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Demand for electricity: evidence of cointegration and causality from Sri Lanka

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Abstract:

This study examines the cointegration and causality relationship between the demand for residential electricity and real income, average real electricity prices, real kerosene prices and real gas prices using annual data for the period, 1960-2007 in Sri Lanka. Error correction (EC) techniques and the Granger-causality (GC) approaches are employed. The long run income elasticity of demand, price elasticity of demand and kerosene price were estimated to be 0.78, -0.62, and 0.14 respectively. The short run elasticities for the same variables were 0.32, -0.16 and 0.10 respectively. The GC results detect bi-directional causality between electricity consumption and real income as well as electricity prices and its consumption. This suggests that these variables are determined jointly. Furthermore, one-way causality running from kerosene price to electricity demand was also found.

Keywords: Electricity demand, causality, cointegration analysis

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Demand for electricity: evidence of cointegration and causality from Sri Lanka

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ABSTRACT:

This study examines the cointegration and causality relationship between the demand for residential electricity and real income, average real electricity prices, real kerosene prices and real gas prices using annual data for the period, 1960-2007 in Sri Lanka. Error correction (EC) techniques and the Granger-causality (GC) approaches are employed. The long run income elasticity of demand, price elasticity of demand and kerosene price were estimated to be 0.78, -0.62, and 0.14 respectively. The short run elasticities for the same variables were 0.32, -0.16 and 0.10 respectively. The GC results detect bi-directional causality between electricity consumption and real income as well as electricity prices and its consumption. This suggests that these variables are determined jointly. Furthermore, one-way causality running from kerosene price to electricity demand was also found.

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Introduction

Sri Lanka's energy sources consist primarily of biomass, petroleum and hydro-electricity. These three sources of energy contribute to 47%, 45% and 9% of total energy used in the country respectively (Central Bank of Sri Lanka, 2007). Respective governments in Sri Lanka, for the last few decades have recognized the importance of electricity as a vital input in increasing economic activity, and have, therefore, taken steps on a priority basis to increase the supply of electricity, especially to rural areas. As a result, the number of households with access to electricity has increased rapidly, especially during the last two decades. At present approximately 80% of the households are connected to the grid, while another 2% of households are provided with basic electricity through off-grid systems (Ceylon Electricity Board, 2005). Despite the importance of electricity as an input in production the country has been experiencing periodic power shortages due to lack of generation capacity and the inability of the hydropower plants to compensate adequately, during droughts which occur every four to five years. Due to the increasing demand for electricity, the frequency of power shortages has been increasing in the recent years.

The demand for electricity that registered as annual growth of eight per cent during the period, 1970-79, grew at a faster rate of 10% during the period, 1978-2008. This figure is estimated to increase at an annual rate of 8%-10% for the next few years as well (Ceylon Electricity Board, 2005). The consumption of electricity by the domestic sector, too, increased during this time period due to the increased use of household appliances. Meeting the demands of ever increasing electricity needs has been one of the major challenges faced by the Sri Lankan authorities in the recent years, especially after the end of the 30 year civil war (Wasantha Athukorala and Wilson, 2010). The major problem associated with the existing hydro electricity generating system is its inadequate generating capacity to meet the demand at peak periods and their inability to ensure continuous supply over the whole year due to vagaries of nature (e.g drought). Therefore, the advantages of thermal power development projects have been recognized in terms of cost effectiveness, capacity and reliability to meet the increasing demand in the future.

Effective electricity planning requires a thorough understanding of the prevailing electricity demand patterns and constraints or future challenges (Pillai, 2001; Hondroyiannis, 2004). The major difficulty in modeling demand arises from the complexity created by its high variability (Holtedahl and Joutz, 2000). The variations in demand are influenced by various economic factors. In order to formulate realistic policies, it is therefore, necessary to know the economic factors such as price and income changes that influence demand for electricity. It is also useful to separately examine the causality among the relevant variables.

However, previous statistical analyses of the demand for electricity in developing countries, including Sri Lanka is extremely limited. Of the few studies conducted on the demand for electricity in Sri Lanka, Morimoto and Hope (2004) investigated the causal relationship between electricity supply and GDP using Granger causality analysis for the period, 1960-1998. They concluded that changes in electricity supply have a significant impact on changes in real GDP in Sri Lanka and, therefore, every MWh increase in electricity supply will contribute to an extra GDP output of approximately US$ 1120-1740. Amarawickrama and Hunt (2008) estimated the electricity demand functions for Sri Lanka using six econometric techniques. According to them there is a wide range in the long-run price and income elasticities of demand. Wasantha Athukorala and Wilson (2010) showed that price and income elasticities were in the range of -0.16 and 0.32 in the short run and -0.62 and 0.78 in the long run respectively.

However, these studies do not adequately analyse the substitution effects as well as the long run causality impacts of the variables in questions. This study attempts particularly to fulfill this need by especially considering the residential sector that consumes approximately 40% of total electricity demand in the country. The study uses cointegration and error correction models developed by Engle and Granger (1987) to estimate household demand for electricity. After estimating the short run and long run elasticities, the chapter examines the long run causality of the relevant variables.

Literature Review

Donatos and Mergos (1991); Silk and Joutz (1997); Christian and Michael (2000); Halvorsen and Larsen (2001); Lin (2003); Hondroyiannis (2004) and Mohammadi (2009) are some of the recent studies that have used the error correction approach to estimate the residential demand for electricity. Donatos and Mergos (1991) examined the determinants of residential electricity consumption in Greece over the period 1961-1986. They concluded that residential electricity demand during this period was price (-0.41) and income elastic (1.56). Silk and Joutz (1997) estimated an error-correction model of annual US residential electricity demand for the period, 1949-1993. They found that the long run income elasticity was close to 0.5 and the long run price elasticity was –0.25. Christian and Michael (2000) analyzed the demand for electricity in China. The model considered the potential effects of deregulation and price increases in the power sector. The results of the study suggested that the demand for electricity will accelerate in the future due to expected structural changes in the economy. Halvorsen and Larsen (2001) estimated the short and long run residential electricity demand using annual Norwegian Survey of Consumer Expenditure data for the period, 1975 - 1994. They found that the estimated long run elasticity was only marginally price elastic than the short run.

Lin (2003) used a macroeconomic approach to develop a long-run electricity demand model in order to analyze the main factors affecting demand for electricity in the People's Republic of China (PRC). He found that the relationship among relevant variables was more stable and significant after the PRCs economic reforms in 1978 when all variables were more responsive to market forces. The demand elasticity of gross domestic product (GDP) has been estimated as 0.8 since the 1978 economic reforms. This is lower than that of the pre-reform period. Hondroyiannis (2004) estimated a model by focusing the issues of structural stability, price and income sensitivity both, in the long and short run for Greece. He used monthly data over the period, 1986-1999 and the results suggest that in the long run residential demand for electricity is affected by changes in real income, real price levels and average temperatures. The value of income elasticity is equal to 1.5 while the value of price elasticity is equal to -0.4. Mohammadi (2009) examined the long run relation and short-run dynamics between electricity prices and different fossil fuel prices such as coal, natural gas and crude oil using annual data for the US. The results of this study strongly support the relationship between real electricity prices and coal and bi-directional long run causality between these two variables. Other important studies that examine the demand for residential electricity include Fisher and Keysen (1962); Anderson (1973); Houthakker *et al.* (1974); Taylor (1975); Barnes *et al.* (1981); Berndt and Samaniego (1984); Hsiao and Mountain (1985); Green and Newbery (1992); Andersson and Bergman (1995); Diabi (1998); Lariviere and Lafrance (1999); Xiaohua and Zhenmin (2001); Jumbe (2004) and Holtedahl and Joutz (2004).

Ghosh (2002) examined the cointegration and Granger causality for India using data between 1950 -1997. The study failed to establish a cointegrating relationship, but found short-run Granger causality running from economic growth to electricity consumption without any feedback effect. Jumbe (2004) used the Granger-causality (GC) and error correction techniques using 1970–1999 data for Malawi to examine cointegration and causality between electricity consumption and GDP. The GC results detect bi-directional causality between electricity consumption and GDP suggesting that electricity consumption and GDP are jointly determined. Yoo (2006) and Chen et al. (2007) provide extensive summary tables of results for Granger causality between economic growth and electricity consumption for various countries.

Judging by the review of previous literature discussed above, there is no consensus in the literature about the magnitude of the price and income elasticity of demand for electricity. Some authors also conclude that non-economic variables are the primary determinants of residential electricity and that price and income have less of an impact in the long-run. The lack of converging estimation of price and income elasticities across countries and time indicate the need to estimate demand function for different countries at different times for the purpose of practical policy formulations. This is more important when considering analyses in developing countries where subsidized electricity markets have been functioning for a considerable period of time without any reforms in the sector. As a result, there is still a considerable lack of understanding of long and the short run impacts of price, income and substitution effects on the demand for electricity in developing countries. This study attempts to fill this gap in the literature by estimating the demand for residential electricity in Sri Lanka and by undertaking a long run causality analysis.

Methods and Data

The study uses national level time series data for the period, 1960-2007. The macro variables used are residential per capita electricity demand, per capita real Gross Domestic Product (GDP), average real price of electricity[1], and average real price of kerosene and natural gas. Data obtained from the Ceylon Electricity Board (CEB) are used for electricity sales and price. Data on GDP are from the Central Bank Annual Reports. Kerosene and gas prices, which are the primary substitutes for electricity among households, are from the Ceylon Petroleum Corporation annual reports. Natural gas was introduced to households in Sri Lanka after liberalization of the economy in 1978. Hence, data available for this variable is from 1978.

We use cointegration and the error correction method developed by Engle and Granger (1987) to capture the long-run as well as the short-run relationship among the relevant variables. The first step of the estimation process is to examine the time series properties of the data series. The patterns and trends in the data were examined and tested for stationarity and the order of integration. For this purpose, we employed the Augmented Dickey-Fuller (ADF) tests. Here the null hypothesis is that $\alpha = 0$, that is, there is a unit root. We use the following Equation (1) with lagged difference terms.

$$\Delta Y_t = \beta_1 + \beta_2 t + \alpha Y_{t-1} + \alpha_i \sum \Delta Y_{t-i} + U_t \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where $i = 1 \ldots n$

ΔY_t = First deference of Y variable

Y_{t-1} = One period lag of Y variable

U_t = Stochastic error term

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[1] In Sri Lanka CEB sets the price based on an increasing block rate system. In this study average price of electricity is calculated by using weighted averages. Here as a weight we used the number of customers in each group. [eg. assumes two block rates such as P1 and P2 and no fixed cost (P1<P2). The number of customers in first block and second block ranges are N1 and N2 respectively. The average price is then = (P1 * N1 + P2 * N2)/(N1 + N2). Thus, the average price for electricity was calculated by weighting the number of customers in each group.

As an alternative test we employed Phillips-Perron test. In these tests, the decision to include intercept and/or trend terms depends on the nature of the data (Dickey and Fuller 1979). For example, if the variable is supposed to have a zero mean (as in the case of the error term), there is no need to include neither a constant nor a trend. Otherwise, as Greene (2000) points out it is advisable to include a constant and a trend to capture any drift and/or the trend in the data. We compared the results of the two approaches and include only the results containing the constant since it provides more robust results.

The second step in our method involves testing the cointegration rank. We form a Vector Autoregressive Regression (VAR) system. This step involves testing for the appropriate lag length of the system, including residual diagnostic tests. The approach is based on the following n-lag vector autoregressive (VAR) model

$$X_t = \phi + \Pi_1 X_{t-1} + ...\Pi_k X_{t-n} + U_t \text{..............................(2)}$$

where X_t is a vector of non-stationary (p x 1) with I(1) variables, ø is a vector of constant terms (p x 1), π_1, …. π_k, are coefficient matrices(p x p) and U_t is the vector of error terms (p x 1). We specify the VAR as a four-variable system with a maximum of two lags. The model includes the logarithm of the number of units sold in Killowatt hours (KWh), real GDP per capita (GDP), own price (OP), price of kerosene (PK) and price of natural gas(PG). Various procedures have been suggested for determining the appropriate lag length in a dynamic model in the literature. The procedure employed here includes the Akaike Information Criterion (AIC) and Schwartz's Criterion (SC)[2]. Equation 2 can be represented into error correction form as follows:

$$\Delta X_t = \alpha + \Pi X_{t-1} + \sum_i^n \Gamma_i \Delta X_{t-i} + U_t \text{....................................(3)}$$

where:

X_t is a vector of variables integrated in the same order,

U_t is a vector of white noise residuals, and

α is a constant vector

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[2] Akaike (1973) Information Criterion (AIC); AIC(p) = Ln (e'e /T)+ (2P/T).
Schwartz's criterion (SC); SC(p) = AIC(p) + (P/T) (lnT -2).
P = Number of Lags, T = Time, n = sample size, e'e = Residual some of squares

The above VAR system would give the long-run and short-run dynamics of a group of integrated variables. The presence of distinct cointegrating vectors can be obtained by determining the significance of the characteristic roots of Π. The procedure developed by Johansen (1992) was used to investigate the cointegrating relationship between the integrated series. The Johansen trace test, as well as the eigenvalue test, was used to determine the significance of the number of characteristic roots that are not different from unity.[3] The adjustments to disequilibrium are captured over *n* lagged periods in the coefficient matrix Γ_i. This part of the Error Correction Model (ECM) represents a traditional vector autoregression of the differenced variables. The ΔX_{t-1} term represents long-run equilibrium or cointegrating relationships, and the coefficient matrix can be decomposed into αβ′ matrix. This cointegrating relationship represents the foundation of a complete dynamic error correction model. For this analysis, the ECM and cointegrating relationship allows us to compare the immediate and overall effects and then, the model will show how fast adjustments occur. Next we interpret the cointegrating relations and test for weak exogeneity. Based on these results a vector error correction model (VECM) of the endogenous variables is specified. Tests of linear hypotheses on β are conducted using χ^2 distribution.

Engle and Granger showed that if two series of X and Y (for example) are individually I(1) and cointegrated, then there would be a causal relationship at least in one direction (Enders, 2004). Granger-causality test is a convenient approach for detecting causal relationships between two or more variables (Ghosh, 2009). Therefore, as the final step, we test the long-run causality among the variables using Granger-causality approach. The causality in the long-run exists only when the coefficient of the cointegrating vector is statistically significant and different from zero (Granger and Lin, 1995). In our analysis we apply the variable deletion (F-type) tests for the coefficient of the cointegrating vector.

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[3] Trace test and eigenvalue test for CI rank: $\lambda_{trace}(r) = -T \sum \ln(1-\lambda_i) \quad \sum i = r+1 \ldots\ldots k$ and $\lambda_{max}(r,r+1) = -T \sum \ln(1-\lambda_{i+1})$ where λ_i is the estimated values of the characteristic roots obtained from the estimated Π matrix, r is the number of cointegrating vectors, and T is the number of observations. This allows for the test of H (r): the rank of cointegrating vector is r, against the alternative that the rank of is k.

Results and Discussion

In this section we provide estimates of short and long run electricity demand coefficients on a sample of Sri Lankan annual data covering the period, 1960-2007. This section also reports the results of the long run causality test. Table 1 shows the descriptive statistics of the data set used. Of all the variables used in the study, a higher variation is seen for real GDP.

Table 1: Summary of descriptive statistics of the data: 1960-2007

Variable	Average	Standard deviation	Maximum	Minimum
Quantity demand (KWh/per consumer)	164.46	199.14	692.80	4.20
Real GDP per capita (Rs.)	31295.34	15705.50	69773.66	13563.06
Real Electricity Price (Rs./unit)	2.02	2.64	9.89	0.07
Real Kerosene Prices (Rs./Litre)	8.72	0.05	68.00	13.06
Real Gas Price (Rs./Kg)	15.28	22.63	101.08	4.20

Source: CB, CEB, and CPC (various issues).

Table 2: ADF and Phillips-Perron tests of unit roots in annual data

Variables	ADF and PP tests for level data		ADF and PP tests in first-differenced data	
	ADF test statistics	Phillips-Perron test statistics	ADF test statistics	Phillips-Perron test statistics
KWh	0.349(2)	0.678	-4.317(2)*	-4.318*
GDP	1.818(1)	2.051	-7.448(2)*	-7.418*
EP	0.141(1)	0.248	-8.366(1) *	-8.355*
KP	-0.843(2)	-0.845	-6.075(2)*	-6.053*
GP	0.416(2)	1.051	-6.448(1)*	-6.481*

Note: The 99% and 95% critical values are -3.57 and 2.92 for all the variables, except gas prices. The critical values gas prices are 3.67 and 2.96. These two are slightly different because the number of data points are different. The SIC-based optimum lag lengths are in parentheses. All variables are in natural logs. Significant variables under 1 % are denoted by an *

In regression analysis, one often obtains a very high R^2 which are often not meaningful (Enders, 2004). This situation exemplifies the problem of spurious regression. This problem arises because the time series involved exhibit upward or downward movements and the R^2 observed is due to the presence of the trend and not due to a true relationship between the variables in question (Gujarati, 1995). It is, therefore, very important to determine whether the relationship between economic variables is true or spurious. This was formally tested using the Augmented Dickey-Fuller (ADF) test and Phillips-Perron test for a unit root. The ADF and Phillips-Perron tests results for the variables in the equation are shown in Table 2.

The results in Table 2 show that all variables in the first-differenced data are integrated in order one. This means that the original series are non-stationary, but the first-differenced data are stationary. According to Engle and Granger (1987), if two series are integrated in order one, I(1) we can conduct tests for cointegration. The implication is that it is possible to have a co-integrating vector whose coefficients can directly be interpreted as long-term equilibrium. Therefore, in the next step, a Johansen trace test is used to check whether there is a cointegrating relationship. The results of the trace test and the maximum eigenvalue tests are reported in Table 3. It shows the number of cointegrating vectors.

Table 3: The Pantula principle test results

H_0	r	n-r	Model 1	Model 2	Model 3
λ trace test					
	0	5	103.97(76.97)	78.47(68.81)	105.00(88.80)
	1	4	66.57(54.07)	41.76(47.85)*	68.29(63.87)
	2	3	39.74(35.19)	18.52(29.79)	34.85(42.91)
	3	2	18.28(20.26)	5.78(15.49)	17.91(25.87)
	4	1	5.65(9.16)	0.03(3.84)	5.17(12.51)
λ max test					
	0	5	37.41(33.80)	36.70(37.87)*	36.71(38.33)
	1	4	26.83(28.58)	23.24(27.58)	33.44(32.11)
	2	3	21.45(22.29)	12.74(21.13)	16.93(25.82)
	3	2	12.63(15.89)	5.74(14.26)	12.73(19.38)
	4	1	5.65(9.16)	0.03(3.84)	5.17(12.51)

Note: i. Model 1 includes intercept (no trend) in cointergration, no intercept or trend in VAR. This is the case where there are no linear trends in the data, and therefore, the first differenced series have a zero mean.

Model 2 includes the intercept in cointergration and VAR and no trends in cointergration and VAR. In this case there are no linear trends in the levels of the data, but we allow both specifications to drift around an intercept.

Model 3 includes intercept in cointergration and VAR, linear trends in cointergration and no trend in VAR. In this model we include a trend in the cointergration as a trend-stationary variable in order to take into account exogenous growth.

ii. Critical values under 5% significant levels are given within brackets. The asterix (*) shows that the null hypothesis is not rejected at the 5% level of significance in the first instance.

iii. SIC-based optimum lag lengths in the VECM are set at two.

According to Table 3, we can easily reject the null hypothesis that no cointegration exists, but fails to reject the hypothesis of existence of more than one stationary linear combinations. Although λ trace test statistic provides more than one cointergrating vector, λ max test results provide evidence of having only one cointergration relationship[4]. After considering the linear combination of the existing cointergration vector, we obtain the following results. The results can be used to interpret the long-term equilibrium relationship among the variables for the period, 1960-2007.

Table 4: Long- run relationship between demand for electricity and influencing factors

Variables	Model
KWh	1.000
GDP	0.785(0.210)*
EP	-0.616(0.032)*
KP	0.142(0.010)*
GP	-0.190(0.232)

Notes: Numbers in parentheses are standard errors of the estimated parameters. Asterix (*) denotes the significant variables at 5 % level of significance.

These values were normalized for *GDP, EP, KP* and *GP.* The estimators presented above indicate the long run equilibrium relations among the variables. The results show that there exists a stable long-run relationship among the variables in the model. As expected, GDP, EP and KP play a significant role in influencing the demand for electricity. Table 4 shows the elasticities of demand for electricity with respect to GDP, EP, KP and GP. According to the results, a one per cent increase of per capita real income results in a 0.78 per cent increase in demand for electricity. Similarly, when a one per cent increase in the average price of electricity, the demand decreases by approximately 0.61 per cent. The positive sign for kerosene prices implies that in the long run, kerosene oil functions as a substitute for electricity. Estimated elasticity values show that a one per cent increase in kerosene prices would result in an increase in demand for electricity by 0.14 per cent. The magnitudes of all the variables imply an inelastic relationship with respect to demand for electricity.

In order to appropriately model the dynamic behavior of demand for electricity, we need to incorporate short-run adjustment factors along with the cointegrating equilibrium relationship. This is best done using the error-correction model technique introduced above. The error correction model provides a generalization of the partial adjustment

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[4] When there are multiple cointegrating vectors, any linear combination of these vectors is also a cointegrating vector (Enders, 2004). In such a situation, it is often possible to identify separate behavioral relationships by appropriately restricting the individual cointegrating vectors.

model and permits the estimation of short-run elasticities. Table 5 shows the estimates of the ECM[5].

Table 5 : Estimates of the vector error correction model

Variables	ΔKWh_t	ΔGDP_t	ΔEP_t	ΔKP_t
ΔKWh_{t-1}	0.23(0.11)*	0.09(0.05)**	0.23(0.12)**	-1.51(2.11)
ΔGDP_{t-1}	0.32(0.19)**	0.43(0.21)*	0.16(0.10)**	0.08(0.04)*
ΔEP_{t-1}	-0.16(0.04)*	-0.58(0.12)*	-1.06(1.14)	0.04(0.01)*
ΔKP_{t-1}	0.10(0.06)**	1.24(0.28)	-0.79(.84)	-0.19(1.23)
ΔGP_{t-1}	0.09(0.03)*	0.39(0.25)	0.03(0.01)*	0.26(0.16)**
u_{t-1}	-0.12(0.05)*	-0.03(0.01)*	0.13(0.12)	0.53(0.46)

Notes: Numbers in parentheses are standard errors of the estimated parameters. The asterix (*) denotes the significant variables at 5 % level of significance. The optimum lag length was set using the SIC criterion and they are one.

The two most important equations in the error correction model are those containing ΔKWh and ΔGDP as dependent variables. These models contain significant error-correction terms. This term was obtained from the long-run relationship and expressed deviations in electricity consumption from its long run mean. This coefficient measures the speed of adjustment in current consumption to the previous disequilibrium demand value. The error-correction term in this equation is significant and has a coefficient of –0.12. This indicates that when demand is above or below its equilibrium level, consumption adjusts by approximately 12 per cent within the first year. Furthermore, we can see that around 20 per cent of the KWh response to disequilibrium occurs within the immediate period after a shock, and around 32 per cent of the domestic production response occurs within this period. The short-run elasticities with respect to EP and KP were approximately -0.16 and 0.10 respectively. The short run elasticity for gas prices is very low. However, it is significant.

The second equation highlights the short-term impact that KWh, GDP, EP KP and GP can have on gross domestic production. Accordingly, the elasticity of electricity demand in relation to the KWh is 0.09 and elasticity of income electricity of demand and own price are 0.43 and –0.58 respectively. However, Kerosene and gas prices in this equation are

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[5] We have dropped the gas price equation since it has not provided robust results.

not significant. Almost all estimated coefficients in this second equation are found to be significant. The error-correction term in this equation is significant and has a coefficient of –0.03 which is very low value. We can compare our results with some other studies conducted that deal with own-price and income elasticity of demand in the short and in the long run. Our estimation of electricity demand shows that the short run elasticities with respect to income and the price of electricity were 0.32 and -0.16 respectively. The short run income elasticity is greater than the price elasticity of demand.

Our price and income inelastic results are consistent with the results of previous studies. Donatos and Mergos (1991); Barnes and Qian (1992); Silk and Joutz (1997); Holtedahl and Joutz (2000); Reiss and White (2001) have also found similar inelastic price and income elasticity of demand for electricity. Our long run estimation of demand for electricity shows that the long run elasticities of electricity with respect to income and electricity price were 0.78 and -0.61 respectively. In the previous literature, some of the studies (see, for example, Halvorsen, 1975; Dunstan and Schmidt, 1988) show that the long run price elasticity is greater than one, while other studies (see, for example, Silk and Joutz , 1997; Miller, 2002) show that the elasticity values are less than one. However, our results are consistent with economic theory where it is shown that the long run price and income elasticities are greater than the short run price and income elasticities. It is clear that our short run income and price elasticities are greater than that of the above results. The results indicate that income and own price are important determinants of demand for electricity in Sri Lanka.

One of the interesting features of the VAR model is that it allows us to test for the direction of causality. The causality in the long-run exists only when the coefficient of the cointergration vector is statistically significant and different from zero (Granger and Lin, 1995). In this analysis we use the long-run Granger causality test. It involves variable deletion (F-type) tests for the coefficient of the cointergrating vector. The results of the Granger causality test are reported in Table 6.

Table 6: Granger type causality

Direction	F Value	Critical Value
ED to GDP	4.321*	3.23
GDP to ED	5.254*	3.23
ED to PRI	3.621*	2.84
PRI to ED	4.413*	2.84
ED to KPI	2.324	3.23
KPI to ED	3.819*	3.23

Notes: F values are calculated by using different sets of variables. Critical values are different due to the different lag lengths.
Asterix (*) denotes rejection of null hypothesis at less than 5% level of significance.

The results shown in Table 6 suggest two-way causality. For example, row one suggests the demand for electricity causes GDP to increase, while row two suggests GDP causes electricity demand to increase. The GC results also detect bi-directional causality between electricity price and its consumption suggesting that these two variables are jointly determined. However, one-way causality running from kerosene price to electricity demand was found (row six). The results show the direct impact of demand for electricity on the economic growth of Sri Lanka during the period,1960-2007.

Conclusions and Policy Implications

This study estimates the determinants of residential electricity demand among households in Sri Lanka using macroeconomic time series data for the period, 1960-2007 in Sri Lanka. The results clearly show that demand for electricity is price and income inelastic. However, as expected it is more responsive in the long-run than in the short-run. It is clearly seen from error correction modeling that both real income and electricity consumption are positively related. The study further reveals that consumers do not adjust immediately after energy price shocks. The error-correction term is significant and has a coefficient of – 0.12, indicating that when demand is above or below its equilibrium level, consumption adjusts by approximately 12 per cent within the first year. Furthermore, the results show that kerosene oil is a substitute for electricity in the short as well as in the long-run. However, natural gas becomes a substitute only in the short-run and not in the long-run. In terms of the direct positive relationship between electricity consumption and GDP, it would seem reasonable that higher incomes lead to the purchase of items that require more electricity consumption. This is to be expected (Chen et al. 2007).

The long-run income elasticity of demand is 0.78. This means that a one percent increase in GDP increases electricity consumption by 0.78 per cent. If the economic growth is persistent and if income doubles in the next 10-15 years, it will increase the demand for electricity by an extra 78 % among the households currently using electricity in Sri Lanka. As far as the price of electricity is concerned, the tariff reforms can play a potentially important role as a long run demand side management tool in Sri Lanka. The effects of any price revisions on consumption will depend on the price elasticity of demand for electricity. The results of the study show that a pricing policy alone will not be effective in managing future household electricity demands in Sri Lanka in the short run. However, the inelastic nature of the demand reveals that any price increase will increase the revenue of the electricity generator which currently is government owned. This finding shows that it possible for the government to reduce the subsidies it provides to the electricity and thereby restore economic efficiency in the sector.

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