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Examining the Feedback Response of Residential Electricity Consumption towards Changes in its Determinants: Evidence from Malaysia

Lee Lian Ivy-Yap, Hussain Ali Bekhet*

Graduate Business School, Universiti Tenaga Nasional (UNITEN) 43000 Kajang-Selangor, Malaysia.
*Email: profhussain@uniten.edu.my

ABSTRACT

Residential electricity consumption (REC) in Malaysia is increasing rapidly and poses a threat to energy security. Therefore, it is very important to understand the way REC responds to its determinants so that effective measures to contain its rapid growth can be undertaken. The current study aims to examine the responsiveness of REC towards real disposable income, price of electricity, price of electrical appliances population and foreign direct investment in Malaysia for 1978-2013 period. REC is only elastic towards real disposable income. The magnitude of own price elasticity is larger than cross elasticity of complements. The study shed some light on the responsiveness of REC, which can help Malaysia in developing new policies to control energy consumption without affecting economic growth adversely.

Keywords: Residential Electricity Consumption, Complements, Co-integration, Elasticities, Malaysia
JEL Classifications: C32, N7, Q41, Q48

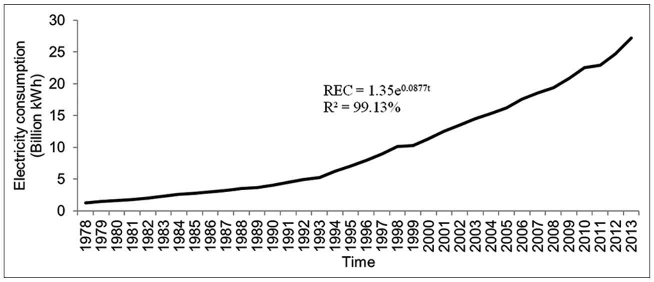
1. INTRODUCTION

In the quest to pursue economic development, the world is consuming more energy than it did ever before. This is especially evident in the world energy consumption, which had almost doubled within the past three decades (International Energy Agency, 2011; 2014). The reason behind the high energy consumption is the role of energy as an important catalyst in economic development. The energy consumption consists of mostly fossil fuels. Since fossil fuels are finite and are not renewable, it will be exhausted eventually. Although new fossil fuels reserves were discovered from time to time through continuous exploitation, it cannot be guaranteed that new reserves will continue to be found in the future.

Consequent to the high energy demand and depleting energy sources, there is growing concern on energy security. As a result, several countries are currently proposing strong energy substitution policies and radical energy conservation measures (Bloch et al., 2015). For example, Japan resorted to nuclear as a main source of energy while Germany advocates the use of renewable energies. Meanwhile, energy conservation practices are encouraged in almost every country. Generally, all these policies and measures are aimed at reducing the consumption of fossil fuels and secure an adequate energy supply in the future.

Malaysia is one of the fortunate countries in the world blessed with oil reserves. Nevertheless, this does not mean that Malaysia can consume energy like there is no tomorrow. Instead, these energy sources have to be managed and utilised in the most efficient manner possible. The Malaysian government is cognizant of the importance of using energy efficiently in order to delay the depletion of these resources and had implemented various energy policies since late 1970's. The first National Energy Policy was introduced in 1979. Subsequent to this policy, many energy policies and strategies were implemented (Bekhet and Ivy-Yap, 2014). However, the residential electricity consumption (REC) continued to grow exponentially despite the implementation of these energy policies and strategies (Figure 1). The growing EC warrants attention and effective, long-term energy policies are urgently needed (Chandran et al., 2010; Fei et al., 2011).

Figure 1: Residential electricity consumption growth in Malaysia for 1978-2013 period



Source: Malaysia Energy Commission (2015), Statistical database available at http://meih.st.gov.my.

Clear evidence on the main factors that influence EC and the quantifications of their impact are crucial in the contemplation of energy policy (Gam and Rejeb, 2012). Unfortunately, the findings of previous studies are not consistent. This may be due to omitted variable bias problem. Among the variables frequently included in these studies are income; electricity price and alternative fuels price i.e. gas, diesel, etc. In recent years, foreign direct investment (FDI) is included as an additional variable. Nevertheless, the role of complements is still missing in the literature. Since electricity cannot be consumed without electrical appliances, complements certainly play an important role and should be included in the consumption function of electricity (Ivy-Yap and Bekhet, 2014). Motivated by this argument, the goal of this study is to investigate the feedback response of REC towards changes in other macroeconomic variables in Malaysia by including price of electrical appliance to capture the role of complements.

The rest of the current paper is organized as follows: Section 2 presents a comprehensive overview of the economic and energy performances as well as the related policies in Malaysia. Section 3 gives the literature review. Section 4 explains the theoretical framework and model specification. Section 5 describes the data sources and methodologies. Section 6 reveals the empirical results and finally, Section 7 discusses the conclusions and policy implications.

2. MALAYSIA ECONOMIC AND ENERGY PERFORMANCES AND RELATED POLICIES

Malaysia economic activities are categorised into five sectors, namely services, manufacturing, mining, agriculture and construction. The contribution of each sector to gross domestic product (GDP) depends on the government policies. This is because the government usually prepares a lot of incentives and infrastructures for the sector that it is promoting. In the 1980's, the agriculture sector was one of the main contributor to GDP. However, the economic activities in this sector slowed down as Malaysia shift towards industrialization. The change in government policy sees a rapid growth in manufacturing activities. In the 1990's, the manufacturing sector overtook the agriculture sector in term of GDP contribution. Nevertheless, the services sector, which include utilities services; transport, storage and communication services; wholesale, accommodation and restaurant; finance and business services; etc. remains as the main GDP generating sector since the 1980's, contributing more than 40-50% of GDP (Indati and Bekhet, 2014).

Energy is an important element in economic growth. The advancement in technology has enabled less energy to be consumed. However, energy remains important to economic growth (Stern, 2011). In Malaysia, electricity is one of the main energy to drive economic development. Figure 2 shows the GDP and EC growth in Malaysia for the period spanning from 1978 to 2013. In 1978, the real GDP (RGDP) recorded RM103.37 billion and hit RM786.70 billion in 2013. This is equivalent to 5.91% growth per year. Within the same period, EC is increasing at 8.65% per year.

In Malaysia, different companies monopolise the electricity market in west and east regions. Tenaga Nasional Berhad (TNB) serves as the sole player in west Malaysia. The electricity market in east Malaysia is dominated by Sabah Electricity Sdn. Bhd. and Sarawak Energy Berhad. Electricity in Malaysia is generated mainly from fossil fuels. Although renewable energy in the form of large hydropower is not new to Malaysia, it only contributes 9.75% of the total installed capacity to date. Other renewable energy potentials such as bio-energy, solar, and mini hydro were only explored in the 21st century. In order to further safeguard energy security, energy conservation practices are promoted to reduce EC (Ivy-Yap and Bekhet, 2014; Oh et al., 2010).

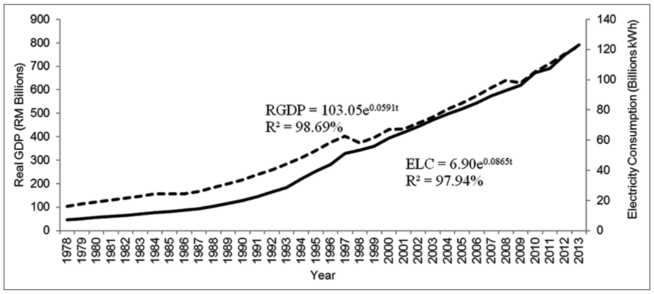
For the residential sector, electricity bill exemption is given to households that consume RM20 or less since October 2008 (TNB, 2013b). Unlike the common rebate, the exemption is only given if it is RM20 or below. If the electricity bill exceeds RM20, it has to be paid in full. This program is aimed to encourage the residential sector to use electricity prudently. Averagely, about one million households consume RM20 of electricity or less. On top of electricity bill exemption, rebate was given for the purchase of highly energy efficient appliances. The rebate was given via the Sustainability Achieved via Energy Efficiency Rebate Program (TNB, 2013c). The objective of the program was to promote the preference of energy efficient appliances among households. Refrigerator and air-conditioner were chosen as the targeted appliances due to their top rankings in terms of EC in Malaysian households (Saidur et al., 2007).

Besides giving incentives, the government imposed penalty on over-consumption. The electricity tariffs were revised on January 1, 2014 to increase the electricity tariffs rates by 10.6% for consumption exceeding 300 kWh (TNB, 2013a). On top of that, beginning April 1, 2015, the government charged a goods and services tax (GST) of 6.0% to the 301st unit of electricity and above (Ministry of Finance, 2013). The adjustment to the electricity tariffs rates and the implementation of GST are aimed to impose higher cost of electricity to households as their EC increases to prevent over-consumption of electricity.

3. LITERATURE REVIEW

Subsequent to the revolutionary work by Kraft and Kraft (1978), new focus was given to energy. Various methodologies were used

Figure 2: Real gross domestic product and electricity consumption in Malaysia



Source: (1) The World Bank (2015), Statistical database available at http://data.worldbank.org/country/malaysia, (2) Malaysia Energy Commission (2015), Statistical database available at http://meih.st.gov.my.

by researchers to investigate on this topic for various time period and geographical locations. These studies were basically interested to investigate the relationship between energy consumption and economic growth. Energy consumption is experiencing a significant shift towards electricity (Al-Faris, 2002; Amusa et al., 2009). This is resulting from the rising concern on the impacts of traditional fuels to the environment. Consequent to the energy transition, the literature is also more interested in electricity compared to other forms of energy. Many studies considered total EC. Nevertheless, due to the different EC patterns of each sector, researchers begin to study EC by sector. The residential sector is one of the most frequently studied sectors. Examples of empirical works focussing on the residential sector are the works of Adom et al., (2012); Atanasiu and Bertoldi (2010); Cebula (2012); Dergiades and Tsoulfidis (2008; 2011); Filippini and Pachauri (2004); Halicioglu (2007); Holtedahl and Joutz (2004); Nakajima (2010); Narayan et al., (2007); Ziramba (2008). There are a few reasons the residential sector is chosen. Firstly, it is an electricity intensive sector in most countries. Secondly, its consumption is expected to increase further. Thirdly, its determinants are amenable to theorization and quantification. Hence, this sector is important in energy policy formulation (Cebula, 2012; Dergiades and Tsoulfidis, 2008; 2011).

Earlier studies depended on bi-variate model in their investigations. However, bi-variate model is heavily criticized as it is prone to suffer from the omitted variable bias problem (Glasure, 2002; Lean and Smyth, 2010). This leads to the widespread use of multivariate model. The vector autoregressive (VAR) and vector error correction model (VECM) frameworks were widely used to investigate the relationship between energy consumption and the macroeconomic variables prior to the advancement in bound testing approach, initially introduced by Pesaran et al. (2001). The VAR is used if the variables are not co-integrated (Chen et al., 2007; Masih and Masih, 1996). Contrary, if there is co-integration relationship, the VECM is employed (Athukorala and Wilson, 2010; Bekhet and Othman, 2011a; 2011b; Bekhet and Yusop, 2009; Ho and Siu, 2007; Jamil and Ahmad, 2010; 2011; Narayan et al., 2007; Odhiambo, 2009). One of the biggest restrictions of VAR and VECM is both models do not allow a mixture of stationary and non-stationary variables. Realizing the restriction of the VAR and VECM, coupled with the advantages of autoregressive distributed lags (ARDL) framework, the ARDL is gaining popularity and is employed in many studies (Adom et al., 2012; Amusa et al., 2009; Chandran et al., 2010; Dergiades and Tsoulfidis, 2011; Halicioglu, 2007; Tang and Tan, 2013).

Among the most frequently included variables in examining EC are income, electricity price, alternative energy price, population, weather and urbanization. Recent studies suggested the inclusion of FDI (Bekhet and Othman, 2011b; Hamdi et al., 2014; Lau et al., 2014). This is because FDI is believed to promote technology advancement, which will enable more efficient equipments to be produced. Consequently, EC will reduce via the utilization of more efficient equipments. One of the aspects investigated in these studies was the elasticity of EC. This is an important criterion in policies formulation. Unfortunately, the findings in the literature are not consistent. Table 1 summarizes the findings on elasticity of energy/electricity towards various variables in the literature.

These diverse results arise due to the different data set, alternative econometric methodologies and different countries' characteristics (Asafu-Adjaye, 2000; Ozturk, 2010). For example, estimates of the elasticities using bi-variate model tend to be less reliable due to omitted variable bias problem.

4. THEORETICAL FRAMEWORK AND MODEL SPECIFICATION

Theories play a prominent role in any empirical study as the backbone to the model specification. They serve as the basis in model building and justify the rational for the model to be specified in a specific manner. The current study is built on two main economic theories, namely production theory and demand theory. The Cobb-Douglas production gives quantity of output as a function of capital and labour at a particular technology. Applying the Cobb-Douglas production function on the residential sector to examine its EC, the quantity of electricity consumed (*REC*) is specified as a function of the stock of the electrical appliances (*K*) and population (*Po*) at a particular state of electrical appliances technology (*T*), given as in Equation 1.

$$REC_t = T_t K_t^{\pi_1} Po_t^{\pi_2} \qquad (1)$$

Where π_1 and π_2 are partial coefficients. However, the state of electrical appliances technology is advancing with the level of FDI (Hamdi et al., 2014). Since FDI usually utilizes advance technologies, it helps in overall technological advancement and diffusion. This enables obsolete and dirty technologies to be replaced with new and cleaner technologies via more active and rigorous research and development activities (Lau et al., 2014). Through these technology innovations, more energy saving products could be produced (Tang and Tan, 2013). Hence, Equation 1 is re-written as in Equation 2.

$$REC_t = a_1 FDI_t^{\varphi_1} K_t^{\pi_1} Po_t^{\pi_2} \qquad (2)$$

Where a_1 is a constant. In the meantime, the stock of electrical appliances (*K*) measures the total electrical appliances operating

Table 1: Summary of literature review

Author (s)	Time period	Country	Method (s)	Findings				
				GDP	Price of electricity	Price of other energies	Population	FDI
Adom (2013)	1971-2008	Ghana	FMOLS	Positive, elastic	NA	NA	NA	NA
Amarawickrama and Hunt (2008)	1970-2003	Sri Lanka	Static EG, Dynamic EG FMOLS, PSS Johansen	Positive, elastic	Negative, inelastic	NA	NA	NA
Araghi and Barkhordari (2012)	1974-2008	Iran	Johansen	Positive, inelastic	Negative, inelastic	NA	NA	NA
Arisoy and Ozturk (2014)	1960-2008	Turkey	Time varying parameters	Positive, inelastic	Negative, inelastic	NA	NA	NA
Athukorala and Wilson (2010)	1960-2007	Sri Lanka	Johansen	Positive, inelastic	Negative, inelastic	Positive, inelastic	NA	NA
Bekhet and Othman (2011a)	1980-2009	Malaysia	EG	Positive, inelastic	Negative, inelastic	Negative, inelastic	Positive, elastic (Urban)	NA
Bekhet and Othman (2011b)	1971-2009	Malaysia	EG	Positive, elastic	Negative, inelastic	NA	NA	Negative, elastic
Casarin and Delfino (2011)	1997-2006	Greater Buenos Aires	Johansen	Positive, elastic	Negative, inelastic	NA	NA	NA
Dergiades and Tsoulfidis (2011)	1964-2006	Greece	Johansen	Positive, inelastic	Negative, inelastic	Positive, inelastic	NA	NA
Fei et al. (2011)	1985-2007	China	Panel co-integration	Positive, inelastic	NA	NA	NA	NA
Fell et al. (2014)	2006-2008 (monthly)	US	GMM	Positive inelastic	Negative and inelastic	NA	NA	NA
He et al. (2014)	2012	China	Computable general equilibrium	NA	Negative and inelastic	Positive, inelastic	NA	NA
Hung and Huang (2015)	2007-2013 (monthly)	Taiwan	Fixed effect Pooled mean group	Positive, inelastic	Negative, elastic	NA	NA	NA
Islam et al., (2013)	1971-2009	Malaysia	ARDL bounds test	Positive, inelastic	NA	NA	Positive, inelastic	NA
Jamil and Ahmad (2011)	1961-2008	Pakistan	Johansen	Positive, elastic	Negative, elastic	NA	NA	NA
Krishnamurthy and Kriström (2015)	2011 (survey)	OECD	Double log	Positive, inelastic	Negative, inelastic	NA	NA	NA
Nakajima (2010)	1975-2005	Japan	Panel co-integration	Positive, inelastic	Negative, elastic	NA	NA	NA
Okajima and Okajima (2013)	1990-2007	Japan	GMM	NA	Negative, inelastic	NA	NA	NA
Pourazarm and Cooray (2013)	1967-2009	Iran	ARDL bounds test	Positive, inelastic	Negative, inelastic	Negative, inelastic	NA	NA
Romero-Jordán et al., (2014)	1998-2009	Spain	Dynamic partial adjustment	Positive, inelastic	Negative, inelastic	NA	NA	NA
Tang (2009)	1970-2005	Malaysia	ARDL bounds test	Positive, inelastic	NA	NA	Positive, elastic	Positive, inelastic
Tang and Tan (2013)	1970-2009	Malaysia	ARDL bounds test	Positive, elastic	Negative, elastic	NA	NA	NA
Zachariadis and Pashourtidou (2007)	1960-2004	Cyprus	Johansen	Positive, elastic	Negative, inelastic	NA	NA	NA

ARDL: Autoregressive distributed lags, FMOLS: Fully modified ordinary least squares, EG: Engle and Granger, PSS: Pesaran, Shin and Smith, GMM: Generalized method of moments, GDP: Gross domestic product, FDI: Foreign direct investment

within the residential sector, which consists of new purchases and replacement of old electrical appliances. Based on the demand theory, consumers cannot purchase infinite quantity of electrical appliances because they are bounded by the income constraint. Hence, consumers can only afford certain quantity of electrical appliances at any particular price. The quantity of electrical appliances is also affected by the price of related goods such as electricity. Therefore, the stock of electrical appliance (K) is determined by the price of electrical appliances (Pa), real disposable income (Y) and price of electricity (Pe) as shown in Equation 3.

$$K_t = a_2 Pa_t^{\varphi_2} Y_t^{\varphi_3} Pe_t^{\varphi_4} \tag{3}$$

Where, a_2 is a constant. Substituting Equation 3 into Equation 2 and rearranging it results in Equation 4. Basically, Equation 4 gives REC as a function of real disposable income, price of electricity, price of electrical appliances, population and FDI.

$$REC_t = AY_t^{\phi_1} Pe_t^{\phi_2} Pa_t^{\phi_3} Po_t^{\phi_4} FDI_t^{\phi_5} \quad (4)$$

Where A is a constant. Since Equation 4 is a non-linear equation, logarithm (l) transformation is applied on both sides of the equation. Besides transforming a non-linear equation into a linear equation, logarithm transformation also linearizes the exponential trend in time series data, which obscure the real relationship among the variables. On top of that, it allows the regression coefficients to be interpreted as elasticities. Due to these reasons, logarithm transformation is very popular in econometric (Asteriou and Hall, 2007). The logarithm transformation of Equation 4 is given in Equation 5.

$$lrec_t = \alpha + \theta_1 ly_t + \theta_2 lpe_t + \theta_3 lpa_t + \theta_4 lpo_t + \theta_5 lfdi_t + \mu_t \quad (5)$$

Where $\alpha = lA$ and μ_t is the error terms with zero mean and constant variance, $\mu_t \sim N(0, \sigma^2)$. Equation 5 represents the long-run relationship between REC with its determinants, which are also the elasticities of REC. The elasticities are derived from the normalised co-integrating equation (Section 5).

5. DATA SOURCES AND ECONOMETRIC TECHNIQUES

5.1. Data

The data are collected for the 1978-2013 period at constant price (2005=100). RGDP; price index for gross rent, fuel and power; and price index for furniture, furnishings and household equipments and operation are used as a proxy real disposable income; price of electricity and price of electrical appliances respectively (Amusa et al., 2009; Asafu-Adjaye, 2000; Athukorala and Wilson, 2010; Bekhet and Othman, 2011a; Chandran et al., 2010). The data on FDI is given as percentage of GDP and is converted into real FDI by multiplying it with RGDP. The data are collected from different sources, namely Malaysia Energy Commission (ST), World Development Indicators (WDI) and Department of Statistic Malaysia (DOSM). Specifically, ST provides the data on REC; WDI provides the data on RGDP and DOSM provides the data on price indices and population. All the computational works in the current study are executed using Eviews version 7.1 and Microfit version 4.1.

5.2. Methodology

Firstly, the data quality techniques are executed to check the data distribution of each variable. Secondly, the augmented Dickey-Fuller (ADF) (Dickey and Fuller, 1979) and Phillips–Perron (PP) (Phillips and Perron, 1988) are employed to test the stationarity of the variables. The hypothesis statements for both tests are the same. The null hypothesis (H_0) of unit root is tested against the alternative hypothesis (H_1) of stationary. Therefore, ADF and PP require the series to be differenced until H_0 is rejected.

After the order of integration of each variable is identified, the ARDL bounds testing approach is employed to verify the existence of co-integration. The optimal lag order has to be determined in order to obtain more reliable results since this approach is sensitive towards the lag order of the variables. There are several information criterions for lag order selection. Nevertheless, the Akaike information criterion is often preferred in small sample (Sbia et al., 2014). The ARDL bounds testing approach has many advantages (Bekhet and Matar, 2013; Bekhet and Al-Smadi, 2014; Bekhet and Yasmin, 2013). Firstly, this method allows the mixture of $I(0)$ and $I(1)$ variables. Secondly, it performs better in small samples ($30 \le t \le 80$). Thirdly, it allows the variables to have different optimal lags. Fourthly, it is gaining popularity in recent years. Equations 6-11 are estimated to infer the presence of co-integration.

$$\Delta lrec_t = \alpha_1 + \beta_{11} lrec_{t-1} + \beta_{12} ly_{t-1} + \beta_{13} lpe_{t-1} + \beta_{14} lpa_{t-1} + \beta_{15} lpo_{t-1} + \beta_{16} lfdi_{t-1} + \sum_{i=1}^{j_1} \delta_{(11)i} \Delta lrec_{t-i} + \sum_{i=0}^{k_1} \delta_{(12)i} \Delta ly_{t-i} + \sum_{i=0}^{l_1} \delta_{(13)i} \Delta lpe_{t-i} + \sum_{i=0}^{m_1} \delta_{(14)i} \Delta lpa_{t-i} + \sum_{i=0}^{n_1} \delta_{(15)i} \Delta lpo_{t-i} + \sum_{i=0}^{o_1} \delta_{(16)i} \Delta lfdi_{t-i} + \mu_{1t} \quad (6)$$

$$\Delta ly_t = \alpha_2 + \beta_{21} lrec_{t-1} + \beta_{22} ly_{t-1} + \beta_{23} lpe_{t-1} + \beta_{24} lpa_{t-1} + \beta_{25} lpo_{t-1} + \beta_{26} lfdi_{t-1} + \sum_{i=0}^{j_2} \delta_{(21)i} \Delta lrec_{t-i} + \sum_{i=1}^{k_2} \delta_{(22)i} \Delta ly_{t-i} + \sum_{i=0}^{l_2} \delta_{(23)i} \Delta lpe_{t-i} + \sum_{i=0}^{m_2} \delta_{(24)i} \Delta lpa_{t-i} + \sum_{i=0}^{n_2} \delta_{(25)i} \Delta lpo_{t-i} + \sum_{i=0}^{o_2} \delta_{(26)i} \Delta lfdi_{t-i} + \mu_{2t} \quad (7)$$

$$\Delta lpe_t = \alpha_3 + \beta_{31} lrec_{t-1} + \beta_{32} ly_{t-1} + \beta_{33} lpe_{t-1} + \beta_{34} lpa_{t-1} + \beta_{35} lpo_{t-1} + \beta_{36} lfdi_{t-1} + \sum_{i=0}^{j_3} \delta_{(31)i} \Delta lrec_{t-i} + \sum_{i=0}^{k_3} \delta_{(32)i} \Delta ly_{t-i} + \sum_{i=1}^{l_3} \delta_{(33)i} \Delta lpe_{t-i} + \sum_{i=0}^{m_3} \delta_{(34)i} \Delta lpa_{t-i} + \sum_{i=0}^{n_3} \delta_{(35)i} \Delta lpo_{t-i} + \sum_{i=0}^{o_3} \delta_{(36)i} \Delta lfdi_{t-i} + \mu_{3t} \quad (8)$$

$$\Delta lpa_t = \alpha_4 + \beta_{41} lrec_{t-1} + \beta_{42} ly_{t-1} + \beta_{43} lpe_{t-1} + \beta_{44} lpa_{t-1} + \beta_{45} lpo_{t-1} + \beta_{46} lfdi_{t-1} + \sum_{i=0}^{j_4} \delta_{(41)i} \Delta lrec_{t-i} + \sum_{i=0}^{k_4} \delta_{(42)i} \Delta ly_{t-i} + \sum_{i=0}^{l_4} \delta_{(43)i} \Delta lpe_{t-i} + \sum_{i=1}^{m_4} \delta_{(44)i} \Delta lpa_{t-i} + \sum_{i=0}^{n_4} \delta_{(45)i} \Delta lpo_{t-i} + \sum_{i=0}^{o_4} \delta_{(46)i} \Delta lfdi_{t-i} + \mu_{4t} \quad (9)$$

$$\Delta lpo_t = \alpha_5 + \beta_{51} lrec_{t-1} + \beta_{52} ly_{t-1} + \beta_{53} lpe_{t-1} + \beta_{54} lpa_{t-1} + \beta_{55} lpo_{t-1} + \beta_{56} lfdi_{t-1} + \sum_{i=0}^{j_5} \delta_{(51)i} \Delta lrec_{t-i} + \sum_{i=0}^{k_5} \delta_{(52)i} \Delta ly_{t-i} + \sum_{i=0}^{l_5} \delta_{(53)i} \Delta lpe_{t-i} + \sum_{i=0}^{m_5} \delta_{(54)i} \Delta lpa_{t-i} + \sum_{i=1}^{n_5} \delta_{(55)i} \Delta lpo_{t-i} + \sum_{i=0}^{o_5} \delta_{(56)i} \Delta lfdi_{t-i} + \mu_{5t} \quad (10)$$

$$\Delta lfdi_t = \alpha_6 + \beta_{61} lrec_{t-1} + \beta_{62} ly_{t-1} + \beta_{63} lpe_{t-1} + \beta_{64} lpa_{t-1} + \beta_{65} lpo_{t-1} + \beta_{66} lfdi_{t-1} + \sum_{i=0}^{j_6} \delta_{(61)i} \Delta lrec_{t-i} + \sum_{i=0}^{k_6} \delta_{(62)i} \Delta ly_{t-i} + \sum_{i=0}^{l_6} \delta_{(63)i} \Delta lpe_{t-i} + \sum_{i=0}^{m_6} \delta_{(64)i} \Delta lpa_{t-i} + \sum_{i=0}^{n_6} \delta_{(65)i} \Delta lpo_{t-i} + \sum_{i=1}^{o_6} \delta_{(66)i} \Delta lfdi_{t-i} + \mu_{6t} \quad (11)$$

Where Δ is the first difference operator, αs are constants, *βs* and *δs* are the long and short-run parameters respectively and μ_ts are the error terms with zero mean and constant variance, $\mu_t \sim N(0, \sigma^2)$. *j, k, l, m, n* and *o* are the optimal lag orders. The level lagged explanatory variables (lec_{t-1}, ly_{t-1}, lpe_{t-1}, lpa_{t-1}, lpo_{t-1}, $lfdi_{t-1}$) are restricted to test for co-integration relationship. The null hypothesis of no co-integration relationship among the variables, H_0: $\beta_{i1} = \beta_{i2} = \beta_{i3} = \beta_{i4} = \beta_{i5} = \beta_{i6} = 0$ is tested against the alternative hypothesis of co-integration, H_a: $\beta_{i1} \neq \beta_{i2} \neq \beta_{i3} \neq \beta_{i4} \neq \beta_{i5} \neq \beta_{i6} \neq 0$. Since the computed *F*-statistic has non-standard distribution, it cannot be compared to the standard *F*-statistic critical values. The upper and lower bound critical values, *I*(1) and *I*(0), for large sample size (>500) were computed by Pesaran et al. (2001). In order to cater for small samples, Narayan (2005) computed new critical values that are suitable for small samples (30-80 observations).

Co-integration relationship is confirmed if the *F*-statistic exceeds *I*(1) critical value. In contrast, the variables are not co-integrated if the *F*-statistic is less than *I*(0) critical value. If the *F*-statistic exceeds *I*(0) but is less than *I*(1), neither the presence nor the absence of co-integration relationship can be confirmed. Conclusion is made by testing the stationarity of the residuals. If the residuals are stationary, the variables are co-integrated and vice versa.

The existence of co-integration is very important in analysis involving non-stationary variables. This is because the model is spurious if the variables are not co-integrated. Co-integration implies that there is long-run relationship among the variables. Comparing the long-run relationships given in Equation 5 and Equation 6, the long-run relationship between REC and its determinants can be written as in Equation 12.

$$lrec_t = \frac{-\alpha_1}{\beta_{11}} + \frac{-\beta_{12}}{\beta_{11}} ly_t + \frac{-\beta_{13}}{\beta_{11}} lpe_t + \frac{-\beta_{14}}{\beta_{11}} lpa_t + \frac{-\beta_{15}}{\beta_{11}} lpo_t + \frac{-\beta_{16}}{\beta_{11}} lfdi_t \quad (12)$$

Equation 12 shows that the long-run relationship is derived from the normalised co-integrating equation. Since all the variables are transformed into natural logarithm, the long-run relationships are also the elasticities of REC towards its determinants (Asteriou and Hall, 2007). The sign of the long-run relationship represent the type of elasticity, i.e. positive or negative. Meanwhile, the absolute value indicates the strength of elasticity, which is summarized in Table 2.

Elasticity measures the responsiveness of a variable towards changes in another variable, ceteris paribus. When the elasticity calculates as a fraction i.e. less than one in absolute value, it lacks of responsiveness whereby the marginal rate of change in REC is less than the marginal rate of change in the determinants. Hence, it is described as inelastic. When elasticity is unitary elastic, the marginal rate of change in the determinants is matched by an equal marginal rate of change in REC. On the other hand, when elasticity is more than one in absolute value, the marginal rate of change in the determinants is exceeded by the marginal rate of change in REC. The theoretical extreme of perfect elasticity is when REC is insensitive to changes in its determinants. The opposite, i.e. the determinants are insensitive to the changes in REC results in perfect inelasticity (McGuigan et al., 2008).

The information on elasticity is very important in policy formulation to reduce REC effectively. The variables that REC is elastic to are often the variables that should be controlled via policies. This is because the marginal rate of change in these variables is exceeded by the marginal rate of change in REC. For example, if REC is more elastic to price of electricity than price of electrical appliances, policies that control price of electricity will be more effective in reducing REC than policies that control price of electrical appliances.

6. RESULT ANALYSIS

Table 3 presents the descriptive statistics of the variables. In general, there is no missing data or outliers and the standard deviation ranges from 0.179 to 1.018. The distribution statistics (skewness, kurtosis and Jarque-Bera) indicate normality in all variables, except for lfdi. The high pair-wise correlations among the variables are expected because most macroeconomic variables contains unit root.

Table 2: Elasticity interpretation

Absolute value	Interpretation
$\left|\frac{-\alpha_1}{\beta_{11}}, \frac{-\beta_{12}}{\beta_{11}}, \frac{-\beta_{13}}{\beta_{11}}, \frac{-\beta_{14}}{\beta_{11}}, \frac{-\beta_{15}}{\beta_{11}}, \frac{-\beta_{16}}{\beta_{11}}\right| < 1$	Inelastic
$\left|\frac{-\alpha_1}{\beta_{11}}, \frac{-\beta_{12}}{\beta_{11}}, \frac{-\beta_{13}}{\beta_{11}}, \frac{-\beta_{14}}{\beta_{11}}, \frac{-\beta_{15}}{\beta_{11}}, \frac{-\beta_{16}}{\beta_{11}}\right| = 1$	Unitary elastic
$\left|\frac{-\alpha_1}{\beta_{11}}, \frac{-\beta_{12}}{\beta_{11}}, \frac{-\beta_{13}}{\beta_{11}}, \frac{-\beta_{14}}{\beta_{11}}, \frac{-\beta_{15}}{\beta_{11}}, \frac{-\beta_{16}}{\beta_{11}}\right| > 1$	Elastic
$\left|\frac{-\alpha_1}{\beta_{11}}, \frac{-\beta_{12}}{\beta_{11}}, \frac{-\beta_{13}}{\beta_{11}}, \frac{-\beta_{14}}{\beta_{11}}, \frac{-\beta_{15}}{\beta_{11}}, \frac{-\beta_{16}}{\beta_{11}}\right| = 0$	Perfectly inelastic
$\left|\frac{-\alpha_1}{\beta_{11}}, \frac{-\beta_{12}}{\beta_{11}}, \frac{-\beta_{13}}{\beta_{11}}, \frac{-\beta_{14}}{\beta_{11}}, \frac{-\beta_{15}}{\beta_{11}}, \frac{-\beta_{16}}{\beta_{11}}\right| = \infty$	Perfectly elastic

Table 3: Descriptive statistics and correlation matrix

Statistics	*lrec*	*ly*	*lpe*	*lpa*	*lpo*	*lfdi*
Mean	1.924	5.728	4.402	4.479	3.023	2.291
Median	2.016	5.877	4.434	4.533	3.042	2.687
Maximum	3.304	6.668	4.724	4.746	3.399	3.616
Minimum	0.246	4.638	3.802	4.074	2.580	−1.030
Standard deviation	0.928	0.627	0.243	0.179	0.255	1.018
Skewness	−0.180	−0.181	−0.723	−0.526	−0.172	−1.102
Kurtosis	1.721	1.683	2.807	2.343	1.753	4.144
Jarque-Bera	2.648	2.800	3.196	2.307	2.510	9.246
P	0.266	0.247	0.202	0.315	0.285	0.010
lrec	1.000					
ly	0.996	1.000				
lpe	0.972	0.961	1.000			
lpa	0.981	0.983	0.981	1.000		
lpo	0.999	0.996	0.969	0.981	1.000	
lfdi	0.494	0.533	0.467	0.532	0.499	1.000

Source: Output of the Eviews software version 7.1.

The unit root tests results are given in Table 4. The series is not stationary if the test statistic is smaller than the critical value. On the other hand, if the test statistic is larger than the critical value, the null hypothesis is rejected and the series is stationary. Both ADF and P-P reject the null hypotheses for the level of price of electricity and the first differences of *lrec*, *ly* and *lpa*. Meanwhile, ADF fails to reject the null hypotheses for the level and first differences of *lpo* and *lfdi* but P-P rejects the null hypotheses for the level of both variables. Hence, it is concluded that *lrec*, *ly* and *lpa* are $I(1)$ variables while *lpe*, *lpo* and *lfdi* are $I(0)$ variables. These results are consistent with the findings of past studies whereby most of the macroeconomic variables were found to be not stationary at level but stationary after first differencing (Bekhet and Matar, 2013; Bekhet and Al-Smadi, 2015; Caraiani et al., 2015; Lau et al., 2014).

Since the unit root tests show that there are $I(0)$ and $I(1)$ variables, the existence of long-run relationship among these variables is tested via the ARDL bounds testing approach. The co-integration results are tabulated in Table 5. The F-statistics for $F_{\text{lec}}(lrec|ly,lpe,lpa,lpo,lfdi)$, $F_{\text{ly}}(ly|lrec,lpe,lpa,lpo,lfdi)$, $F_{\text{lpe}}(lpe|lrec,ly,lpa,lpo,lfdi)$, $F_{\text{lpa}}(lpa|lrec,ly,lpe,lpo,lfdi)$,

Table 4: Unit root tests on each variable

Variable	ADF		PP		Conclusion
	I (0)	*I* (1)	*I* (0)	*I* (1)	
lrec	−2.806[c]	−5.142[a]	−2.786[c]	−5.160[a]	*I* (1)
ly	−1.383	−4.782[a]	−1.314	−4.787[a]	*I* (1)
lpe	−4.026[a]	NA	−3.331[b]	NA	*I* (0)
lpa	−1.609	−3.556[b]	−2.747[c]	−2.997[b]	*I* (1)
lpo	−1.990	0.982	−4.780[a]	NA	*I* (0)
lfdi	−1.617	−2.453	−4.033[a]	NA	*I* (0)

[a,b,c]statistical significance at 1%, 5% and 10% level respectively. Source: Output of the Eviews software version 7.1. ADF: Augmented Dickey-Fuller, PP: Phillips-Perron

$F_{\text{lpo}}(lpo|lrec,ly,lpe,lpa,lfdi)$ and $F_{\text{lfdi}}(lfdi|lrec,ly,lpe,lpa,lpo)$ are larger than the upper bound critical value, which show that the variables are co-integrated.

Furthermore, the cumulative sum (CUSUM) and CUSUM of squares are performed to ensure model parameters stability (Figure 3). Since both curves fluctuate within the 5% critical boundaries, model parameters are stable over the sample period.

Since there is evidence of co-integration, the variables share a genuine long-run relationship. The long-run relationship is derived from the normalised co-integration equation (Equation 12). The coefficients of the long-run relationships are the elasticities, since all the variables are transformed into natural logarithm. The sign of these coefficients indicates the direction of the long-run relationship while the magnitude shows the type of elasticity that existed (Table 2). The results on the elasticities of REC towards its determinants are summarized in Table 6.

REC is elastic towards real disposable income, consistent with the findings of Bekhet and Othman (2011b) and Tang and Tan (2013). However, REC is inelastic towards other determinants. The own price and cross price elasticities of REC is −0.942 and −0.028 respectively, which shows that REC is more responsive towards price of electricity than price of electrical appliances. The elasticitites of REC towards its determinants are illustrated in Figure 4.

REC responded positively towards real disposable income and population but negatively towards prices and FDI. The directions of the long-run relationship are in line with the theory. The long run elasticity of REC towards FDI is negative, which implies that FDI in Malaysia is energy efficient (Sbia et al., 2014).

7. CONCLUSIONS AND POLICY IMPLICATIONS

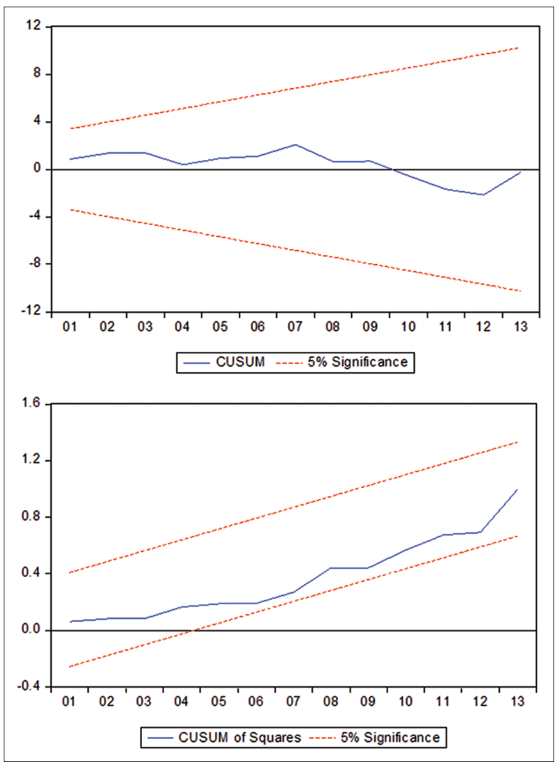
The current paper shed some light on the macroeconomic variables that affected REC. Contrary to existing studies, the current paper considers price of electrical appliances in the consumption function of residential electricity. Focussing on the residential sector enables the special characteristics of this sector to prevail, making the model more accurate model. The co-integration results show that all the variables are co-integrated, proving the existence of a genuine relationship among them in the long-run. This also shows that real disposable income, price of electricity, price of electrical

Table 5: ARDL co-integration test

Model	*F*-statistic	Critical values						Decision
		1%		5%		10%		
		I (0)	*I* (1)	*I* (0)	*I* (1)	*I* (0)	*I* (1)	
lrec|*ly, lpe, lpa, lpo, lfdi*	4.875[b]	4.257	6.040	3.037	4.443	2.508	3.763	Co-integrated
ly|*lrec, lpe, lpa, lpo, lfdi*	74.844[a]	4.257	6.040	3.037	4.443	2.508	3.763	Co-integrated
lpe|*lrec, ly, lpa, lpo, lfdi*	9.917[a]	4.257	6.040	3.037	4.443	2.508	3.763	Co-integrated
lpa|*lrec, ly, lpe, lpo, lfdi*	5.147[b]	4.257	6.040	3.037	4.443	2.508	3.763	Co-integrated
lpo|*lrec, ly, lpe, lpa, lfdi*	8.794[a]	4.257	6.040	3.037	4.443	2.508	3.763	Co-integrated
lfdi|*lrec, ly, lpe, lpa, lpo*	18.492[a]	4.257	6.040	3.037	4.443	2.508	3.763	Co-integrated
Diagnostic tests								
R^2	0.835			χ^2_{normal}		0.585		
Adj-R^2	0.605			χ^2_{serial}		0.925		
F-statistic	3.643[b]			χ^2_{arch}		2.339		
Framsey				F_{ramsey}		0.423		

[a,b,c]statistical significance at 1%, 5% and 10% level respectively. Critical values for unrestricted intercept and no trend (*k*=5, *T*=35) computed by Narayan (2005). Source: Output of the Eviews software version 7.1. ARDL: Autoregressive distributed lags

Figure 3: Cumulative sum (CUSUM) and CUSUM of squares statistics plots



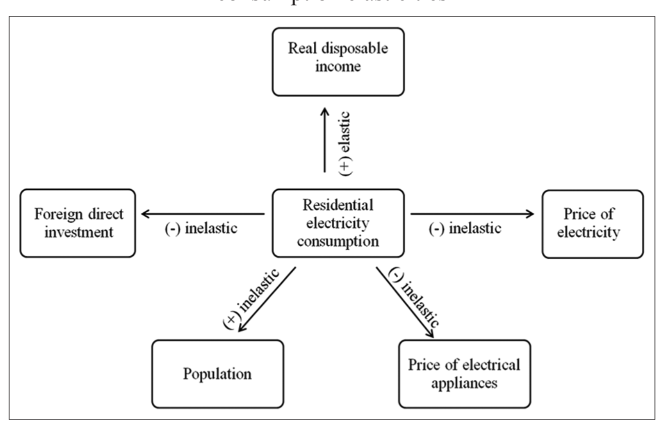
Source: Output of the Eviews software version 7.1

Table 6: Elasticities of residential electricity consumption towards its determinants

Determinant	Elasticity	*t*-statistic	Conclusion
Real disposable income	1.417	4.003[a]	Positive and elastic
Price of electricity	−0.942	−1.783[c]	Negative and inelastic
Price of electrical appliance	−0.028	−0.066	Negative and inelastic
Population	0.623	0.713	Positive and inelastic
Foreign direct investment	−0.009	−0.732	Negative and inelastic

[a,b,c]Statistical significance at 1%, 5% and 10% level respectively. Source: Output of the Microfit software version 4.1

Figure 4: Direction and magnitude of residential electricity consumption elasticities



appliances, population and FDI are important determinants of REC. Therefore, policies on these variables will affect REC.

The results show that policies on both prices included in the model (price of electricity and price of electrical appliances) affect REC. Nevertheless, since REC is more responsive towards own price rather than price of electrical appliances, controlling the price of electricity gives more impact to EC compared to controlling the price of electrical appliances. This is because the marginal rate of change in price of electricity will result in a higher marginal rate of change in REC. Hence, the electricity tariffs revision beginning January 1, 2014 and the GST of 6% beginning April 1, 2015 are plausible moves in promoting energy efficiency and conservation.

It is also worthwhile to note that the long run elasticity of REC towards FDI is negative, which indicate that FDI could reduce EC via technology innovation and the utilization of more advanced technology. However, the magnitude of the long run elasticity of REC towards FDI is very small. This shows that there are still a lot of untapped potentials of FDI to reduce REC. Hence, the government should be more stringent in allowing the type of FDI that enters the country to ensure that only highly energy efficient technologies enter the country.

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