleaner alternative energy production, the nation is deemed to minimise its carbon emissions by decreasing its dependence upon coal to generate electricity.

Keywords: Electricity Consumption, Carbon Emissions, Autoregressive Distributed Lag Model
JEL Classifications: O1, Q2, Q4

1. INTRODUCTION

Increment in electricity consumption demonstrates vital consequences in economic growth and trade. Although increased consumption of electricity energy is bound to enhance income; pollutions, externalities, and environmental issues cringe into massive national problems, Richard et al. (2015). In Malaysia, the rapid growing economy is parallel with enhancing household income, urbanisation, and industrialisation, while concurrently escalating demand for electricity. The growing population, which seems consistent with higher level of standard of living, appears to trigger demand for domestic electricity energy. As such, numerous determinants happen to affect the growing demand of electricity energy in the country. For instance, Taylor (1975) noted that certain econometric issues, particularly those that focus on the estimation of price responsiveness of electricity demand, have become more challenging when compared to general estimation of the demand curve.

Based on the Central Intelligence Agency 2016 report (2016), China was ranked top with 5,920,000,000,000 electricity consumption per capita (kWh per individual), while the United States at the second place with 3,911,000,000,000 kWh, and Malaysia ranked at 29th place with 133,000,000,000 kWh. Many countries seem to neglect the aspect of energy conservation and efficiency as economic growth is made priority. With more need of energy, mounting pressure is placed on upstream energy resources, including crude oil, coal, and natural gas, hence exhausting availability of non-renewable energy. Due to overdependence on fossil fuels, particularly power plants generation, the energy sector has also become accountable towards the impact of greenhouse gases, global warming, climate change, and other environmental woes.

Consumers have the choice to opt for electrical energy efficient appliances at homes in the attempt of minimising use of energy towards attaining the national vision. The industrial sector also has vast opportunities to enhance energy efficiency through improved equipment and process design, as well as viable energy management systems and practices. Sustainable energy aims to provide sufficient supplies of energy to reduce adverse effects on our planet, which can be implemented at appropriate levels. Sustainable energy caters to demands with less energy input through healthier energy efficacy. In Malaysia, energy sustainability may be vulnerable if energy issues, such as, increment in electricity consumption and carbon dioxide (CO_2) emissions, are not addressed in near time.

With that, this paper estimated electricity consumption per capita that influenced macroeconomic determinants, such as economic growth, foreign direct investment (FDI) inflows, trade liberalisation, population growth (POP), urbanisation population growth (UPOP), financial development (FD), industrialisation, inflation (INF), and household consumption expenditure (HCE), for the period of 1970-2016. The data are subsequently significant in portraying determinants that mostly affected electricity energy consumption in Malaysia. The organisation of the study is as follows: Section 2 reviews relevant literature and past, Section 3 describes model formulation and the methods used, Section 4 explains and discusses the study outcomes, and finally, Section 5 concludes the study and lists several policy recommendations.

2. LITERATURE REVIEW

The literature includes various studies that exclusively investigated the profiles of macroeconomic indicators. Jones and Lomas (2015) analysed the main factors that contributed to high demand of electrical energy. Some essential determinants that have been reported to significantly affect energy consumption are FDI inflows, trade openness (TO), economic growth, and human development index, Azam et al. (2015). These indicators have been tested profoundly to substantiate their correlation with energy consumption via econometric techniques. The authors concluded that FDI inflows and real gross domestic product (GDP) exerted positive relationships with energy consumption, while POP rate emerged as a significant determinant of energy consumption.

Next, Ivy-Yap and Bekhet (2016) reported genuine correlations among residential electricity consumption, GDP, prices of electricity and electrical appliances, population, and FDI in Malaysia. The article probed into the important tools that measured the rapid growth in electricity consumption towards achieving better energy security. Magazzino (2015) performed a co-integration analysis and revealed a long-run relationship between GDP and energy consumption. Through the use of time series approach, the article concluded that energy consumption and economic growth complemented each other and boosted economic growth, which eventually surged energy consumption. Similarly, many studies have found the direct link between energy consumption and economic growth (Dogan, 2015; Karanfil, 2009; Alshehry and Belloumi, 2015; Salahuddin et al., 2015; Bhattacharya et al., 2016).

Tang et al. (2016) investigated the relationship between energy consumption and economic growth from the lens of neoclassical Solow growth framework in Vietnam. Their findings showed long-run relationships between economic growth and its determinants. The regression analysis displayed positive impacts on economic growth when energy consumption, FDI, and capital stock were modified. Alper and Oguz (2016) observed the causality amongst economic growth, renewable energy consumption, capital, and labour by employing asymmetric causality test approach and autoregressive distributed lag (ARDL). The results indicated the positive impact of renewable energy consumption upon economic growth.

Other studies have documented unidirectional causality that ran from energy consumption and CO_2 to real income in both long- and short-run. The authors concluded that degradation of environmental quality may exert negative externalities upon economy that are bound to adversely affect the tourism sector and human health, thus declining nation productivity and growth in the long-run (2018). Policies on minimising energy consumption and reducing CO_2 are needed to sustain and to preserve the environment for the next generations without impairing the economy.

Limited prior studies regarding the determinants of electrical demand consumption model have motivated more academicians to begin investigating the causes of higher electricity demand and their impacts on demand for renewable energy. Many past studies within this area have analysed only a handful of determinants, leading to biased estimation and neglect of potential determinants. To the best of the author's knowledge, this study analysed the widest spectrum of potential macroeconomics determinants that may affect the demand for electricity in Malaysia. The study outcomes offer vital insights and bridge the gap in the existing body of knowledge.

3. METHODOLGY

The formulation of the model is explained briefly in this section. The macroeconomic determinants of electricity consumption demand model for Malaysia had been carefully selected based on the support of hypotheses derived from past studies.

3.1. Model Specification

The general functional form of the model introduced in this study reflects the modified version of Adom et al. (2012), Amusa et al. (2009), Zuresh and Peter (2007), and Lin's (2003) model, while several new macroeconomic determinants were treated as control variables to avoid bias estimation. The model is presented in equation 1 below:

$$EC_t = f(GDP_t, FDI_t, TO_t, POP_t, UPOP_t, FD_t, IND_t, INF_t, HCE_t) \quad (1)$$

where
EC_t represent electrical consumption
GDP_t represent real output or economic growth
FDI_t represent foreign direct investment inflows
TO_t represent trade openness
POP_t represent population growth
$UPOP_t$ represent urban population
FD_t represent financial development
IND_t represent industrialization
INF_t represent inflation
HCE_t represent household consumption expenditure

All the variables were transformed into log-linear form called LN to translate the outcomes into long-run elasticities and to reduce the sharpness of the time series data resulting in consistent and reliable estimates, Shahbaz (2010). The log version of the model is given in equation 2 below:

$$\begin{aligned} LNEC_t = {} & \alpha_0 + \beta LNGDP_t + \chi LNFDI_t + \delta LNTO_t + \phi LNPOP_t \\ & + \gamma LNUPOP_t + \eta LNFD_t + \kappa LNIND_t + \lambda LNINF_t + \\ & \mu LNHCE_t + \varepsilon_t \end{aligned} \quad (2)$$

where, α_0 refers to intercept, i denotes subscripts are for country, and t represents time period. et is defined as the white noise stochastic disturbance term. LN stands for natural logarithm operator, whereas $\alpha = LN_\alpha$; β, χ, δ, ϕ, γ, η, κ, λ, and μ refer to the parameters to be estimated.

Real output or GDP appears to be a major factor in determining electrical consumption in most studies (Zaman et al., 2015; Narayan et al., 2007). Progressive economic conditions reflect higher purchasing power that allows people to consume more electricity. Similar studies performed in other nations integrated price of electricity, which was excluded in this study due to unavailability of data.

This research proposes other potential exogenous variables that might influence electrical consumption in Malaysia, such as FDI, TO, POP, UPOP, FD, IND, INF, and HCE. Population growth and urbanisation, for instance, are linked with increased electricity consumption, as more people tend to use up more electricity to perform increasing daily activities, especially when they move from rural areas to cities. Such urbanisation shift escalates electricity consumption as urbanites have more access to electrical appliances, live a civilised lifestyle, and work mainly in industries or services companies. Industrialisation, as introduced in this model, served as a proxy by industrial value-added. According to Zuresh and Peter (2007), as value-added of industry generates a greater share in GDP, associated electricity usage is expected to increase for operating industrial machinery, mining, and construction, to name a few. Higher INF has also been expected to influence the demand for electricity due to its impact on consumers' purchasing power. With rising INF, consumers tend to minimise their electrical consumption by adopting more energy-efficient products. The rise in HCE can also influence the demand for electricity as a survey has shown that over years, households pay more for their utilities, including electricity bills, as more technology or electrical products are used in daily life activities.

This study hypothesised that the coefficients signs of all the explanatory variables to be positive. The ARDL model based on Unrestricted Error Correction Model (UECM) is as stated 3 below:

$$\begin{aligned} \Delta LNEC_t = {} & \beta_0 + \theta_0 LNGDP_{t-1} + \theta_1 LNFDI_{t-1} + \theta_2 LNTO_{t-1} \\ & + \theta_3 LNPOP_{t-1} + \theta_4 LNUPOP_{t-1} + \theta_5 LNFD_{t-1} \\ & + \theta_5 LNIND_{t-1} + \theta_6 LNINF_{t-1} + \theta_7 LNHCE_{t-1} \\ & + \sum_{i=1}^{p} \beta_i \Delta LEC_{t-i} + \sum_{i=0}^{q} \gamma_i \Delta LNGDP_{t-i} + \sum_{i=0}^{r} \delta_i \Delta LNFDI_{t-i} \\ & + \sum_{i=0}^{s} \lambda_{t-i} \Delta LNTO_{t-i} + \sum_{i=0}^{t} \vartheta_{t-i} \Delta LNPOP_{t-i} \\ & + \sum_{i=0}^{u} \zeta_{t-i} \Delta LNUPOP_{t-i} + \sum_{i=0}^{v} \xi_{t-i} \Delta LNFD_{t-i} \\ & + \sum_{i=0}^{w} \psi_{t-i} \Delta LNIND_{t-i} + \sum_{i=0}^{x} \omega_{t-i} \Delta LNINF_{t-i} \\ & + \sum_{i=0}^{y} o_{t-i} \Delta LNHCE_{t-i} + \upsilon_t \end{aligned} \quad (3)$$

where Δ stands for the first difference operator, and ut is the white-noise disturbance term. Residuals for the UECM were serially uncorrelated and the models appeared stable. The final model represented in equation (3) above can also be viewed as an ARDL of the following order: (p, q, r, s, t, u, v, w, x, y). The model indicated that the level of electrical consumption (LNEC) was influenced and explained by its past values, this involving other disturbances or shocks. From the UECM estimation, the long-run elasticities refer to the coefficient of one-lagged explanatory variables (multiplied by a negative sign) divided by the coefficient of the one-lagged dependent variable. Meanwhile, the short-run effects were captured by the coefficient of the first differenced variables.

Both null and alternative null of no co-integration in the long-run relationship are defined by:

H_0: $\theta_0 = \theta_1 = \theta_2 = \theta_3 = \theta_4 = \theta_5 = \theta_6 = \theta_7 = \theta_8 = \theta_9 = 0$

(Absence of a long-run relationship),

H_1: $\theta 0 \neq \theta 1 \neq \theta 2 \neq \theta 3 \neq \theta 4 \neq \theta 5 \neq \theta 6 \neq \theta 7 \neq \theta 8 \neq \theta 9 \neq 0$

(Presence of a long-run relationship),

If the computed F-statistics is below the bound critical value, the null hypothesis of no integration is not rejected. However, if the computed F-statistics exceeds the upper bound critical value, the null hypothesis of no co-integration is rejected. Nonetheless, if the computed value falls between the lower and upper bound critical values, the result is inconclusive.

3.2. Sources of Data

The sources of data for all the selected variables in this study derived from the World Development Indicator (2018). Detailed information of each variable is presented in Table 1.

4. DATA ANALYSIS AND DISCUSSION

Preliminary data analysis, such as testing of the unit root for each variable, gave important information regarding data stationarity. Using Augmented Dickey Fuller (ADF) and Phillip Perron (PP) unit root tests, the analysis was run both at level and at first difference, as presented in Table 2. The results showed that almost all variables were not stationary for both ADF and PP unit root tests, except for LNFDI, LNFD, LNINF, and LNHCE. The yields of unit roots at first difference signified that most of the variables were stationary at 1% significant level, except for a few variables; LNEC and LNPOP, which were not stationary at any level. The outcomes from this test pointed out the existence of mix stationarity of the variables, thus fulfilling the condition of using ARDL estimation for regression analysis.

To proceed with ARDL estimation, the evidence of long-run co-integration was initially tested by comparing the values obtained from model F-statistics with the critical values reported by Pesaran (2001). Based on the results tabulated in Table 3, the F statistics of the model, which was 7.92, exceeded the upper bound value of 1% significant level, hence verifying the presence of long-run co-integration in this model.

In producing reliable estimation, several diagnostic tests, such as normality test, serial correlation test, Ramsey Reset test (functional form), and Breusch Pagan test (Heteroscedasticity), were carried out and the outcomes are presented in Table 4. All the tests were conducted to ascertain that the econometric model, as suggested in this study, is free from any econometric issue that may yield biased results. Given the P-value of each test >10% significant level, the model did not suffer from any econometric issue.

In addition to the four diagnostic tests introduced above, the stability of the model was assured via cumulative sum of recursive residual (CUSUM) and cumulative sum of squares of recursive residuals (CUSUMSQ) (Figure 1). The condition of stability is only achieved when both CUSUM and CUSUMSQ lines (blue) fall within the 5% significant level, represented by two dotted red lines.

The model in this study was indeed stable as it satisfied the conditions described above. With confirmation of diagnostics and stability tests, it is concluded that the econometric model

Table 1: Sources of data

Variables	Description	Sources
EC	Electric power consumption (kWh per capita)	WDI
GDP	GDP per capita (constant 2010 US$)	WDI
FDI	Foreign direct investment, net inflows (% of GDP)	WDI
TO	Trade (% of GDP)	WDI
POP	Population growth (annual %)	WDI
UPOP	Urban population growth (annual %)	WDI
FD	Domestic credit to private sector (% of GDP)	WDI
IND	Industry, value added (% of GDP)	WDI
INF	Inflation, consumer prices (annual %)	WDI
HCE	Household final consumption expenditure (constant 2010 US$)	WDI

WDI stands for World Development Indicator 2018

Table 2: Results of unit root tests

Stage	Variable	ADF test statistic		PP test statistic	
		Intercept	Trend and intercept	Intercept	Trend and intercept
Level	LNEC	−1.727	−0.657	−2.191	−0.134
	LNGDP	−1.566	−2.508	−1.566	−2.131
	LNFDI	−2.160	−2.393	−5.757***	−5.718***
	LNTO	−1.891	−0.273	−1.433	0.168
	LNPOP	−0.023	−1.470	0.508	−1.065
	LNUPOP	1.573	−0.808	1.167	−0.909
	LNFD	−2.216	−1.813	−2.647*	−1.467
	LNIND	−2.336	−1.249	−2.336	−1.201
	LNINF	−3.940***	−4.247***	−3.907***	−4.247***
	LNHCE	−0.089	−3.664**	−0.065	−2.634
First Δ	LNEC	−1.731	−2.385	−4.940***	−5.832***
	LNGDP	−5.794***	−5.959***	−5.805***	−5.959***
	LNFDI	−2.818*	−2.830	−25.564***	−25.255***
	LNTO	−4.985***	−5.589***	−4.985***	−5.555***
	LNPOP	−0.948	−2.160	−2.113	−2.605
	LNUPOP	−4.926***	−5.302***	−4.913***	−5.302***
	LNFD	−2.477	−2.828	−5.985***	−6.445***
	LNIND	−6.225***	−7.156***	−6.223***	−7.167***
	LNINF	−8.985***	−8.896***	−9.450***	−9.328***
	LNHCE	−4.506***	−4.547***	−4.353***	−4.334***

*,**,***Indicate significant at 10%, 5% and 1% significance level respectively. Δ is refer to difference

Table 3: Result of ARDL cointegration

Model	F-statistics		Lag order
EC=*f* (GDP, FDI, TO, POP, UPOP, FD, IND, INF, HCE)	7.962***		2,1,0,0,0,2,1,0,1,1
	Significant level	**Lower I (0)**	**Upper I (1)**
k=9	1%	2.65	3.97
	5%	2.14	3.3
	10%	1.88	2.99

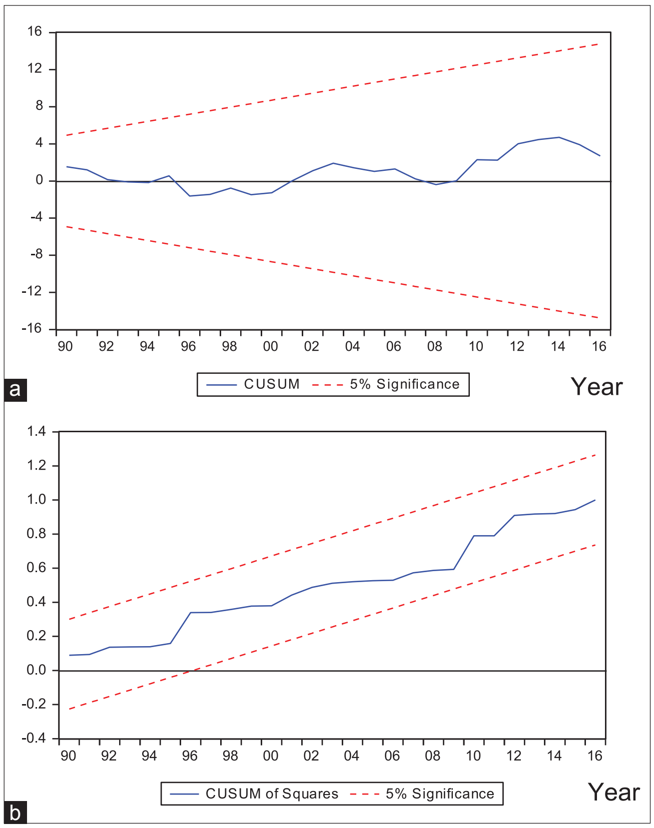
#The critical values are based on Pesaran et al. (2001), Case III: unrestricted intercept and trend., k is a number of variables; *,**,***represent 10%, 5% and 1% level of significance, respectively

Table 4: Result of diagnostic checking

Normality	Serial correlation	Functional form	Heteroscedasticity
0.254	0.296	0.337	1.098
[0.880]	[0.745]	[0.566]	[0.403]

The numbers in brackets [ ] are P-values.

Figure 1: (a and b) CUSUM and CUSUMSQ



introduced in this study can produce the best outcomes from its main analysis, as displayed in Table 5.

The main analysis of this study focused on the outcomes of long- and short-run elasticities. As a result, only four (LNGDP, LNUPOP, LNFD, and LNINF) out of nine possible macroeconomic determinants established significant correlations with electrical consumption in Malaysia for both long- and short-run. As for LNGDP, it had been confirmed that higher GDP increased consumption of electricity (LNEC). Based on the coefficient value of long-run, a 1% increment in the GDP hiked EC by 3.5%. On the other hand, smaller coefficient value was detected in the short-run, where a 1% increase in GDP only increased EC by 0.4%. Among all the nine selected macroeconomics determinants of energy consumption, GDP in the long-run produced the highest elasticities, wherein change in this aspect can largely affect electrical consumption activities. This outcome is in line with that reported by Amusa et al. (2009) in Africa and Amarawickrama and Hunt (2008) in Sri Lanka, who concluded that GDP was a major determinant and gave positive impact on electrical consumption in the long-run. Next, urban population (LNUPOP) positively influenced the level of electrical consumption in the long-run. Statistically, 1% increase in LNUPOP increased LNEC by 1.2%. The rise of urban population or urbanisation in any developing nations, such as Malaysia, has taken place since three decades ago. For example, the rapid development in centred in several locations, for example, Kuala Lumpur, Penang, and Johor Bahru, which have created more job opportunities to the local people, thus influencing those from the rural area to move into urban states. Apart from representing the concentration of economic activities, urbanisation also implies a change in lifestyle and consumption patterns amidst urban dwellers. Elliot et al. (2014) claimed that urbanites tend to acquire intensive energy products, such as air conditioners and refrigerators, for more comfortable lifestyle, thus increasing electricity consumption. However, the short-run outcomes showed an unexpected opposite expected sign, where 1% increase in LNUPOP decreased LNEC by 0.14%. Next, deepening of FD exhibited a positive relationship in the short-run, but negatively for long-run. Statistically, 1% increment in LNFD hiked LNEC by 0.14% in the short-run, but reduced LNEC by 0.34% in the long-run. Perhaps, at the earlier phase of FD, most banking sectors received better returns from their borrowing activities by lending to industries that heavily focused on manufacturing activities. This led to an upsurge of electrical consumption at that time. On the contrary, FD could potentially lower electrical consumption by achieving efficiency in its use. Following Karanfil (2015), deepening FD in the long-run could portray a lower cost of credit offered to potential customers, hence promoting spending activities on high-technology and energy-efficient products that minimise electrical consumption. Aside from FD, higher inflation (LNINF), both in short- and long-run could also decrease electrical consumption. Statistically, a 1% hike in LNINF reduced LNEC by 0.01% and 0.12%, respectively. With the rising cost of living, home residents tend to substitute their home electrical appliances with more energy-saving home appliances so as to reduce their electricity bills and cope with the

Table 5: Estimation of long-run and short-run elasticities

Variables	Standard error	t-Statistic	Coefficient
Long run elasticities			
LNGDP	1.118	3.087	3.452***
LNFDI	0.024	0.960	0.023
LNTO	0.219	0.041	0.009
LNPOP	0.338	−0.162	−0.054
LNUPOP	0.540	2.259	1.220**
LNFD	0.181	−1.846	−0.335*
LNIND	0.355	−1.312	−0.466
LNINF	0.036	−3.343	−0.122***
LNHCE	0.563	−1.402	−0.789
C	6.488	−0.157	−1.019
Short run elasticities			
$\Delta LNEC_{-1}$	0.109	−2.932	−0.321***
ΔLNGDP	0.173	2.438	0.424**
ΔLNFDI	0.004	1.038	0.004
ΔLNTO	0.045	0.041	0.001
ΔLNPOP	0.070	−0.160	−0.011
ΔLNUPOP	0.102	0.896	0.091
$\Delta LNUPOP_{-1}$	0.073	−1.882	−0.139*
ΔLNFD	0.033	1.926	0.064*
ΔLNIND	0.065	−1.459	−0.096
ΔLNINF	0.005	−1.998	−0.010*
ΔLNHCE	0.119	0.415	0.049
$CointEq_{-1}$	0.061	−3.373	−0.206***

*,**,***Indicate significant at 10%, 5% and 1% significance level respectively. Δ refer to difference

escalating cost of living. The other variables, such as LNFDI, LNTO, LNPOP, LNIND, and LNHCE, did not significantly influence electricity consumption, thus failing to influence LNEC based on this sample period of studies.

Table 5 shows the estimated lagged ECT in ARDL regression for the nation, which appeared to be negative and statistically significant with the value of -0.206. ECT reflects the speed of adjustment for the model and the negative value means that the variables in the model will converge in the long-run. For instance, more than 21% of adjustments were completed within less than a year for Malaysia.

5. CONCLUSION AND POLICY RECOMMENDATIONS

This paper investigated the determinants of electricity consumption demand both in the long-run and short-run periods based on ARDL Bounds co-integration approach using sample derived from year 1970 until year 2016. The test of level relationship revealed that real per capita GDP, degree of urbanisation, FD, and INF in the economy can be treated as the ‘long-run forcing’ variables that explain aggregate domestic electricity demand in Malaysia.

Based on the yields of this research paper, there is a need for Malaysia’s policymakers to devise viable and effective short- and long-term plans for sustainable energy. The suggested short-term plan may consist of the following:

- Urbanisation that leads to lower electricity consumption indicates that the government needs to continuously monitor housing or industrial development. For example, the government could give more priority by giving tenders to housing developers who are able to build smart houses equipped with solar panel as a way to conserve energy and reduce electricity consumption on their housing project for citizens. As for business owners, the government can provide tax redemption, especially for companies that are able to lower electricity usage from their business operations.

The long-term plans may consist of the following:

- Offer more encouragement to financial institutions that provide loans to renewable energy-based sector by lowering the interest rates.
- Effective awareness advertisement and continuous campaign on energy-saving could educate the public to control their usage, especially during high inflation. Campaigns, such as the Earth Hour event, promote citizens to stop using electricity for a certain period of time. Hence, in order to save the Earth, more campaigns and events should be organised frequently instead of only once annually.

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