Analysis of Residential Electricity Consumption: Is Reform Needed?

Ahmad Rafdi Endut
Institute of Energy Policy Research (IEPRE)
Universiti Tenaga Nasional

Idris Jajri
Faculty of Economics and Administration
University Malaya

ABSTRACT

The aim of this research is to examine the relationship between Malaysia's residential and industrial electricity consumption function and its determinant in a multivariate framework. Economic theories suggested that as the economic grows resulting from the consumption of electrical appliances, the demand for electricity would keep on expanding. The study uses quarterly time series data for the period of 1985 to 2006 and employs bound testing approach together with newly developed ECM-based F-test in examining the potential long run relation and autoregressive distributed lag (ARDL) model to estimate long run and short run elasticity, as well as applying a standard Granger causality test in determining the causality direction between the residential and its determinants. The result for residential electricity consumption function indicates that it is not co-integrated in the long run with its determinants. The income elasticity assures that the residential sector demands are near unitary in the long run and highly significant. However, new evidence proposes that there is no causality running from the residential consumption and economic growth, but the consumption runs bi-directionally with temperature in the short run. This finding provides new evidence on the electricity consumption function in Malaysia, and could lead to a better understanding for the policy makers to formulate a remedial demand policy to support sustainable development in Malaysia

Introduction

There are around 27 million people living in Malaysia and a total of 80 per cent live in the Peninsular Malaysia, which is also considered as the hub of the Malaysians' economy. Apart from that, similar to other developing countries around the world, energy has become the prime contributor to the rapid growth of the Malaysian economy. With a rapid growth of 5.8 per cent in 2006, the rural-urban migration coupled with the higher standard of living and increased per capita income have spurred an ever-increasing demand for energy especially electricity. Therefore, the overall demand for energy is expected to increase by an average rate of 6.3 per cent annually between 2005 and 2010 (RMK-9, 2006).

The increasing of energy consumed raised numerous concerns by the government of Malaysia. In order to overcome the phenomena, the government had come up with the idea of promoting the end-use energy efficiency, which equals to decrease the use of energy while maintaining the same level of service. This can be achieved by increasing the production rate per unit of energy consumed or improving energy efficiency. However, the task of promoting the energy efficiency is not sufficed due to the fact that Malaysian depended highly on the energy in production of goods and services (MEWC, 2005). Over dependency on one resource to produce energy need to be overcome by policies to ensure resources can be used at the most optimum and efficient manner, which would cause minimal negative effect on the environment. Hence, the government needs to analyze the relationship between the energy consumed within the country to come out with a better policy with regards to the energy.

The electricity consumption in Malaysia is becoming of an interest nowadays given the fact that the Malaysia's electricity consumption per capita is the second highest among the five ASEAN founding nation as shown in Table 1. As electricity consumption per capita grows rapidly since 1971, one may deduce that this may be one of the important factors that lead to a growth of a nation. Although many studies have been done to look at this issue, most of them are produced in developed countries. Study on electricity consumption in Malaysia, yet, is relatively few, and limited to Yoo (2006) and Chen et al. (2007) with recent contribution by Tang (2008a; 2008b) and Chandran et al. (2009). However, these studies are only limited to analyzing the relationship between two variables - except for Tang (2009) which has developed a multivariate approach on electricity consumption framework - namely electricity consumptions and economic growth in short- and long-term. The analysis, nevertheless, ignores other important variables that determine the electricity demand function, which is considered as the main component in consuming electricity in Malaysia. Besides that, the studies are limited to analyzing the aggregate consumption function instead of disaggregated data of other sectors in the economy namely, residential, industrial and commercial.

Table 1: Electricity per Capita Consumption in ASEAN (kWh per capita)

Country	1980	1990	2000	2006
Malaysia	670.25	1,178.07	2,742.89	3,387.60
Singapore	2,718.31	4,859.86	7,575.41	8,520.02
Indonesia	44.37	161.37	400.36	529.72
Thailand	291.26	708.13	1,462.14	1,984.33
Philippines	367.96	352.73	501.29	572.28

Source: World Development Indicator,2010

Many economic analysts ignored the fact that the residential sector do contributes significantly to the development of economic growth in terms of electricity consumption. By coming to term that other factors might as well contributed to the determination of electricity consumption on disaggregate level and not only economic growth has led to the launching of this research. Most of the analyses being done especially in Malaysia are limited to predicting the level of consumption in electricity which is solely being determined by the level of economic growth (Tang, 2008a, 2008b; Chandran, 2009). Based on our knowledge, short-run and long run relationship for different sectors in the economy as well causality for this variables are never being established by many analyst in the field of energy economics in Malaysia.

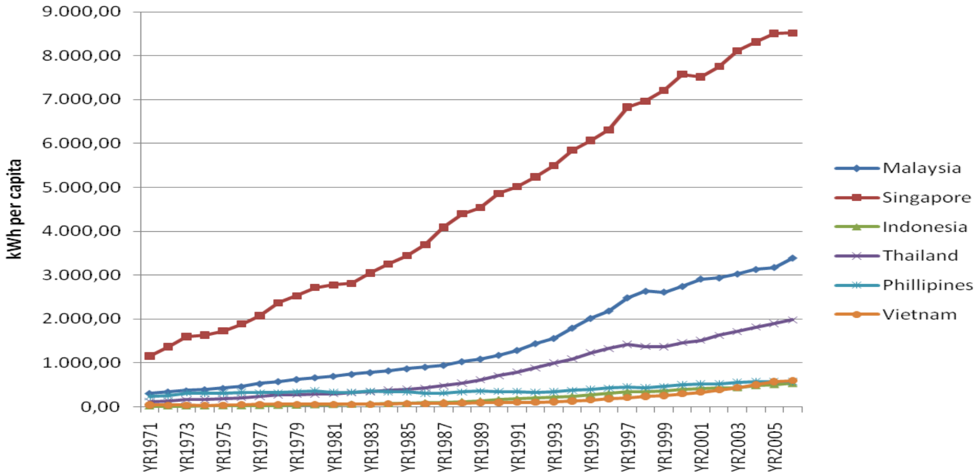
Information on the residential electricity demand with respect to the level of its determinants and economic growth is important in analyzing the effect of electricity usage and its demand management policies. However, there have only been a small number of researches being conducted in this area in Malaysia. In this sense, the quantitative analysis of the electricity demand policies is rather limited or non-existence in the cases of Malaysia. Therefore, the aim of this paper will be to empirically examine the elasticity between residential electricity consumption to the economic growth of Malaysian economics as well as its other related determinants and to establish short-run and long-run causal relationship between residential consumption with its determinants as well as the causal relationship with economic growth.

Electricity consumption in Malaysia

The past decade witnessed the industrialization development occurs in Association of South East Asia Nations (ASEAN) such as Malaysia. The industrialization as well as the increase in the number of population either from crude rate or immigrants, contributes to the increasing demand for electricity (Tang, 2009a). The electricity consumptions for ASEAN countries are moving on upward trend in between 1980 and 2004. This can be seen in Figure1 below.

Within the ASEAN members, Malaysia is the second largest electricity consumption economy (Tang, 2009a; Tang, 2008b; Chandran et al., 2009) with the growth of the electricity consumption is recorded at 13 percent and way above the gross domestic product of the country of 5.8 percent in 2006. The electricity consumption per capita for Malaysia has increased from 822 KWh to 3318 KWh per capita during 1980 to 2006. The increment was contributed by the successful implementation of the industrialization plan in 1985 which has brought forth rapid economic growth and structural transformation away from agricultural-based economy (Gan and Li, 2008). This figure could be perceived as an indicator for the Malaysia's economic development towards achieving Vision 2020. As Gan and Li (2008) have projected, the total primary energy consumption would triple by 2030 while the final energy demand is projected to reach 116 mega ton of oil equivalent (Mtoe) by 2020 based on 8.1 percent annual growth rate (Keong, 2005; Chandran et al., 2009).

Figure 1: Electricity consumption per capita in ASEAN Countries

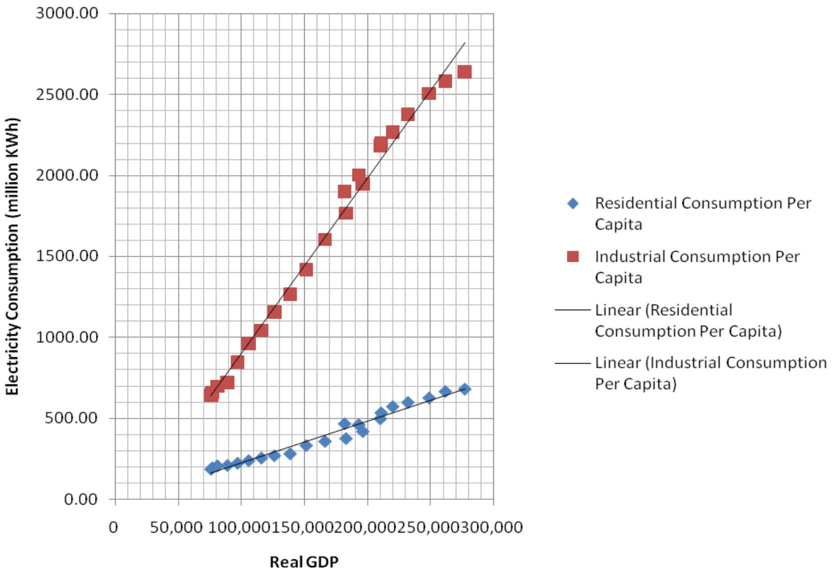


Tang (2008a) argues that population growth might contribute to the increasing trend of electricity consumptions. By looking at Figure 2, we can see from the plot of the residential electricity growth from 1985 to 2006 that shows a minor increase in the number of residential electricity consumption compared to the trend in the industrial consumption. Although the data implies that the population is growing, there is an indication that the residential electricity consumption did not contribute a lot to the development of Malaysian economy as company to the industry. The average growth of electricity consumption is about 9.1 per cent during the phase in which most of the usage is due to consumption of refrigerators and air conditioning as mentioned earlier. Tang (2008a) in his study found a uni-directional causality running from population growth to electricity consumption connotes that any policy on the population will affect the usage of the electricity and contributes significantly to the economic growth in Malaysia. Moreover, he also noted that the population growth is more stable compared to the analysis by Narayan and Singh (2007) who uses employment level to ascertain the relationship in the electricity consumption and the economic growth.

The relationship between the electricity consumption and real GDP at 1987 price is depicted in Figure 3 below. Both residential and industrial consumption shows a positive linear relationship in which as the real GDP increases, the amount of electricity consumption also increases. However, further inspection found out that the industrial consumption is more inelastic as compared to the residential consumption. This analysis proved that the economic growth influences the usage of industrial electricity dispensed more than the residentials. In regards of minimal increase in real GDP, the electricity consumption might increase as a result to the increase of the production level, or perhaps due to purchases of new machineries to improve on production.

Unlike industrial consumption, residential consumptions are less responsive to any changes in the movement of real GDP. Theoretically, any changes in the real GDP can stimulate demands for consumption in goods and services, especially in the electrical appliances. A crescendo in the consumption of electrical appliances portrays the demand for electricity that will be stimulated. Hence, positive linear relationship will occur. This argument has been substantiated a study by Mohd Taha (2005) and found that 64 per cent electricity usage in the Malaysian households have been taken up by the use of refrigerator and air conditioner.

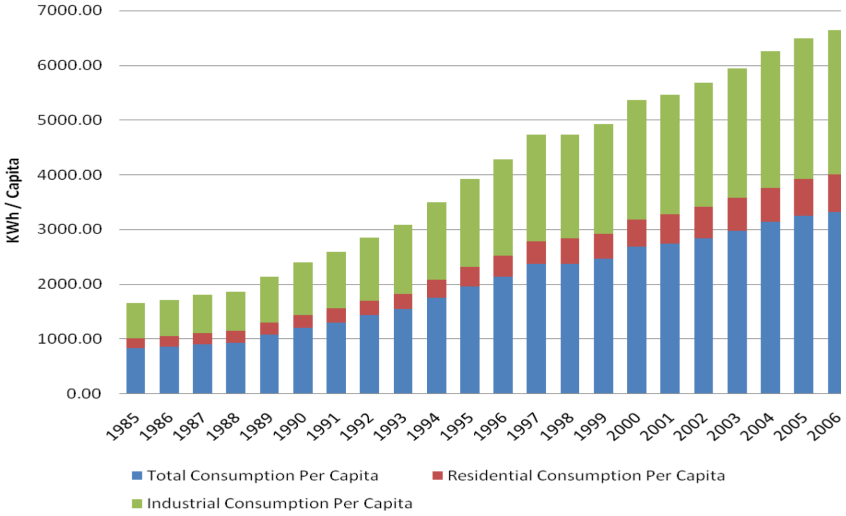
Figure 3: Relationship between Electricity Consumption and Economic Growth



Chandran et al. (2009) in his study on the electricity consumption-growth nexus in Malaysia of 1971 to 2003 observed that 1997 – 1998 has a significant influence on the level of economic growth which implicitly manipulate the level of electricity consumptions. The study, however, failed to establish which sectors were the most affected during the 1997-98 crisis. The elasticity of electricity consumption that grew is reported to be around 0.7 in the long run seeing that the causality running from both ways of electricity consumption and economic growth.

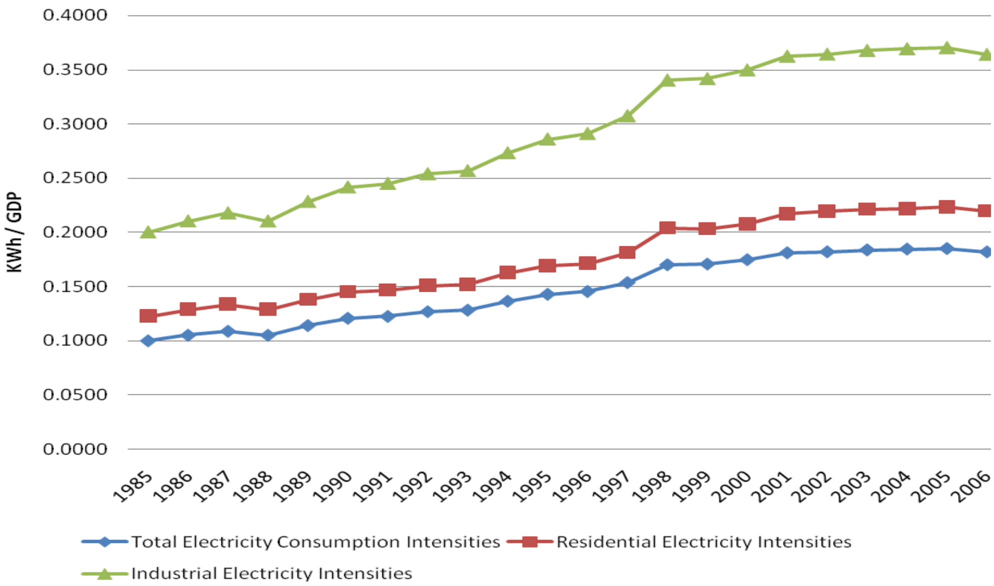
The per capita electricity consumption is depicted in Figure 4 below. From the visual inspection, we observed an increasing trend for the per capita electricity consumption with the average growth for per capita industrial usage of 7.1 per cent over the period of 1985 to 2006 while the residential growth per capita usage is about 6.5 per cent during the same period. In fact, the industrial consumption per capita usage experience a negative growth in 1998 that support the argument of the financial crisis slows down the economy. The economic slowdown lowers the production of a producers and thus lowering electricity consumption. A likely incident occurs to residential per capita usage in 1999 and 2002 due to the crisis and electricity tariff increment respectively. The lower consumption per capita resulted from lower disposable income of an individuals during the crisis and lowering the consumption of electrical appliances. The per capita usage, however, was gearing up again from 2000 with the average usage of 2181 KWh to 2637 KWh in 2006 and 497 KWh to 681 KWh for industrial and residential sector respectively.

Figure 4: Per Capita Electricity Consumption for Malaysia



In order to ensure a successful policy recommendation and implementation on electricity consumption, it is essential for the government to see the intensities of the electricity consumption. The electricity intensities can be defined as the quantity of electricity required or needed per unit of output or activity. Figure 6 below depicts the electricity intensities with respect to the economic growth. The inspection in the plot shows that both residential and industrial electricity consumption portrays an increasing trend. The increasing trend, especially in the industrial sector, may give some indication to reverberate the shift in the Malaysian economy and rules into more capital intensive industries, and thence, reflect in the effect of residential climate change. Moreover, it might also give some indication that there is inefficient use of energy which are mostly descended from residential sector to which the tariff is highly subsidized by the government. Since the government is concerned of the inefficient use of electricity that occurs, Mohd Taha (2005) argues that this will result in a costly unsustainable energy supply if this trend is not dimished. Therefore, it is important to study the direction for each of the variable to ensure a correct policy is being recommended and implemented.

Figure 6: Electricity Consumption Intensities



Literature Review

The literature on the residential electricity consumption can be traced back to the early 1950s. Various researchers had performed studies to estimate income and price elasticities for the consumption either on a long-run or a short-run basis. The earliest study was conducted by Houthhakker (1951) in examining the residential demand for 42 towns in the UK over the period of 1937 to 1938. The estimation exercising the double log model of OLS during the period shows that the elasticity of income was estimated to be around 1.17 while the price elasticity was somewhere around -0.89. The research, however, did not mention whether the elasticity was applicable for a short-run or a long-run. A similar study was done in the U.S by Fisher and Kaysen (1962) who revealed that price did not have much influence on the level of domestic electricity consumption in the 47 states during 1946 to 1957. The study has been extended further by Houthakker and Taylor (1970) by estimating the short-run and the long-run elasticities and by extending the dataset provided by Fisher and Kaysen (1962) to 1964 and starting from as early as 1947. The result disclosed the income and price elasticity in the short-run are 0.13 and -0.13 respectively. Conversely, in a long-run, the income and price elasticities are 1.93 and -1.89.

Several studies, such as Anderson (1973), Houthakker et al. (1973) and Halvorsen (1975), were carried out by looking at the residential electricity consumption elasticities. Most of these studies focus on the income and price elasticity. Halvorsen (1975) used the pooled data of 48 states in the U.S over the period of 1961 to examine the domestic usage of electricity. The result of the two-staged least squares employed by Halvorsen (1975) illustrate the price elasticity is between -1.00 to -1.21, while the estimated income elasticity ranges from 0.47 to 0.54. The cross elasticity with respect to gas price, on the other hand, is scoping from 0.04 to 0.08. In a more recent study, Fillipini (1999) examine the residential electricity demand in Switzerland from 1987 to 1990. The difference of this study as compared to the former is that Fillipini (1999) employed a multivariate Ordinary Least Squares (OLS) econometric framework for the households in 48 cities who had to face two-tier tariff. As a result, the estimation shows the income and price elasticities are 0.391 and -0.595 respectively.

Bentzen and Engsted (2001) have a different idea in terms of estimation of the elasticity for residential electricity consumption. They were riveting on the technique of estimating the elasticity instead of the economic problem itself and argued that different techniques yield different results. Auto Regressive Distributive Lag (ARDL) model was compared with co-integration and error-correction model (ECM). The result, however, did not indicate any obvious discrepancy except that the ARDL model give more valid and robust results especially for a small sample size in estimating the residential electricity data as what had been practiced until the late 1980s and early 1990s.

While most of the study on the residential electricity consumption uses annual data for their estimation, Hondroyiannis (2004) in his study that was conducted in Greece uses monthly data integrating a co-integration and standard Granger causality analysis in years from 1986 to 1999. The inclusion of the temperature variable used has been one of the strengths in this study since temperature is considered as one of the important economic element in the determination of the residential electricity consumption. The result of the study shows that the long-run elasticity for income was 1.56 and price elasticity is determined at -0.41 while the temperature variable is high and statistically significant. The short-run result for the study depicts the positive income elasticity of 0.20 and 22 of the deviation in it is being corrected in the long run using the error-correction model. Holtedahl and Joutz (2004) do a smiliar study in Taiwan and found that the income elasticity in the long run is unitary and inelastic in the short run. In addition, the price elasticity for the short is also found to be inelastic.

Narayan and Smyth (2005) use 2 models in estimating the electricity demand for Australia. The annual data of 1960 to 2000 were used in this estimation. ARDL bound testing approach was employed and the result portrayed that the elasticity of electricity demands for Australia ranging from 0.0121 to 0.0415 in the short run while, in the long run, the income elasticity ranging from 0.323 and 0.408.

Erdogdu (2006), on the other hand, estimates the short- and long-run elasticity for residential demand in Turkey over the period of 1984 to 2000. Using the co-integration approach, he discovers that the income elasticity for Turkey was quite low which implies that any response to the change in the income is very limited in which the government can easily devise an energy policy that could response to a limited change in the income. The forecast for Turkey that was done by Erdogdu (2006) also reflects the projection done by the officials responsible for energy is over-estimated. Furthermore, the projection by Erdogdu (ibid.) for the case of Turkey as well deliberated the economic situation especially on the economic crises that hit Turkey in 1994, 2000 and 2001. Hence, the projection of the energy should be taken into considerations on the level of economic activities.

Recent study by Derdiages and Tsouldifis (2009) grounding the Greek economy arrived at some diverse results as reported by Hondroyianis (2004). Using an ARDL model and assuming that the electricity consumption depends on the price of electricity, per capita income, the weather conditions and the price of substitute, there is an evidence of a single long run relationship with relations to electricity consumption. The long run income elasticity for the Greek economy over the period of 1964 to 2006 is around 0.79 and the own price elasticity is -0.61. In the intervening time, the short run elasticity renders the same relation which is around 0.64 and the own price is -0.09. The result was somewhat contrasting from Hondroyianis (2004) in terms of long run elasticity where Derdiages and Tsoudifis (2009) found that the income elasticity is much lower as compared to Hondroyianis (2004) who found that the elasticity for the Greek electricity consumption is unitary. The conflicting results may come from different methodological approach by both researchers. Derdiages and Tsouldifis (2009) also discovered that there is a uni-directional causality running from per capita income to per capital electricity consumption, temperatures to electricity consumption. In the long run, the causality for model runs from income, price, temperature and price of substitutes to the electricity consumption.

Methodology

Following the work of Beenstock et al. (1999), the paper embarks on the nested demand function. In this function, the behavioral equation of the nested household demand function can be presented as follows:

$$HD = f(C, P; Z) + \mu \qquad (1)$$

where HD denotes household electricity consumption or demand, C is consumer spending proxied by real GDP per capita, P is the price of relative electricity consumption and Z is the measure of other influences that controls for the electricity consumption whilst the error term is denoted by μ. However, as the price of electricity in Malaysia is highly subsidized by the government, using the data will result in bias estimates. Therefore, the pricing level is excluded form the model and the model for household demand is:

$$HD = f(C; Z) + \mu \qquad (2)$$

where C is the real GDP per capita and Z measures the influences of the electricity consumption proxied by the average temperature in order to avoid seasonal bias.

Real GDP per capita for the residential is used as a proxy for legal income for the country in each of the model which in turn serves as an indicator of household level spending on electrical appliances for personal use, which as well includes electricity consuming activities.

The Econometric Model

Following the specification by Beenstock et al. (1999) and Fatai et al. (2003) as well as Clements and Madlener (1999), Hondroyiannis (2004), Tang (2008a, 2008b), Dergiades and Tsoulfidis (2009) and Chandran et al. (2009), a double-logarithmic form which is estimated by OLS using real GDP per capita and temperature for residential demand model are used as an independent variable is employed. The model is formed as:

$$\ln(res) = \alpha_0 + \alpha_1 \ln(rgdp_t) + \alpha_2 \ln(temp_t) + \alpha_3 Dum97 + e_t \quad (3)$$

where $\ln res$ is the natural log of residential electricity consumption per capita, with $\ln rgdp$ is the natural log of real GDP per capita. $\ln temp$ is the natural log of average temperature in Malaysia which is being calculated by the average of 14 meteorological station across Peninsular Malaysia, Sabah and Sarawak. The lags of the variables are often included as regressor in order to capture the dynamic aspects of electricity demand. The variable DUM97 is the dummy variable to take into account the Asian Financial Crisis 1997/98 which in theory reflects the lower consumption occurs during the period (Chandran et al., 2009).

The basic statistical assumption underlying the model is that the variables are stationary stochastic processes - which are processes with constant unconditional means and variance. The problem with this solution is that by taking first-differences, one has to filter the low frequency or the long-run variation, thereby making the model only capable of explaining the short-run. In this research, the long run estimate has to be viewed as well in order to assess the implication on any policy relating to the demand management.

As pointed out by Granger (1987) and Banerjee et al. (1993), in order to make the procedures of classical econometrics being applied appropriately, one must ensure that the variables of interest do not exhibit unit roots. Therefore, it is crucial to know the time series properties whether these can determined if given time series is stationary.

The standard ADF and PP unit root test have been criticized recently for its low power in distinguishing between unit root and a near unit root process (Campbell & Perron, 1991; DeJong et al., 1992). The low power of ADF and PP unit root tests resulted for the study to also use KPSS semi-parametric unit root (Kwiatkowski et al., 1992) for the degree of integration.

The KPSS semi-parametric procedure tests for the null hypothesis for level (η_μ) or trend (η_t) stationarity are put against the alternative hypothesis of non-stationarity. The advantage of using KPSS test is that it has superior properties in small sample (Kwiatkowsi et al., 1992). Furthermore, the test is able to distinguish between unit root and a near unit root process. As a result, KPSS test performs better than ADF and PP unit root test.

The following expressed the KPSS testing equation:

$$LM = \eta_\mu(\eta_t) = \frac{1}{s^2(k)T^2} \sum_{t=1}^{p} S_t^2 \quad (4)$$

where $S_t = \sum_{t=1}^{p} \hat{\mu}_i, \hat{\mu}_t$ are the estimated residuals from the ordinary least squares (OLS) from a regression of the time series on a constant and a linear deterministic trend. If no linear trend is present, the time series will be regressed in a constant. $s^2(k)$ is a non-parametric estimate of the long-run variance of $\hat{\mu}_t$ and k represents for the lag truncation parameter.

To address the issue of stationarity, Engle and Granger (1987) proposed a co-integration technique to see the long-run relationship between the variables. In other words, although the variables are individually non-stationary, *I(1)* processes, linear combination of the variables may well be stationary, *I(0)* processes. In this case, the variables are tied together in the long run so that the variable estimated in Equation 3 is stationary.

Most of the studies in the electricity consumption literature employ Johansen-Juselius's (1990) maximum likehood test to examine the long-run equilibrium relationship among the set of interest variable. The approach is used in a multivariate framework that tests for all the number of co-integrating vectors between the variables. By and large, the co-integration procedure requires time series in the system to be non-stationary in their levels. Thus, as what has been implied, the method can be applied to *I(1)* variables.

Nevertheless, the Johansen co-integration technique is widely criticized for its biasness towards rejecting the null hypothesis of no co-integrations. Studies by Reimer (1992) and Cheung and Lai (1992) using a Monte Carlo experiment in a finite sample confirmed this problem. On top of that, Huang and Yang (1996) also found out that the Johansen procedure is very sensitive to assumptions that errors are independently normal. When the errors are not independently normal, the Johansen test has the highest tendency to obtain a spurious co-integration. A simulation test by Gonzalo and Lee (1998) revealed that Johansen's likelihood ratio (LR) test tends to find spurious co-integration with probability approaching to one when the order of integration of the estimated series are not purely I(1) process (Tang, 2008). This finding is consistent with studies done by Abeysinghe and Tan (1998) which disclosed that Johansen's estimator was the worst of the six co-integrating estimators.

In addition to the spurious co-integration condition, the Johansen estimator is highly sensitive to the lag length of VAR and its deterministic components namely constant and trend included in the co-integration equations (Ahkin, 2002; Hjelm and Johansson, 2005). The Pantula procedure proposed by Johansen (1992) in selecting a proper model for co-integration test was highly criticized by Hjelm and Johansson (2005) in which they argued that the procedure cannot overcome the problems effectively as the procedure tends to select model with an unrestricted constant.

This study will adopt the approach of bound testing within an autoregressive distributed lag (ARDL) recently developed by Pesaran et al. (2001) which was further developed by Kanioura and Turner (2005) to avoid spurious co-integration and biasness that occured in Johansen's co-integration framework. Given the finite sample size, the approach is more suitable to avoid any deviation from its asymptotic distribution (Zigot and Andrews, 1992).

ARDL Approach to Co-integration

The long run relationship and dynamics interactions among the variables of interest were estimated using the bound testing or ARDL approach on co-integration procedures developed by Pesaran et al. (2001). There are several reasons on why the approach was adopted. Firstly, the bound test is simple as opposed to the Johansen and Juselius's (1990) in which it allows for the co-integration relationship to be estimated by OLS once the lag order is identified. Secondly, the procedures do not require any pre-test in the model of unit root since it is applicable in the model if the regressors are purely I(0), I(1) or mutually co-integrated. However, in this study, the pre-testing in the unit root model was done since the procedure will collapse if there is a presence of I(2) series in the model (Fosu & Magnus, 2006). Thirdly, the test is relatively more efficient in small or finite sample sizes as is the case of this study.

Following Pesaran et al. (2001), the bound test procedures is applied by modeling the long run equation as a general vector autoregressive (VAR) model of order *p* in z_t :

$$z_t = c_0 + \beta t + \sum_{i=1}^{p} \phi_i z_{t-i} + \varepsilon_t, t = 1, 2, 3, ..., T \tag{5}$$

with c_0 respresenting a $(k+1)$-vector of intercepts and β denoting a $(k+1)$-vector of trend coefficients (or dummy variables in this case). Pesaran et al. (2001) further derived the equations following vector equilibrium correction model (VECM) corresponding to (3.15):

$$\Delta z_t = c_0 + \beta t + \Pi z_{t-1} + \sum_{i=1}^{p} \Gamma_i \Delta z_{t-i} + \varepsilon_t, t = 1, 2, 3, ..., T \tag{6}$$

where the $(k+1)\times(k+1)$ -matrices $\Pi = I_{k+1} + \sum_{i=1}^{p} \Psi_i$ and $\Gamma_i = -\sum_{j=i+1}^{p} \Psi_j, i = 1, 2, ..., p-1$ contain the long run multipliers and short-run dynamics coefficient of the VECM. z_t is the vector of variables y_t and x_t respectively. According to Pesaran et al. (2001), y_t must be I(1) a variable, but the regressor x_t can either be I(0) or I(1). There are 2 exploratory variables in the model to which y_t is defined as a log of residential consumption per capita ($\ln res_t$) and $x_t = \left[rgdp_t, temp_t \right]$. The variable of x_t in the model is a vector of 'forcing' I(0) and I(1) regressors as already defined with a multivariate *i.i.d* with zero means error vector $\varepsilon_t = \left(\varepsilon_{1t}, \varepsilon'_{2t} \right)$, and a homoskedastic process.

Assuming that a unique long-run relationship exists among the variables, the conditional VECM now becomes:

$$\Delta y_t = c_{y0} + \gamma_{yy} y_{t-1} + \gamma_{xx} x_{t-1} + \sum_{i=1}^{p-1} v_i \Delta y_{t-i} + \sum_{i=0}^{p-1} \eta_i \Delta x_{t-1} + \beta_t Dum97 + \varepsilon_{yt}, t = 1, 2, ..., T \tag{7}$$

On the basis of the above equation, the conditional VECM of the model is as follows:

$$\begin{aligned} \Delta \ln res = c_0 + \gamma_1 \ln res_{t-1} + \gamma_2 \ln rgdp_{t-1} + \gamma_3 \ln temp_{t-1} + \sum_{i=1}^{p} \eta_t \Delta \ln res_{t-i} \\ + \sum_{i=0}^{q} \kappa_t \Delta \ln rgdp_{t-i} + \sum_{i=0}^{r} \lambda_t \Delta \ln temp_{t-i} + \beta dum97 + \varepsilon_t \end{aligned} \tag{8}$$

where γ_t are the long run multipliers, c_0 is the intercept while ε_t are the white noise errors and Δ is the difference operator. Equation (3.18) also can be viewed as an ARDL of order (*p.q,r)*. The lag structures are determined by minimizing the AIC and according to Enders (2004), the maximum lag for the quarterly data can be set to 4.

Bound Testing Procedures

There are three (3) steps identified by Pesaran et al. (2001) in estimating the ARDL bound testing approach. Firstly, both of the equations (3.18) and (3.19) are estimated using the Ordinary Least Square (OLS) to determine the existence of the long-run relationship among the variable. This procedure is conducted using an F-test by restricting the lagged variables of $\ln res_{t-1}$, $\ln rgdp_{t-1}$ and $\ln temp_{t-1}$ as well as $\ln com_{t-1}$, $\ln rgdp_{t-1}$ and $\ln inv_{t-1}$ for Model (1) and (2) respectively. The F-test can be conducted by imposing a restriction on the estimated long run coefficient of residential and industrial electricity demand, real GDP, temperature and value of investment in the country. The null and alternative hypotheses are as follows:

$H_0 : \gamma_1 = \gamma_2 = \gamma_3 = 0$ (no long-run relationship)

$H_1 : \gamma_1 \neq \gamma_2 \neq \gamma_3 \neq 0$ (a long-run relationship exists)

The test will be denoted by normalizing on *res* by $F_{res}\left(res \mid rgdp, temp\right)$. It is undeniably crucial to note that the F-statistic obtained while performing the Wald test has a non-standard distribution, whose asymptotic critical values provide a test for co-integration when the independent variables are *I(d)* (where $0 \leq d \leq 1$). A lower value assuming the regressors is *I(0)* and an upper value is assumed purely *I(1)* regressors. The critical values are provided by Pesaran et al. (2001) which has been generated using samples of 500 and 1000 observations. However, Narayan (2005) has argued these critical values are inappropriate for a small sample size which is the usual case for annual macroeconomic variables. For this reason, Narayan (2005) provides a set of critical values for samples ranging from 30 to 80 observations for the same level of significance.

While Narayan (2005) observed on the critical values based on the univariate framework, Kanioura and Turner (2005) had studied on the critical values on the multivariate model. Using the newly adopted ECM-based F-test which is similar to the model used by Pesaran et al. (2001) and employing Monte Carlo experiment, Kanioura and Turner (2005), using a sample size of 50 to 500, has provided a set of critical values which is more powerful than the two-step Engle-Granger using a quarterly data as of the case of this study (Tang, 2008). If the statistics obtained from Kanioura and Turner's tables exceeds the respective for upper critical value, it may be argued that there is an evidence for a long-run equilibrium relationship. If the test statistics falls below the lower critical value, we cannot reject the null hypothesis of no co-integration. Finally, if the test statistics lies between the two bounds, the test would be inconclusive.

In the second step as proposed by Pesaran et al. (2001), having established the conditional ARDL (*p*,*q*,*r*), long run model for Model 1 and Model 2 can be estimated as:

$$\ln res_t = c_0 + \sum_{i=1}^{p} \gamma_1 \ln res_{t-1} + \sum_{i=0}^{q} \gamma_2 \ln rgdp_{t-1} + \sum_{i=0}^{r} \gamma_3 \ln temp_{t-1} + \beta_t DUM97 + \varepsilon_t \quad (9)$$

where all variables are as previously defined, the structural lags are also determined by minimizing AIC. Once the parameters of (7) is estimated, the long-run multipliers for the ARDL (*p*,*q*,*r*) model can be estimated as follows:

$$\alpha_0 = {c_0} \Big/ {1-\sum_{i=1}^{p}\gamma_i} \quad \text{and} \quad \alpha_j = {\gamma_m} \Big/ {1-\sum_{i=1}^{p}\gamma_i}, \text{ with } j = 1,...,4 \text{ and } m = 2,...,5$$

The third and the final step is to estimate the dynamics of short-run coefficients for the optimal ARDL model using an error correction model that is associated with the long run estimates. This can be specified as follows:

$$\begin{aligned}\Delta \ln res_t &= c_0 + \sum_{i=1}^{p}\eta_i \Delta \ln res_{t-1} + \sum_{i=1}^{q}\kappa_i \Delta \ln rgdp_{t-1} + \sum_{i=1}^{r}\lambda_i \ln \Delta temp_{t-i} \\ &\quad + \upsilon ecm_{t-1} + \beta_t Dum97 + \varepsilon_t\end{aligned} \tag{10}$$

where ecm_{t-1} is the error correction term resulting from the verified long-run equilibrium relationship and υ represents the speed of adjustment to the equilibrium level after a shock. η, κ and λ represent the short-run dynamic coefficients of the model convergence to the equilibrium. Pesaran et al. (2001) proposed that it is very important to ascertain the consistency of the long-run multipliers by testing the error-correction model for stability of its parameters. The commonly used tests for this purpose are the cumulative sum (CUSUM) and the cumulative sum of squares (CUSUMQ), both of which were introduced by Brown et al. (1975).

Causality Tests

This paper employs standard Granger causality to see the link between variables understudy. In order to perform this test, if the series is not co-integrated, a vector autoregressive (VAR) for the first difference is used in performing the Granger causality. Alternatively, if the series are integrated, the Granger causality with inclusion of the lagged error-correction term will be used as additional independent variables in the equation. Engle and Granger proposed the additional variables have to be added to the equation in order to avoid any misleading usage of VAR estimation (Chandran et al., 2009).

The VAR model for Granger causality test for the model is as in follows:

$$\begin{aligned}\begin{bmatrix}\Delta \ln res_t \\ \Delta \ln rgdp_t \\ \Delta \ln temp_t\end{bmatrix} &= \begin{bmatrix}c_1 \\ c_2 \\ c_3\end{bmatrix} + \begin{bmatrix}A_{11i} & A_{12i} & A_{13i} \\ A_{21i} & A_{22i} & A_{23i} \\ A_{31i} & A_{32i} & A_{33i}\end{bmatrix} \times \begin{bmatrix}\Delta \ln res_{t-i} \\ \Delta \ln rgdp_{t-i} \\ \Delta \ln temp_{t-i}\end{bmatrix} \\ &\quad + \begin{bmatrix}\phi \\ \kappa \\ \pi\end{bmatrix} \times \left[ECT_{t-1}\right] + \begin{bmatrix}\beta_{1t} \\ \beta_{2t} \\ \beta_{3t}\end{bmatrix} \times \left[DUM97\right] + \begin{bmatrix}\xi_{1t} \\ \xi_{2t} \\ \xi_{3t}\end{bmatrix}\end{aligned} \tag{11}$$

The appropriate lag orders for the VECM is determined by minimizing AIC while the term ξ_{1t}, ξ_{2t} and ξ_{3t} are the stationary residuals with a spherical distribution. To implement the Granger causality test, equation (11) is estimated and the F-test is applied on the restriction of the parameters of the VAR model (Tang, 2008a, 2008b; Chandran et al., 2009). By imposing these restrictions, we estimate a likely for short-run causality while t-statistics were used for the lagged error correction term. If the results indicate that the lagged error-correction term is significant, there could be an evidence of long-run causality in the model.

Nature and Sources of Data

The sample consists of several variables in the electricity demand and covers the period of 1985:1 to 2006:4 (T=88). The time period, rationally, was chosen because this was the time when the booming industries in Malaysia resulted from the privatization exercises. In addition, the condition of the economy that was just recovered from a severed recessions contributes as one of the reasons why this era was selected. Quarterly data used in this study is being interpolated using Gandolfo (1981) technique (see Appendix A) since the data for electricity is only available on the annual basis. This interpolation technique is opted due to the simplicity of its nature, its encompassing acceptance in the field and is being used by numerous published empirical studies such as Baharumshah and Rashid (1999), Baharumshah (2006) and Tang (2008b). To fortify on the argument of the usage of this technique, Smith (1998) has conducted a Monte Carlo analysis to estimate the effects of the linearly interpolating technique on the co-integration test. The result encapsulates that the interpolated series do not show any bias in the estimates of the co-integrating vectors even when the sample size is small (Tang, 2008).

Electricity demand is measured by total electricity consumption by both industrial and household in kilowatt hour (kWH). The data was obtained from various publication including TNB annual report and Department of Statistics of Malaysia. The real income (*rgdp*) was in actuality gained from the data provided by Abeysinghe (2004) using the price in 1987. The data was acquired through interpolation of GDP for various countries in ASEAN using the Chow-Lin interpolation procedures and has been used by many literatures (Tang, 2008). It is also being updated quarterly by Abeysinghe (2004). Since the data produced by Abeysinghe (ibid.) is not seasonally adjusted, *X-12-ARIMA* procedure introduced by U.S. Census Bureau (2007) was used to filter and remove seasonal movements in the data in order to have a better view and distortion of the series behavior, hence provides a reliable estimate in short- and long-run.

The data for temperature is obtained by averaging the temperature from 24 main meteorology stations across the country inclusive of Sabah and Sarawak before being converted into a quarterly average series.

Results and Analysis

Although ARDL Bound testing approach does not require the pre-testing of the series, it is crucial to do so in order to avoid the existence of I(2) series. In fact, the unit root testing is equally important to determine the exact order of integration involved in the variables.

KPSS test was conducted and it is found that all the estimated variables are non- stationary at level terms, but it is stationary after first-differencing and the result implies that the residential electricity consumption per capita (LNRES) and real GDP per capita variables are integrated at order 1, I(1) process while the temperature variable (LNTEMP) are integrated at order (0) [Table 1].

Table 1: Unit Root Test

	Level		First Difference	
Variables	**Constant No Trend**	**Constant Trend**	**Constant No Trend**	**Constant Trend**
Data Period: 1985Q1 – 2006Q4				
lnres	1.202205 (7)	0.163775 (6)	0.075511** (3)	0.074670** (3)
lnrgdp	1.142282 (7)	0.235149 (7)	0.112899** (4)	0.101394** (4)
lntemp	0.781406 (6)	0.052595** (5)	0.036521** (7)	0.036668**(7)

From the result of unit root, we can conclude that there are mixtures of integrational properties in the variables understudy and therefore the bound testing procedures to examine the presence of long run equilibrium relationship in between the electricity consumption and its determinants can be implemented for residential demand model.

Bound Testing Approach for Residential Consumption Model

Having estimated the conditional VECM Model (3.18) in the residential electricity consumption using OLS, the ARDL approach to co-integration requires the testing of null hypothesis of $\lambda_1 = \lambda_2 = \lambda_3 = 0$ against the alternatives that at least one of these coefficients is different from zero. Since the value of F-statistic in any OLS estimation is very sensitive to the numbers of lag imposed each time in the differenced variable (Bahmani-Oskooee and Goswami, 2003), the appropriate lag order was set to use AIC. Due to the fact that study employs quarterly data, duration of lag minimizes that AIC can be taken as four (Erbaykal, 2008). However, if the model established with minimum AIC involves autocorrelation, then the duration of lag that selected 2nd minimum value of AIC is selected. The selection of AIC in identifying the data is taken since AIC has high power over a small data sample (Tang, 2008a).

The result of the co-integration based on the bound testing procedures for the residential electricity consumption model is displayed in Table 2. By normalizing the on residential consumption function, we found a compelling evidence that suggests no co-integration between electricity consumption acts as dependent variables. The computed F-statistic was compared with the critical values obtained by Pesaran et al. (2001) as well as the small sample size critical values which are obtained from Narayan (2005). When the residential electricity consumption is the dependent variables, the calculated F-test $F_{res}\left(res \mid rgdp, temp\right)$ = 3.2347 is lower than the critical bound provided by both Pesaran and Narayan. This result is consistent with Tang (2008a) and Chandran et al. (2009) who suggested that the income per capita does not coalesce in the long run with any of the variables in their study. However, the study was merely looking at the aggregate level data instead of individual sector and the result should be noted with cautions.

Table 2: Bound Testing Result for Residential Electricity Consumption

<table>
<tr><th rowspan="3">Normalized Model</th><th rowspan="3">Calculated F-Statistics</th><th rowspan="3">Lag</th><th rowspan="3">Significance Level</th><th colspan="4">Critical Bound</th><th rowspan="3">Conclusion</th></tr>
<tr><th colspan="2">F-Statistic@</th><th colspan="2">F-Statistic#</th></tr>
<tr><th>I(0)</th><th>I(1)</th><th>I(0)</th><th>I(1)</th></tr>
<tr><td>$F_{res}\left(res \mid rgdp, temp\right)$</td><td>3.2347</td><td>7</td><td>1%</td><td>4.30</td><td>5.23</td><td>3.908</td><td>5.004</td><td>Not Cointegrated</td></tr>
<tr><td>$F_{rgdp}\left(rgdp \mid res, temp\right)$</td><td>7.8579</td><td>2</td><td>5%</td><td>3.38</td><td>4.23</td><td>2.920</td><td>3.838</td><td>Cointegrated</td></tr>
<tr><td>$F_{temp}\left(temp \mid res, rgdp\right)$</td><td>5.3978</td><td>2</td><td>10%</td><td>2.97</td><td>3.74</td><td>2.474</td><td>3.312</td><td>Cointegrated</td></tr>
</table>

Notes: @ denotes critical value obtained from Pesaran et al. (2001)
# denotes critical value obtained from Narayan (2005)

In an effort to ensure that the independent variables can be treated as long-run forcing variables, we tested for other possible co-integration relationships. Interestingly, when we normalized the equation with respect to the real GDP per capita and temperature variable - in which both of the variables serving as a dependent variable - we did found an evidence of co-integration. For example, we ran a model using real GDP as the dependent variables and computed the F-statistics indicated by $F_{rgdp}\left(rgdp \mid res, temp\right)$ = 7.8579 which is above both Pesaran's and Narayan's critical value while the calculated F-value for temp as the independent variable is $F_{temp}\left(temp \mid res, rgdp\right)$ = 5.978 which is a similar result as per capita income.

It is important to point out that we have tried a host of variables that was used in a similar study but we regrettably had to drop them from the analysis. For example, we have tried the oil prices, the variables that have been used by Dergiades and Tsoufilidis (2009) in their study on the residential demand model in Greece, in which the variables acts as an input forcing variable to the electricity demand with an expectation of a positive relationship with the dependent variables. However, the coefficient of the oil price is not statistically significant for the entire period of the analysis and thus, we had to drop the variable. We also practiced the population growth variable which considers not only the variable is not statistically significant, but also the sign of the coefficient is not as expected as accordance to the economic theory. This preliminary result has motivated us to use the temperature variable to be used in the model.

Given that the model is not co-integrated, the short run dynamic will only be determined by the first difference of the level term using the standard VAR model. The empirical results that are obtained are based on the re-parameterization of the estimated ARDL (8,0,0) model as shown in Table 3 below:

Table 3: Short Run representation for ARDL (8,0,0) of Residential Consumption Model

Short-run representation			
Dependent Variable: $\Delta \ln(res)$			
Independent Variable	**Coefficient**	**t-statistic**	***p*-Value**
Constant	0.53177 (0.011109)	4.7867	0.000**
$\Delta \ln(res)_{t-1}$	-0.46449 (0.10980)	-4.2303	0.000**
$\Delta \ln(res)_{t-2}$	-0.41691 (0.11567)	-3.6044	0.001**
$\Delta \ln(res)_{t-3}$	-0.22832 (0.12151)	-1.8791	0.064***
$\Delta \ln(res)_{t-4}$	0.13838 (0.12960)	1.0678	0.289
$\Delta \ln(res)_{t-5}$	-0.14541 (0.11996)	-1.2122	0.230
$\Delta \ln(res)_{t-6}$	-0.33125 (0.11947)	-2.7727	0.007**
$\Delta \ln(res)_{t-7}$	-0.28393 (0.11947)	-2.5133	0.014**
$\Delta \ln(rgdp)_{t}$	-0.42094 (0.26373)	-1.5961	0.115
$\Delta \ln(temp)_{t}$	0.74361 (0.38175)	1.9479	0.055***
DUM97	-0.013011 (0.0079131)	-1.6443	0.105
R-Squared = 0.589; R-Bar-Squared = 0.52915; F-stat = 9.8780; AIC = 156.36; SBC = 143.2603;			
Diagnostic Test: Serial Correlation= 0.46222 [0.977] ; Functional Form = 11.2376 [0.001]; Normality = 2.6316 [0.268] ; Heteroscedasticity = 0.24559 [0.620]			

Notes: *,** and *** denotes significant at 1%, 5% and 10% respectively. The number in parentheses is the standard error.

The diagnostic that has been done on the short-run is rather unstable; especially the Ramsey's RESET which indicates the rejection of null hypothesis of no specification error. However, all other tests including the Breuch-Godfrey LM serial correlation shows that the residual is uncorrelated as well as Jarque-Bera test which shows the residuals are normal.

The coefficient of per capita income in the short run does not have the same sign as in the long-run estimations. While the long-run estimates shows a positive sign as expected in any economic analysis, the short-run coefficient indicates a negative coefficient. A credible reason for the different sign in the short run may be due to the subsidy enjoyed by the residents mainly for the low income level which take pleasure in a significantly lower price on the electricity usage, and thus, this does not affect much on their disposable income.

The temperature variable, on the other hand, has the same sign as in the long run coefficient and statistically significant as compared to the long-run. This indicates that only the current temperature that affects the electricity consumption and to achieve the equilibrium is only on the short-run. This can be further analysed by looking at the coefficient in which the temperature variable relatively has a high impact to the electricity consumption where 1 per cent increase in the variable will increase the consumption by 0.74 per cent when compared to changes in the per capita income to the consumption.