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Keywords

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Abstract

This study examines the short and long-run relationship between electricity demand and its determinants in the Iranian residential sector. The study employs unit root tests, cointegration and error-correction models on annual time series for the period, 1967–2009. The results show that electricity price is insignificant and income elasticity is lower than unity. The most influential factor influencing household electricity demand is cooling degree days. The number of electrified villages (an indicator of economic progress) is statistically significant, showing that economic progress has a positive impact on electricity demand. Electricity demand is forecast until 2020. The results show under the most probable projection, electricity consumption in the residential sector will grow at an annual rate of 29% and 80% by 2014 and 2020, respectively.

Keywords: Iran; Residential electricity demand; Economic development; Electrified villages; ARDL; Structural breaks; Short- and long-run price and income elasticities.

JEL Codes: C22, C51, D12, Q41, Q43, Q48

1. Introduction

Electricity generation and distribution are controlled by both the private and government sectors in Iran, predominantly the state. Electricity in Iran is subsidized. In order to support and encourage private contribution, electricity generated by the private sector is bought by the state and distributed to final consumers. Currently, the retail electricity price is set by the government and the electricity price at all levels of consumption, is below its production cost (Bureau of Electricity and Energy Planning, 2010, BEEP). The real price of electricity for the residential sector during the sample period experienced over a 95% decrease from 1967 to 2009 (Figure 1)[1].

[Figure 1, about here]

Major concerns of Iranian energy policy makers relate to the high growth rate of domestic demand and inefficient use of electricity. Per capita electricity consumption tripled in the last two decades (1990-2010) and the average growth of per capita electricity consumption in Iran (7.9%) was over two times higher than the global average (3.3%) (TAVANIR Deputy of Human Resources and Research, 2008, TAVANIR).[2] These statistics show that if the current growth rate remains unchanged, electricity consumption will double within one decade. Therefore, investigating the issue of electricity demand in Iran is of crucial importance. Table 1 presents historical data for the per capita electricity consumption growth rate from 1975 to 2010. As can be seen the growth rate has been very volatile between 1.5 in 1980 and 15.1 in 1983.

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[1] The reason for such a large decline in real electricity price is the considerable increase in the consumer price index (CPI) after the Islamic revelation. In 2009, the CPI was 586 times higher than that of 1967 and rose from 0.98 to 575.12 (base year 1997).

[2] TAVANIR denotes the Management Organization of Iranian Electricity Generation, Transmission, and Distribution.

[Table 1, about here]

Households in many countries account for a large proportion of electricity consumption. The residential sector is the major electricity end user in Iran accounting for 33.2% of total electricity consumption (IIES, 2010). The equivalent figure for the world and other regions is much lower than that of Iran (BEEP, 2011).[3] In 2009, household electricity consumption experienced a 41% increase compared to 1989 and reached 2,803 kWh. The International Energy Agency (IEA) statistics show that per capita electricity consumption in Iran in 2008 was 2,423 and this figure for the world reached 2,782 kWh (IEA, 2010). The large volume of electricity consumption by households is mainly due to the inefficient utilisation of electric appliances (BEEP, 2008). Therefore an investigation of the behaviour of residential end users is essential for policy makers to establish energy policies aimed at persuading consumers toward more efficient utilization of energy.

This paper makes several significant contributions to the analysis of residential electricity demand of the Iranian economy. This is the first study to examine several variables for modelling electricity demand in Iran taking into account features specific to the Iranian power industry such as weather conditions and economic progress. This study forecasts electricity demand (until 2020). Moreover, preveious Iranian studies on residential demand have not employed the Autoregressive Distributed Lag (ARDL) approach, which is consistent with the properties of a small sample (Mah, 2000), or examined the data for structural breaks. This study

[3] The residential sector share for the world is 27.4% and for Asia and Oceania, Central and South America, Eurasia and Africa are 20.6%, 26.5%, 26.2%, 31.4% respectively.

employs the multiple structural break tests of Lee and Strazicich (2003) and Narayan and Popp (2010).

The rest of this paper is structured as follows. Section 2 reviews the literature. Section 3 presents the theoretical framework. Section 4 details the data and methodology. Section 5 discusses the empirical results; Section 6 forecasts electricity demand until 2020 and Section 7 concludes.

2. Literature review

The literature on residential electricity consumption has employed diverse methodologies. See for example, the studies of Flaig (1990) for Germany, Filippini (1999) for Switzerland, Kamerschen and Porter (2004) for the US, Atakhanova and Howie (2007) for Kazakhstan, Narayan *et al.* (2007) for the G7 countries and Nakajima (2010) for Japan (see Table 2 for a summary of studies). The present study employs unit root tests allowing for multiple structural breaks and the ARDL method. Studies using the time series methods are discussed below.

Flaig (1990) and Narayan *et al*. (2007) find that income and price elasticities are lower than unity in the short-run suggesting that electricity consumption is inelastic with respect to changes in income and price. Long-run elasticities in the former are lower than unity suggesting that consumers are not responsive to changes in income and electricity price. But in the latter, price elasticity is -1.45 indicating that electricity demand would decrease by 1.45% if electricity price increases by 1%. Flaig considers fuel oil and Narayan *et al*. (2007) gas as substitutes for electricity. In both studies, the coefficients of the considered fuel are positive which confirms the complementarity with electricity. Filippini (1999), Kamerschen and Porter (2004), Atakhanova and Howie (2007), and Nakajima (2010) present long-run price and income elasticities. The first two studies show that price and income elasticities are lower than unity. The study of Atakhanova and Howie (2007) shows that price elasticity depending on the method used, varies between -0.22 and -1.10 and income elasticity between 0.12 and 0.59. Nakajima (2010) finds that price elasticity varies between -1.20 and -1.13 and income elasticity between 0.60 and 0.65. The number of households and size of household are two significant variables affecting the electricity demand of Swiss households in the study of Filippini (1999) with elasticities of 0.90 and 1.53 for price and income, respectively.

Silk and Joutz (SJ) (1997) use the Johansen and Juselius (1990) methodology, Holtedahl and Joutz (HJ) (2004) apply the Hendry and Juselius (2000; 2001) method and Dergiades and Tsoulfidis (DT) (2008) and Narayan and Smyth (NS) (2005) the ARDL approaches. DT use the critical values (CVs) employed by Narayan (2004).[4] They show that residential electricity demand has a low sensitivity to price and income changes in the short-run. SJ and NS find that income and price elasticities in the long-run are lower than unity, whereas the studies of DT and HJ find elasticities of -1.60 and 1.04 for price and income respectively. DT and SJ show the coefficients for weather conditions to be statistically significant but lower than unity in the short and long run for the US. HJ finds only cooling degree days to be significant in the short-run for Taiwan. Conversely, NS finds that residential electricity demand within Australia is sensitive to weather conditions in the long-run with an elasticity of 1.69. Both SJ and DT find fuel oil to be a replacement for US residential electricity. HJ incorporate the world price of oil into the model and find that oil is a good alternative for residential electricity in Taiwan. NS consider natural gas. Their results show that natural gas is not a substitute for electricity.

[4] Narayan (2004) computed critical values (CVs) for the ARDL approach for sample sizes ranging from 30 to 80, and found that the CVs in Pesaran *et al*. (2001) are 35% lower than those found in his research.

HJ (2004) argues that electricity modelling for developing countries could be different to industrialized countries, and introduces a general model for the residential sector. They use the degree of urbanization as a proxy for technological change in the stock of electrical appliances. The results show that urbanization elasticity in the short- and long-run are 1.61 and 3.91, respectively. DT use the occupied stock of houses as a proxy for the stock of electrical appliances. The coefficient for the stock of occupied houses is 1.50 implying a strong impact on the electricity use of households.

The literature on residential electricity demand for developing countries, including Iran is limited. The only investigations of residential electricity demand for Iran have been conducted by Amini Fard and Estedlal (2003) and Askari (2002) which use the Johansen and Juselius (1990) and generalized least squares methods, respectively. In addition to price and income, the latter includes the rate of power outage and the former, dummy variables for the quality of electricity supply and the Iran-Iraq war. The impact of these variables on residential electricity consumption are negative. The short- and long-run price elasticities in the former study are -0.97 and -1.36 while the latter presents own price elasticities of 0 and -0.59 respectively, suggesting that households are not responsive to price. The short- and long-run elasticities for income in the Askari study are 0.11 and 0.16, while in Amini Fard and Estedlal, they are 0 and 0.24. That is, household electricity demand is not sensitive to changing household income.

Iranian studies have applied the ADF tests, however, they have not taken into account the presence of structural breaks. In the presence of structural breaks, the results from unit root tests can be misleading in terms of the non-stationarity of time series data (Perron, 1989). In addition, the use of traditional cointegration methods on small samples can lead to small sample size bias and the results obtained from these studies could be unreliable. Therefore the present study corrects for this by taking into account structural breaks.

As seen in Table 2 all studies have investigated the impacts of price and income on electricity demand of households. Few studies have considered the effect of weather conditions and the price of substitute energy for electricity. In a limited number of studies electricity and income have elasticities higher than unity (see the studies of Beenstock *et al.* (1999), Holtedahl and Joutz (2004) and Zachariadis & Pashourtidou (2007)). The majority of studies have found electricity demand inelastic with respect to income and electricity price.

[Table 2, about here]

3. Theoretical framework

The theoretical foundation of studies on residential electricity demand, are mainly based on theories of consumer behaviour.[5] Here, electricity is a good which has direct effects on consumer utility. Maximization of consumer utility subject to a budget constraint, taking the first derivative and solving the system of equations will yield the demand for electricity and other commodities. If the demand function is characterised by a constant elasticity of demand, then the total electricity demand of all consumers at time *t* will be a function of price of electricity, substitute

[5] The theoretical foundation also can be based on a household production function which presents electricity as a good which is purchased by households in the market and combined with a capital stock of appliances to produce an electric composite commodity (Dubin, 1985; Flaig, 1990). Electricity impacts consumer utility indirectly and through electric composite goods. Electricity demand is derived as a function of the price of composite goods produced by households (such as food), the price of electrical appliances, energy price, income, price of substitute energy. Due to the lack of data for the price of composite goods the majority of studies analyse residential electricity demand in the context of consumer behaviour theory.

and other goods, consumer income and geographical and demographic factors. Taking the log transformation of the electricity demand function results in:[6]

$$q_t = \alpha p_{et} + \beta p_{st} + \tau p_{xt} + \gamma y_t + \delta g_t \qquad (1)$$

where the q_t, p_{et}, p_{st}, p_{xt}, y_t and g_t display the log values of the electricity demand, price of electricity, substitute and other goods, consumer income and geographical factors respectively.

Rapid development can be another factor influencing electricity demand in developing countries (Halicioglu, 2007; Holtedahl & Joutz, 2004). In addition, considering that households use electricity for air conditioning it is expected that variations in temperature may impact residential electricity demand. Therefore, inserting a weather variable to the model is important. Deriving a composite price for other goods (p_{xt}) is generally difficult particularly in the case of Iran where data is limited. Moreover, changes in price of other goods do not play a significant role in the consumption of electricity by households due to two reasons. First electricity cost share in the total expenditure of an Iranian household is very low (between 0.5 to 1.7% (BEEP, 2011) and second, electricity is an essential service for households. Therefore, considering the low sample size of this study and in order to save degrees of freedom, p_{xt} is omitted from the residential model. The modified model is redefined as:

$$q_t = \alpha p_{et} + \beta p_{st} + \gamma y_t + \theta e_t + \eta w_t \qquad (2)$$

where e and w represent economic progress and weather conditions. Other variable definitions are the same as for Equation (1).

[6] Appendix A contains details of obtaining the demand function.

4. Data and Econometric Methodology

This analysis relies on annual observations from 1967 to 2009. The following variables are used in the study. The influence of household income on electricity consumption is proxied by final fixed expenditure of household consumption (*hco*)[7]. Development can increase the social well-being of people by providing critical infrastructure such as electricity. Therefore, the number of electrified villages (*nv*) is used as a proxy for economic progress. Cooling degree days (*cd*) is used to test for the effects of weather on electricity demand. A one degree *cd* shows that the outside temperature is one degree higher than the base temperature (21^{oC}). The annual index is an accumulation of daily indices. In the current paper *cd* for the overall country is obtained by summing the results for 25 cities.

The series used in the study are residential electricity demand (*cr*), residential electricity price (*epr*), residential natural gas price (*gp*), final fixed expenditure of households (*hco*), number of electrified villages (*nv*) and cooling degree days (*cd*). The data are collected from TAVANIR, the Ministry of Petroleum and the climate factors from the Iranian Meteorological Organization and the Iranian Central Bank. The nominal data have been deflated using CPI with 1997 as the base year. All data series are converted into logarithmic form for the empirical analysis.

Dickey and Fuller developed a unit root test (1981, ADF) to study the time series properties of the data. Perron (1989) showed that the ADF test may be biased in favour of non-

[7] Initially, income was considered in the model, but the estimated coefficient was negative, which might have been due to unreliability and low accuracy of data for household income. This is possibly because, households do not express their real income due to safety issues. Therefore, final fixed expenditure is used. Additionally, a theoretical justification for this can be found in the Permanent Income Hypothesis which suggests that consumption is a good measure of expected permanent income.

rejection of the null hypothesis of a unit root when the series has a structural break. Lee and Strazicich (LS) (2003) argued that rejection of the null hypothesis of the ADF-type tests[8] implied rejection of a unit root without breaks rather than rejection of unit roots *per se*. Under the LS (2003) tests structural breaks are allowed under the null and alternative hypotheses and the results remain unaffected by breaks under the unit root null hypothesis.

Since the 1970's, several political and economic incidents (such as the Islamic revolution and the Iran-Iraq war) have occurred which may have affected the macroeconomic series and consequently the microeconomic data including the applied series used in this research. Therefore, it seems important to check the time series for stationarity and structural breaks. In this research the stationarity of the applied series are examined using the ADF, LS and NP tests. The ADF test is based on the following regression:

$$\Delta y_t = \alpha y_{t-1} + \sum_{i=1}^{k} \beta_i \Delta y_{t-i} + x_t' \gamma + u_t \qquad (3)$$

where y is the time series being tested for a unit root at time t and T is the number of observations. x_t is the exogenous variable (a constant or a constant and trend). Δ denotes the first difference operator and u_t is an *i.i.d* error term. Following Engle and Yoo (1987) the Akaike information criterion (AIC) is used to determine the optimal lags.

The LS test statistic is the *t*-statistic of α in Equation (4):

$$\Delta y_t = \delta' \Delta Z_t + \alpha \tilde{y}_{t-1} + \sum \Delta \tilde{y}_{t-i} + u_t \,;\; \tilde{y}_t = y_t - \tilde{\psi}_x - Z_t \tilde{\delta} \,;\; \tilde{\psi}_x = y_1 - Z_1 \tilde{\delta} \qquad (4)$$

Where Z_t is a vector of exogenous variables, δ' is the corresponding parameters of the vector. LS defined Model AA capturing two breaks in the level and $Z_t=[1,t,DU_{it}]'$ and Model CC capturing

[8] ADF-type tests such as Zivot and Andrews (1992) and Lumsdaine and Papell (1997) tests are derived under the null hypothesis of a unit root without break(s).

two breaks in the level and trend and $Z=[1,t,DU_{it},DT_{it}]'$. Where, DU_{it} are dummy variables capturing breaks in the level and DT_{it} are breaks in the level and trend, respectively. DU_{it} and DT_{it} are one and $t\text{-}Tb_i$, respectively if $t\geq Tb_i+1$ and zero otherwise ($i=1,2$). $\tilde{y}$ is the detrended value (following Schmidt and Phillips (1992)). $\tilde{\delta}$ are the coefficients in the regression of Δy_t on ΔZ_t. $\Delta\tilde{y}_{t-i}$ corrects for the presence of autocorrelated disturbances. The optimal lag length is selected by applying the general-to-specific method proposed by Ng and Perron (1995).

As was mentioned LS (2001; 2003) argued that the results of the ADF-type unit root tests, in the presence of a break may be biased. Narayan and Popp (2010) solved this problem and introduced models M1 and M2 which allow two breaks in the level and two breaks in the level and trend. The NP test is based on the following equations:

$$y_t^{M1} = \rho y_{t-1} + \alpha_1 + \beta' t + \sum \theta_i D(Tb')_{it} + \sum \delta_i DU'_{it-1} + \sum_{j=1}^{k} \beta'_j \Delta y_{t-j} + e'_t \quad (5)$$

$$y_t^{M2} = \rho y_{t-1} + \alpha'_1 + \beta'' t + \sum k_i D(Tb')_{it} + \sum \delta'_i DU'_{it-1} + \sum \gamma'_i DT'_{it-1} + \sum_{j=1}^{k} \beta''_j \Delta y_{t-j} + e''_t \quad (6)$$

where Tb'_{it} are the break dates, $i=1,2$. DU_{it} and DT_{it} are one and $t\text{-}Tb_i$, respectively if $t> Tb_i$ and zero otherwise. $D(Tb'_i)$ is one if $t=Tb_i+1$ and zero otherwise. The t-statistic of ρ is used to test the null hypothesis of a unit root with two breaks (H_0: $\rho=1$) against the alternative hypotheses (H_1: $\rho<1$).

The Autoregressive Distributed Lags (ARDL) method is suited for a small sample such as the current research. This approach can be used for a mix of I(1) and I(0) regressors along with the structural break elements in the model. Following Pesaran and Pesaran's (2001) approach, this study estimates an unrestricted error correction model applying the OLS method:

$$\Delta cr_t = c_0 + \sum_{i=1}^{p} c_{1i}\Delta cr_{t-i} + \sum_{i=0}^{q_1} c_{2i}\Delta epr_{t-i} + \sum_{i=0}^{q_2} c_{3i}\Delta gp_{t-i} + \sum_{i=0}^{q_3} c_{4i}\Delta hco_{t-i} + \sum_{i=0}^{q_4} c_{5i}\Delta nv_{t-i} + \sum_{i=0}^{q_5} c_{6i}\Delta cd_{t-i} + \lambda_1 cr_{t-1} + \lambda_2 epr_{t-1} + \lambda_3 gp_{t-1} + \lambda_4 hco_{t-1} + \lambda_5 nv_{t-1} + \lambda_6 cd_{t-1} + \eta DUM_j + \varepsilon_t \quad (7)$$

where *i* is the number of the optimal lag. The maximum number of lags for yearly data is two lags (Pesaran & Shin, 1999). *DUM* is the vector of deterministic components of structural breaks (*j=1,2*). In the ARDL method the null hypothesis is that there is no long-run relationship between the variables (H_0: $\lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 = \lambda_5 = \lambda_6 = \eta = 0$). If the *F*-statistic falls outside of the upper bound the null hypothesis is rejected and a long-run relationship exists. If cointegration is detected the following regression estimates the long-run equilibrium:

$$cr_t = a_0 + \sum_{i=1}^{k} a_1 cr_{t-i} + \sum_{i=0}^{l} a_2 epr_t + \sum_{i=0}^{m} a_3 gp_t + \sum_{i=0}^{n} a_4 hco_{t-i} + \sum_{i=0}^{p} a_5 nv_{t-i} + \sum_{i=0}^{r} a_6 cd_{t-i} + \alpha_7 DUM_j + \kappa_t \quad (8)$$

Considering that the determinants of residential electricity demand are microeconomic data, which theoretically do not play a significant role for each other, we do not expect to detect more than one cointegrating relationship. Although, Inder (1993) argues that the endogeneity bias in the ARDL models is minimal, in this study to examine the endogeneity of the regressors the Hausman (1978) test is used. The short-run model is constructed on the error correction term (*ecm*)[9] derived from the long-run model as follow:

$$\Delta cr_t = \beta_0 + \sum_{i=1}^{k} \beta_1 \Delta cr_{t-i} + \sum_{i=0}^{l} \beta_2 \Delta epr_t + \sum_{i=0}^{m} \beta_3 \Delta gp_t + \sum_{i=0}^{n} \beta_4 \Delta hco_{t-i} + \sum_{i=0}^{p} \beta_5 \Delta nv_{t-i} + \sum_{i=0}^{r} \beta_6 \Delta cd_{t-i} + \beta_7 ecm_{t-1} + \mu_t \quad (9)$$

[9] $ecm = cr_t - a_0 - \sum_{i=1}^{k} a_1 cr_{t-i} - \sum_{i=0}^{l} a_2 epr_t - \sum_{i=0}^{m} a_3 gp_t - \sum_{i=0}^{n} a_4 hco_{t-i} - \sum_{i=0}^{p} a_5 nv_{t-i} - \sum_{i=0}^{r} a_6 cd_{t-i} - \alpha_7 DUM_j$.

5. Results and Discussion

The results of unit root tests show that only cooling degree days is I(0) based on the ADF test while, the results of the LS unit root test[10] show that all series are I(0) except electricity price. This could be due to a large change in the real price of residential electricity (over 95% declines) during the sample period (see Figure 1). Based on the NP test, residential electricity demand, number of villages and cooling degree days are I(0) (see Table 3). The ADF and NP tests do not reject the null hypothesis of unit root for five and three series respectively, while the LS test does not reject the null hypothesis only for one series. These contradictory results among different unit root tests can be due to the tendency of the ADF-type tests not to reject the null hypothesis of a unit root as argued by Perron (1989). The LS and NP tests detect two breaks for all series of interest. However, the break dates reported by the tests are identical in a few cases (shown in bold). Considering the possibility of under rejection of the null hypothesis by the NP test, the LS test will be considered for estimation of the models of electricity demand. The breaks for electricity consumption occurred in 1980 and 1990 based on the LS test. The former break is the start of the Iran-Iraq war and the latter date the post-war reconstruction period.

[Table 3, about here]

As seen, the variables under consideration are of order I(0) and I(1). This confirms that the ARDL approach, which applies I(1) and I(0) series in the models, is an appropriate technique in the case of this research. In addition, the LS unit root test finds that residential electricity demand has two significant breaks and this is another reason for using the ARDL method. However this variable is stationary which confirms that the transitory impacts of the breaks

[10] The trimmed region is [0.1T, 0.9T].

should be examined when modelling electricity demand. The ARDL method allows for inclusion of two dummy variables relevant to the break dates, to take into account the impacts of structural breaks on the system.

The computed *F*-statistic is 3.92 which is greater than the upper bound value at the 10% significance level suggesting that there is a long-run relationship between the series of interest.[11] Table 4 presents the results of the long-run equation.

[Table 4, about here]

The insignificant variables are price of electricity and natural gas. Long-run price and income elasticities are zero and 0.58, respectively, which implies that households are not responsive to changes in income. This result is expected because electricity is a basic commodity for households. Moreover, the low price of electricity may be another reason for the insensitivity of household electricity consumption to changes in electricity price.

The most influential factor on residential sector electricity demand is cooling degree days indicating that the amount of electricity used for cooling buildings is considerable. Another factor impacting electricity demand is the number of electrified villages, an indicator of

[11] Evidence shows that electricity consumption from many years ago does not impact the demand for electricity in the current year. Therefore, Pesaran *et al*. (1999) recommend a maximum number of two lags for annual data. The SBC and AIC were used to define the order of the ARDL model but the results presented by the AIC gave a better estimation.

economic progress.[12] This implies that there is a positive and statistically significant relationship between residential electricity consumption and economic progress.

The results show that natural gas is not a substitute for electricity in the residential sector. This inference is not unexpected because electricity is mainly used for lighting, air conditioning, and electrical appliances and none of the other fuels can be used for these purposes.[13] The relevant dummy variables have no explanatory power and have unfavourable impacts on the diagnostic tests, and so were omitted from the model. This is not an unexpected result as the inferences of the LS and NP unit root tests show that residential electricity demand is I(0). That is, the impacts of shocks on this variable are transitory.[14]

The short-run model for residential electricity demand is given in Table 5.

[Table 5, about here]

Consumption of residential electricity in the short-run is mainly impacted by the growth rate of household expenditure and weather conditions. The short-run elasticities of price and income are insignificant. These results are reasonable given the contradictory results in unit root tests.

[12] Urbanization and literacy rates were used in the model as proxies for economic development, but the model including the number of electrified villages gave a better result. An issue arises regarding the direction of causality which can run from electricity demand to the number of electrified villages, as growth in electricity demand could be assumed to be a determining factor of the extent to which rural electrification projects are carried out. This is examined by applying the Durbin-Wu-Hausman exogeneity test (Table 7). The result shows that the causal relationship is not from electricity consumption to the number of electrified villages. Moreover, considering the fact that providing infrastructure such as electricity mainly depends on government funding resources, therefore, it is not expected that electricity demand impacts the number of electrified villages.

[13] Kerosene and liquid gas were tested as the substitutes for electricity but no relationship was detected.

[14] Fisher & Keysen (1962) argued that the stock of electrical appliances is another factor that could be considered in electricity demand modelling. In this study total annual final expenditure on home durable goods was examined in the model as a proxy for this variable. The applied proxy did not demonstrate the expected results and reduced the reliability of the estimated model; thus, it was omitted from the model.

Additionally, households take time to respond to changes in electricity price and income, changes in preferences and habits, and replace old electrical appliances with more modern and electricity efficient ones. The coefficient on the error correction term is -0.21 suggesting that 21% of any disequilibrium is adjusted each year. That is, the full convergence process to its equilibrium occurs after about 4.8 years.

The long- and short-run equations pass the standard diagnostic tests for autocorrelation (Durbin and Watson 1950; 1951), functional form (Ramsey 1969), normality (Jarque and Bera, 1980) and heteroskedasticity (Koenker 1981) at the 5% level. The cumulative sum (CUSUM), the cumulative sum of squares (CUSUMSQ) and Quandt-Andrews (Andrews 1993; Hansen 1993; Quandt 1960) tests are applied to determine whether the functions are stable over time. As seen in Figure 2 the CUSUM and CUSUMSQ tests reveal that the coefficients of the models during the sample period of the study are stable, with the two statistics falling within the 5% critical bounds. The results of the Quandt-Andrews test confirm the stability of the parameters. As seen in Table 6 the null hypothesis of no breakpoints within trimmed data cannot be rejected by any of the statistics.

[Figure 2, about here]

[Table 6, about here]

The estimated long-run model is examined for the presence of endogeneity. The results of the Wu-Hausman statistic tests show that the null hypothesis of exogeneity cannot be rejected for any of the regressors (See Table 7). The Wu-Haushman statistic is the F-statistic which is 1.62.

As seen in the table the t-ratio of all exogenous variables suggest that the hypothesis of exogeneity cannot be rejected.

[Table 7, about here]

6. Residential Electricity Demand Outlook

2010-2014

Prior to using the models to forecast electricity demand the performance of the estimated equation is evaluated through the one-step-ahead predictor and an in-sample forecast. Under the former, electricity consumption during the sample period is forecast using the estimated model. The forecast and comparison is conducted for the whole sample period rather than what usually is done for the last 5 years of the sample period. Under the latter method, the model is examined with respect to a change in one of the determinants during the sample period. Figure 3 part (a) shows that the forecast moves closely to the actual data and part (b) shows that a 30% increase in household expenditure results in an increase in electricity demand of the residential sector with changes in accordance with economic theory. Therefore, the model can be used to estimate future residential electricity demand.

[Figure 3 about here]

Scenarios

To forecast electricity consumption in the years ahead, future values for the exogenous variables should be determined. Applying the most probable cases that may occur for each regressor, nine scenarios are defined to predict residential electricity consumption in Iran from 2010 to 2014 (the years of the Fifth Five-Year Economic, Social and Cultural Plan) and then from 2015 to 2020.

Iranian energy policy makers aim to remove the implicit energy subsidy by end of 2014.[15] Three cases for electricity price are defined: High (H), Moderate (M) and Low (L) cases - 66%, 46% and 20%. If electricity is generated under non-subsidised fuel for power plants, the retail electricity price should increase by 66% to reach the electricity generation cost by 2014 and under subsidised fuel 46%. 20% is chosen because it is a lower percentage than the moderate case. If the energy subsidy were removed, it is expected that household expenditure in the years ahead would increase considerably. Three cases, Low (L), Moderate (M) and High (H) are considered as 6%, 9% and 12%.[16]

The growth rate of the price of natural gas is based on the assumption that the price will be equal to the generation cost by 2014 (70% per year).[17] Cooling degree days for the years 2010 to 2014 is computed based on the average of each variable in the last five years of the sample period.[18] The number of electrified villages is based on the announcement of the MOE that in 2010, 646 villages had been electrified, and that 15.2% of villages with fewer than 20 households do not have access to electricity (TAVANIR, 2011a). This figure represents around 2,143 villages (author's calculations).[19] Considering the pace of electrification of villages in Iran recently, it can be expected that each year 900 villages are electrified.[20] Therefore, in 2011 and 2012 the variable is increased by 900 villages. In 2013, the remaining number of villages (343) are added. In 2014 the number of total electrified villages is unchanged, as all villages will have access to electricity by 2013. Figure 4 summarises the forecast assumptions for the annual

[15] Details concerning the removal of energy subsidies can be found in the Targeting of Subsidies Plan approved by the Iranian parliament in January 2010.

[16] 6% (Low case) is the average growth rate of household expenditure within the sample of this study (1967-2009). 9% and 12% are the highest growth rates of household expenditure during the last two decades (1991-2010).

[17] The nominal price of the natural gas price in 2010 remained unchanged from 2009.

[18] Data for these variables are not available for 2010 and 2011.

[19] The total number of villages with fewer than 20 households was 14,100 in 2009 (TAVANIR, 2011a) .

[20] This figure is the average of the number of electrified villages during the last decade (2001-2010).

growth rates of the variables. Scenario LL in the graph corresponds to the low case for electricity price and the low case for household expenditure.

[Figure 4 about here]

Electricity demand from residential households can be forecast using the model for the residential sector and the scenarios described above. Figure 5 shows that electricity demand continues to rise during the forecast period under most scenarios. However, in some graphs the slope of electricity demand seems to be zero or very close to zero. Table 8 confirms the negative trend of electricity demand in 2014 under most scenarios. In scenarios ML, HL and HM, residential electricity use will decline by 1%, 2% and 1% by 2014 respectively, while under other scenarios it will rise by 2% to 3%. Two scenarios, LL and MM, cause a zero growth rate of electricity demand by the end of the forecast period.

The demand projections show that residential electricity demand in 2014 varies between 64,749 (in the HL scenario) and 77,982 GWh (in the LH scenario). Low-cost electricity does not change electricity demand in the sector significantly, so it is not appropriate from an energy conservation standpoint. In this case there is an increase of 19% to 34% in residential electricity demand compared to 2009. Inefficient electricity demand by residential users and a high discrepancy between electricity price and production cost results in higher electricity demand. The high electricity price case seems unrealistic, as it gives a very high annual growth in household electricity price (66%). Therefore, the moderate case for electricity price seems the most plausible.

In the case of household expenditure, it is expected that the removal of the energy subsidy and economic sanctions will escalate household expenses significantly. That is, the high electricity price case for household expenditure appears to be the most plausible case. Therefore, the most viable scenario is that of MH. Under these demand projections, electricity use increases from 58,101 GWh in 2009 to 74,849 in 2014, the annual growth rate is cut from 8% to 2% in 2014, and the electricity demand of households rises by 29% compared with 2009.

[Figure 5 and Table 8 about here]

2015-2020

Applying the most probable scenario (MH) and models estimated in this study, the residential electricity demand outlook during the period 2015 to 2020 is estimated. The assumptions for electricity price for the period 2015 to 2020 is that it increases until it reaches the production cost level (non-subsidised fuel for power plants), remaining fixed thereafter. Table 9 illustrates the forecast of residential electricity demand estimated by this study and during 2010 and 2020. The actual residential electricity demand in 2010 was 62,525 GWh (TAVANIR, 2011b), which is very close to the forecast of this study. The results show that residential electricity demand will increase by 80% compared to 2009 and will reach 104,548 GWh by 2020.

[Table 9 about here]

7. Conclusions

The estimated model illustrates the influential factors which may be used to assist policy makers in devising appropriate energy policies for Iran. Temperature has the strongest effect on electricity demand in the residential sector. Weather proofing buildings and replacing old coolers with modern air conditioners would be feasible solutions for reducing power consumption considerably. The state could offer financial incentives such as interest rate discounted loans to families. The significance of household income shows that electricity taxation can be used to manage electricity demand. Given the large number of low income households, taxation should be applied with caution. The number of electrified villages is another factor influencing residential electricity demand. This shows that it is necessary to provide rural electricity through solar systems rather than through power plants, so that the state can play an important role in assisting rural households to install solar systems. The zero price elasticity of electricity confirms the inefficiency of previous electricity pricing and the importance of modifying pricing policy. Due to the high level of electricity consumption by rich households the suggestion is that the electricity price for high usage electricity consumers is set significantly higher than the electricity price for low electricity usage consumers.

The results of forecasts revealed that electricity demand in the residential sector will continue rising until 2020 under the most probable scenario. If the government relies only on the implementation of the Fifth Plan they need to expand the current capacity by 80% compared to 2009 to cover electricity demand of households by 2020. This shows the necessity of long-run planning of capacities expansion to cover electricity demand of households and efficient and effective energy policy making along with the implementation of the Fifth Five-Year Economic, Social and Cultural Plan to be able to meet future demand. Plans are underway to increase the role of the private sector in electricity distribution and generation which might ease the problem to some extent. This however, will take time.

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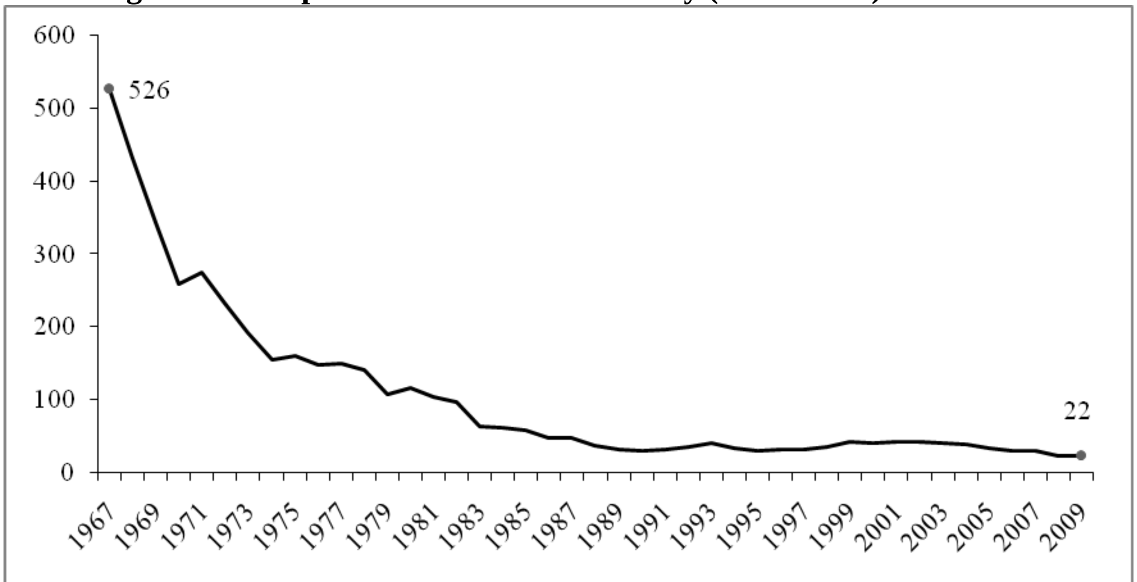
Figure 1: Real price of residential electricity (Rials/KWh)



Source: (CBI, 2010; IIES, 2010; author's calculations)[21].

Table 1: Per Capita and Annual Growth Rate Electricity Consumption in Iran (1975-2010)

Year	Per capita (KWh)	Growth Rate (%)	Year	Per capita (KWh)	Growth rate (%)	Year	Per Capita (KWh)	Growth Rate (%)	Year	Per Capita (KWh)	Growth rate (%)
1975	318.3	11.1	1984	609.9	7.7	1993	1010.9	9.5	2002	1584.8	6.5
1976	348.1	9.4	1985	644.5	5.7	1994	1090.8	7.9	2003	1702.8	7.4
1977	376.2	8.1	1986	659.7	2.4	1995	1112.6	2.0	2004	1821.1	6.9
1978	392.1	4.2	1987	685.7	3.9	1996	1160.1	4.3	2005	1915.2	5.2
1979	418.9	6.9	1988	696.4	1.6	1997	1203.9	3.8	2006	2051.2	7.1
1980	425.4	1.5	1989	751.2	7.9	1998	1255.8	4.3	2007	2136.8	4.2
1981	442.3	4.0	1990	827.7	10.2	1999	1349.4	7.5	2008	2224.0	4.1
1982	491.9	11.2	1991	880.7	6.4	2000	1419.4	5.2	2009	2307.0	3.7
1983	566.0	15.1	1992	923.2	4.8	2001	1488.0	4.8	2010	2525.0	9.4

Source: CBI (2010); TAVANIR (2010); author's calculations.

[21] CBI and IIES both refer to the Central Bank of Iran and the Institute for International Energy Studies.

Table 2: Studies on Residential Electricity Demand Modelling

Author / Country / Sample	Methodology / Unit root test	Variables & (Long-run elasticity/Short-run elasticity)	Conclusion
Flaig (1990) Germany 1964-1983 (22 years)	Wold (1974) No unit root test	-Real electricity expenditure (0.14 / 0) -Electricity price index (-0.25 / -0.15) -Real price of electric appliances(-0.43/ 0) -Real price of services of laundries (0.63 / 0.37) -Real price of fuel oil (0.11 / 0.07)	The relationship between electricity demand and capital stock plays a significant role in the estimated model. Higher prices of market services lead to a growing rate of household production and higher income and lower prices of durables cause a substitution of energy for labour.
Silk & Joutz (1997) US 1949-1993 (45years)	-JJ[22] -ADF	-Real disposable income (0.52 / 0.39) -Real electricity price (-0.48 / -0.63) -Real price of fuel oil (0.06 / 0.05) -cdd (0.26 / 0.16) -hdd (0.16 / 0.12) -Dummy for 1963 (-0.06 / N) [23]	-A break was found in electricity demand in 1963 which was important for energy policy making associated with policy changes of the 1960's. -Adjustment speed to long-run mean: -0.37
Beenstock *et al.* (1999) Israel 1973-1994 (Quarterly data)	-Johansen (1988) -EG[24] -DRM[25] Dickey *et al.* (1984)	-Real consumer spending (1.00 to 1.09/N) -Relative price of electricity (-0.21 to -0.58 / N) -hdd and cdd (0 / N) -Seasonal dummies (0 / N)	A cointegrating relationship was not detected. The elasticities of the Johansen and DRM approaches are similar.
Filippini (1999) Switzerland 1987-1990 Cross sectional data (40 cities)	-OLS -Error component model (Balestra & Nerlove, 1966) No unit root test	-Price index (-0.25 to -0.60 / N) -Real household income (0.33 to 0.39 / N) -Number of households (0.90 to 0.92 / N) -Size of household (1.08 to 1.53 / N) -HDD (0.06 to 0.30 / N)	Lower elasticities compared to previous studies. There was little room to persuade consumers to decrease electricity demand using a price rise.

[22] Johansen and Juselius (1990)
[23] N denotes that the elasticity has not been estimated by the study.
[24] (Engle and Granger, 1987).
[25] Dynamic Regression Model.

Table 2: Continued

Author / Country / Sample	Methodology / Unit root test	Variables & (Long-run elasticity/Short-run elasticity)	Conclusion
Askari (2002) Iran 1995-1999 (Panel data)	-GLS[26] No unit root test	-Residential electricity consumption -Real residential electricity price (-1.36 / -0.97) -Squared real price of residential electricity (0.44 / 0.32) -Real price of substitute fuel (0.48 / 0.34) -Real income (0.16 / 0.11) -Lagged residential electricity demand (0.41 / 0.29)	Due to elastic price, pricing policies could be appropriate tools for controlling residential electricity demand. The rich and climatically warm provinces have higher price elasticities than other provinces.
Amini Fard & Estedlal (2003) Iran 1967-2000 (33 years	-JJ -ECM -ADF	-Electricity consumption, I(1) -Real electricity price, I(1), (-0.59 / 0) -Real liquid-gas price, I(1), (0.46 / 0) -Real disposable income, I(1), (0.24 / 0) -Number of consumers, I(1), (1.10 / 0.64)	The impact of an income shock on electricity demand is bigger than the effect of an electricity-price shock. The reason for the low price elasticity is the small proportion of an electricity bill in household expenditure. Low income elasticity shows that electricity is a necessary good for households. -Adjustment speed to long-run mean:-0.5
Holtedahl & Joutz (2004) Taiwan 1956-1995 (40 years)	-Hendry & Juselius(2000; 2001) -ADF	-Real per capita disposable income (1.04 / 0.23) -Real electricity demand (-0.15 / -0.15) -Urbanization (3.91 / 1.61) -CDD (0 / 0.03)	The positive coefficient on the urbanization rate a sign of Taiwan Power industry requirement to serve clients, but also a sign of a tendency of urban consumers to use more electricity compared to rural end users. - Adjustment speed to long-run equilibrium: -0.11
Kamerschen & Porter (2004) US 1973-1998 (26 years)	-SEM (3SLS)[27] -The partial adjustment Model No unit root test	-Real income (0.65 to 0.69 / N) -Real marginal electricity price (-0.85 to -0.94/ N) -Real price of natural gas (0.33 to 0.34 / N)	Residential end users are more responsive to price changes compared to industrial customers. Cold weather affects residential electricity demand more than hot weather. Iignoring endogeneity of prices leads to spurious results.
Narayan & Smyth (2005) Australia 1969-2000 (32 years)	-ARDL -ECM -ADF	Model 1: -Real per capita income (0.32 / 0) -Real price of electricity (-0.54 / -0.26) -Real price of gas (0 / 0) -Temperature (1.69 / 0)	Changes in carbon emissions due to the imposition of a carbon tax in Australia are slower than what Akmal and Stern (2001) found. Reduction of carbon emissions will be minor in the short-run in response to policy changes for carbon emissions reduction.

[26] Generalised Least Squares.

[27] Simultaneous equations method three stage least squares.

Table 2: Continued

Author / Country / Sample	Methodology / Unit root test	Variables & (Long-run elasticity/Short-run elasticity)	Conclusion
		Model 2: -Real per capita income (0.41 / 0) -Relative price (electricity/gas) (-0.47 / -0.27)	-Adjustment speed to long-run mean: -0.10 to -0.37
Narayan *et al*. (2007) G7 1978-2003 (26 years) Panel data	-Pedroni (2004) -OLS -Panel DOLS[28] (Breitung, 2000) -ADF -PP[29]	Model 1: -Real per capita income (0.26 to 0.31 / 0) -Real price of electricity (-1.45 to -1.56 / -0.11) -Real price of gas (1.77/ 0) Model 2: -Real per capita income (0.35 to o.37 / 0) -Relative price (electricity/gas) (-6.87 to -7.41 / 0)	There is room to use pricing policies in the G7 countries to curb residential electricity demand and carbon emissions, in the long run, through the imposition of a carbon tax. -Adjustment speed to long-run equilibrium: -0.01
Zachariadis & Pashourtidou (2007) Cyprus 1960-2004 (45 years)	-Johansen (1988; 1991) -ECM -ADF -PP	-Real private consumption expenditure (1.18 / 0) -Real price of residential electricity (-0.43 / 0) -Total degree-day (0 / 0.02)	The speed of commercial electricity demand to revert to long-run equilibrium after a one-time shock is quicker than the residential sector. -Adjustment speed to long-run equilibrium: -0.16 to -0.23
Atakhanova & Howie (2007) Kazakhstan 1994-2003 Cross sectional data (14 regions)	-GMM[30] No unit root test	-Real per capita consumer expenditure (0.12 to 0.59 / N) -Real electricity price (-0.22 to -1.10 / N)	Energy policy initiatives are necessary to guarantee affordability by lower income residential consumers of electricity. Electricity consumption may rise at either 3% or 5% per year in the future. If real electricity prices rise toward their long-run cost-recovery levels, the planned supply growth can cover increasing electricity consumption.

[28] Dynamic Ordinary least squares.
[29] (Phillips and Perron (1988).
[30] Generalized method of movement (Arellano & Bond, 1991).

Table 2: Continued

Author / Country / Sample	Methodology / Unit root test	Variables & (Long-run elasticity/Short-run elasticity)	Conclusion
Dergiades & Tsoulfidis (2008) US 1965-2006 (42 years)	-ARDL -ECM -ADF	-Real per capita income (0.27/0.10) -Real price of electricity (-1.60/-0.38) -Real price of oil (0.20/ 0) -Weather condition (0.73 / 0.26) -Per capita occupied housing stock (1.50/ 0)	The results support the existence of a stable long-run relationship. The size and sign of the short-run and long-run elasticities are comparable to other similar studies. -Adjustment speed to long-run equilibrium: -0.36
Nakajima (2010) Japan 1975-2005 (31 years) Cross sectional data (46 regions)	-Pedroni (1999) -Maddala and Shaowen (1999) -Group-mean DOLS[31] -Levin *et al*. (2002) -Im *et al.* (2003)	-Real disposable income per household (0.60 to 0.65 / N) -Real price of electricity (-1.20 to 1.13 / N)	Contrary to previous studies on Japanese electricity demand, prices are elastic. Higher incomes do not result in a substantial rise in electricity demand because most consumers already have many household electric appliances.

[31] Dynamic Ordinary least squares.

Table 3: Unit Root Test Results

a) ADF test $\Delta y_t = \alpha y_{t-1} + \sum_{i=1}^{k} \beta_i \Delta y_{t-i} + x_t^{'} \gamma + u_t$

Variables	Level			Results
	k	α	Exogenous	
cr	0	-1.65	C&T	I(1)
epr	0	-0.93	C&T	I(1)
nv	2	-3.11	C&T	I(1)
gp	0	-1.92	C&T	I(1)
hco	4	-2.50	C&T	I(1)
cd	0	-3.62*	C	I(0)

Note: *,**,*** denote significance at the 1%, 5%, and 10% level. *k* is number of optimal lagged length and the maximum lag is four. *C* denotes intercept and *T* denotes trend.

b) LS test with (level) $\Delta y_t = \delta' \Delta Z_t + \alpha \tilde{y}_{t-1} + \sum \Delta \tilde{y}_{t-i} + u_t$

Variable	Model	k	α	Tb1 Tb2	D_{1t}	DT_{1t}	D_{2t}	DT_{2t}	Results
cr	CC	4	-1.03* (-5.99)	**1980** 1990	-0.156 (-4.48)	0.05 (2.04)	0.10 (2.99)	-0.18 (-7.72)	I(0) with two breaks
epr	CC	2	-0.98 (-4.72)	1978 1986	-0.33 (-2.00)	0.30 (2.80)	0.27 (1.60)	-0.29 (-2.68)	I(1) with two breaks
nv	CC	4	-0.31* (-7.36)	**1977** 1993	-0.13 (-3.71)	-0.08 (-2.78)	0.09 (2.81)	-0.15 (-10.39)	I(0) with two breaks
gp	CC	4	-1.25* (-6.18)	1980 1990	-0.73 (-3.37)	0.47 (4.43)	0.94 (4.21)	-0.97 (-5.38)	I(0) with two breaks
hco	CC	4	-0.74** (-5.67)	1984 1994	0.10 (1.95)	-0.20 (-6.55)	-0.09 (-1.86)	0.06 (3.27)	I(0) with two breaks
cd	CC	0	-1.05* (-5.98)	1990 1994	0.05 (0.50)	-0.07 (-1.18)	-0.08 (-0.84)	0.24 (3.47)	I(0) with two breaks

Note: *,**,*** denote significance at the 1%, 5%, and 10% level. Critical values are tabulated in Lee and Strazicich (2001, Table 1). Critical values at the 1 and 5, and 10% for AA model are -4.545, -3.84, and -3.504 and for CC model are -5.823, -5.286, and -4.989. For models with one break the critical values tabulated in Lee and Strazicich (2003, Table 2). The critical values for model C depending on the location of the break change from -5.05 to -5.11, -4.45 to -4.51, and -4.17 to -4.20 and for Model A are -4.239, -3.566, and -3.211, respectively. TB1 and TB2 are the break dates, *k* is number of optimal lagged length and maximum lag is four. Numbers in parentheses are the *t*-statistics for the estimated coefficients.

c) NP test with two breaks (level)

$$y_t^{M2} = \rho y_{t-1} + \alpha_1' + \beta'' t + \sum k_i D(Tb')_{it} + \sum \delta_i' DU_{it-1}' + \sum \gamma_i' DT_{it-1}' + \sum_{j=1}^{k} \beta_j \Delta y_{t-j} + e_t$$

$$y_t^{M2} = \rho y_{t-1} + \alpha_1' + \beta'' t + \sum k_i D(Tb')_{it} + \sum \delta_i' DU_{it-1}' + \sum \gamma_i' DT_{it-1}' + \sum_{j=1}^{k} \beta_j \Delta y_{t-j} + e_t$$

Series	M2					M1					Results
	k	Test stat.	TB1 TB2	κ_1	κ_2	K	Test stat.	TB1 TB2	θ_1	θ_2	
cr	0	-0.33* (-7.60)	1974 **1980**	0.02 (3.43)	-0.01 (-3.00)	-	-	-	-	-	I(0) with two breaks
epr	2	-1.00 (-3.85)	1988 1995	-0.08 (-1.66)	0.06 (0.93)	0	-0.69 (-2.86)	1982 1998	-0.10 (-2.09)	0.09 (1.65)	I(1) with two breaks
nv	1	-0.13* (-6.47)	1974 **1977**	-0.02 (-3.27)	-0.03 (-4.79)	-	-	-	-	-	I(0) with two breaks
gp	3	-1.15 (-4.24)	1981 1996	0.14 (2.56)	0.01 (1.28)	0	-0.27 (-1.41)	1981 1996	0.25 (4.28)	0.12 (2.10)	I(1) with two breaks
hco	0	-0.10 (-1.20)	1975 1985	-0.03 (-5.81)	-0.01 (-3.55)	-	-	-	-	-	I(1) with two breaks
cd	0	-0.81* (-6.22)	1978 1991	-0.04 (-4.48)	0.03 (-3.31)	-	-	-	-	-	I(0) with two breaks

Note: *,**,*** denote significance at the 1%, 5%, and 10% level. Critical values are tabulated in Narayan and Popp (2010, Table 3). Critical values at the 1 and 5, and 10% for M1 model are -5.259, -4.514, and -4.143 and for M2 model are -5.949, -5.181, and -4.789. TB1 and TB2 are the break dates, *k* is number of optimal lagged length and maximum lag is four. Numbers in parentheses are the *t*-statistics for the estimated coefficients.

Table 4: Major Determinant of Long-Run Residential Electricity Demand, 1967-2009

Regressors	Coefficient	T-Ratio[Prob]
epr	-0.11	-0.92 [0.37]
hco	0.58	4.53 [0.00]
nv	0.36	5.69 [0.00]
cd	1.04	3.31 [0.00]
gp	-0.10	-1.12 [0.27]
c	-10.08	-3.37 [0.00]
$\bar{R}^2$: 0.99	*DW* :1.91	*F*-statistic: 3.92
Diagnostic tests	LM version Test statistic [Prob]	F version Test statistic [Prob]
Serial Correlation	0.01 [0.94]	0.00 [0.95]
Functional Form	0.36 [0.55]	0.23 [0.63]
Normality	3.44 [0.18]	Not applicable
Heteroscedasticity	2.66 [0.10]	2.71 [0.11]

Table 5: Major Determinants of Short-Run Residential Electricity Demand, 1967-2009

Regressors	Coefficient	T-Ratio[Prob]
c	0.01	0.51 [0.61]
dhco	0.04	0.43 [0.67]
dhco(-1)	0.19	1.90 [0.07]
depr	-0.03	-0.66 [0.52]
dcd	0.14	3.21 [0.00]
ecm(-1)	-0.21	-8.30 [0.00]
$\bar{R}^2$: 0.73	DW : 2.48	---
Diagnostic tests	LM version Test statistic [Prob]	F version Test statistic [Prob]
Serial Correlation	3.10 [0.08]	2.78 [0.11]
Functional Form	0.03 [0.87]	0.02 [0.88]
Normality	5.75 [0.06]	Not applicable
Heteroscedasticity	0.00 [0.97]	0.00 [0.97]

Note: *d* denotes the first difference value of the variables.

Figure 2: Stability Test of Estimated models of Residential electricity Demand

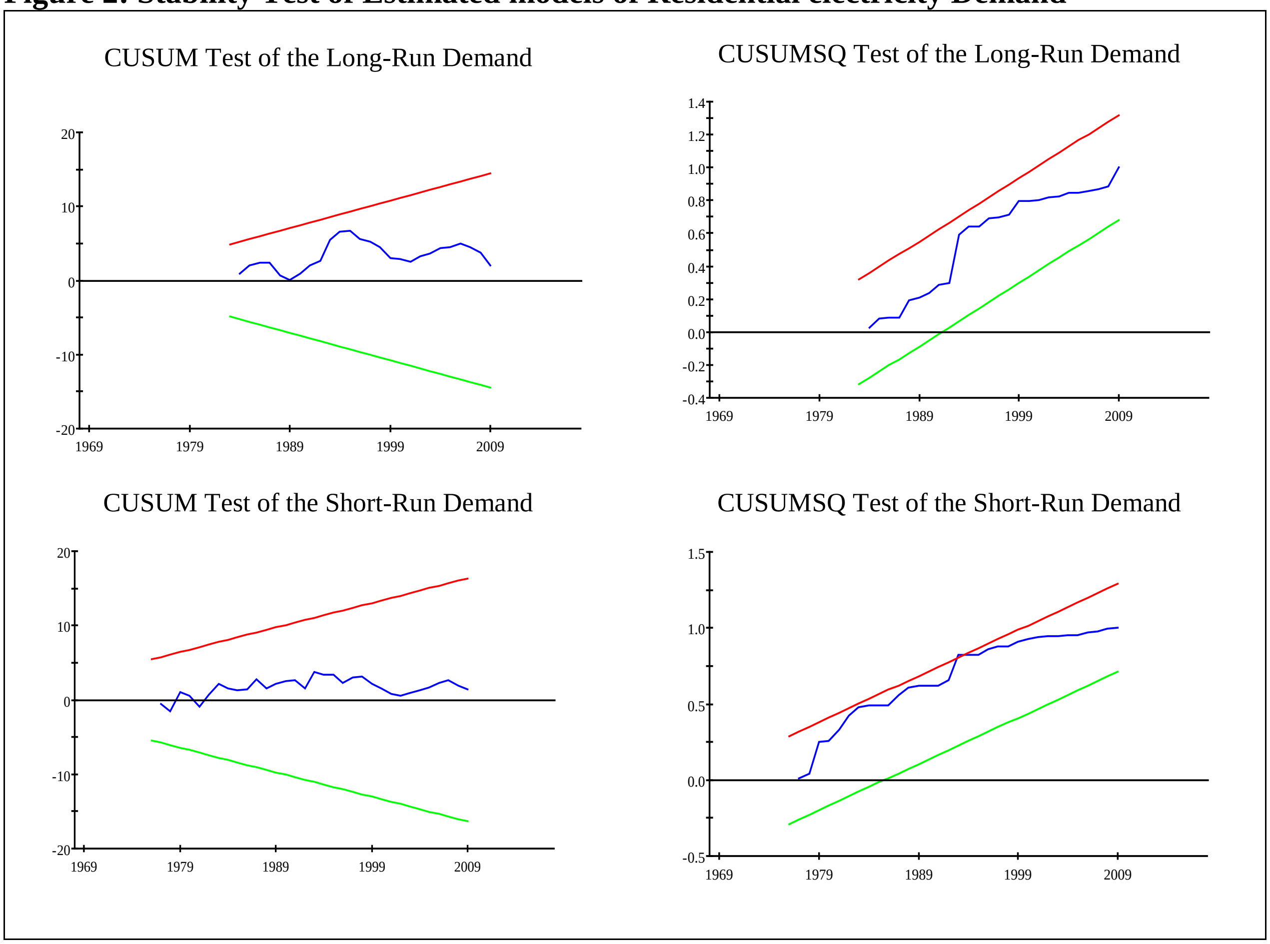


Table 6: Quandt-Andrews unknown breakpoint test

Null Hypothesis: No breakpoints within trimmed data

Varying regressors: C LOG(EPR) LOG(HCO) LOG(NV) LOG(CD) LOG(GPR)

Equation Sample: 1969 2009

Test Sample: 1976 2002

Number of breaks compared: 27

Statistic	Value	Prob.
Maximum LR F-statistic (1980)	4.854316	0.9908
Maximum Wald F-statistic (1980)	4.854316	0.9908
Exp LR F-statistic	0.952181	0.9997
Exp Wald F-statistic	0.952181	0.9997
Ave LR F-statistic	1.459397	0.9998
Ave Wald F-statistic	1.459397	0.9998

Table 7: Durbin-Wu-Hausman exogeneity test

Dependent variable is cr

List of the variables added to the regression (residual of the independent variables):

r_epr r_hco r_gp r_nv

41 observations used for estimation from 1969 to 2009

Regressor	Coefficient	Standard Error	T-Ratio[Prob]
c	-.40346	.43444	-.92871[.361]
cr(-1)	.78094	.16406	4.7600[.000]
epr	.069368	.13844	.50108[.620]
epr(-1)	-.081276	.12236	-.66424[.512]
hco	.44480	.36816	1.2082[.237]
hco(-1)	-.31437	.29303	-1.0728[.293]
gp	.070507	.072323	.97489[.338]
gp(-1)	-.047245	.038662	-1.2220[.232]
nv	-.026067	.45453	-.057348[.955]
nv(-1)	.12898	.50332	.25625[.800]
r_epr	-.072600	.15156	-.47903[.636]
r_hco	-.49017	.39360	-1.2453[.224]
r_gp	-.053803	.079353	-.67802[.504]
r_nv	.18697	.47932	.39007[.700]

Joint test of zero restrictions on the coefficients of additional variables:

Lagrange Multiplier Statistic	CHSQ(4)=	7.9538[.093]
Likelihood Ratio Statistic	CHSQ(4)=	8.8423[.065]
F Statistic	F(4,27)=	1.6246[.197]

Figure3: Forecast Assumptions of Residential Electricity Demand

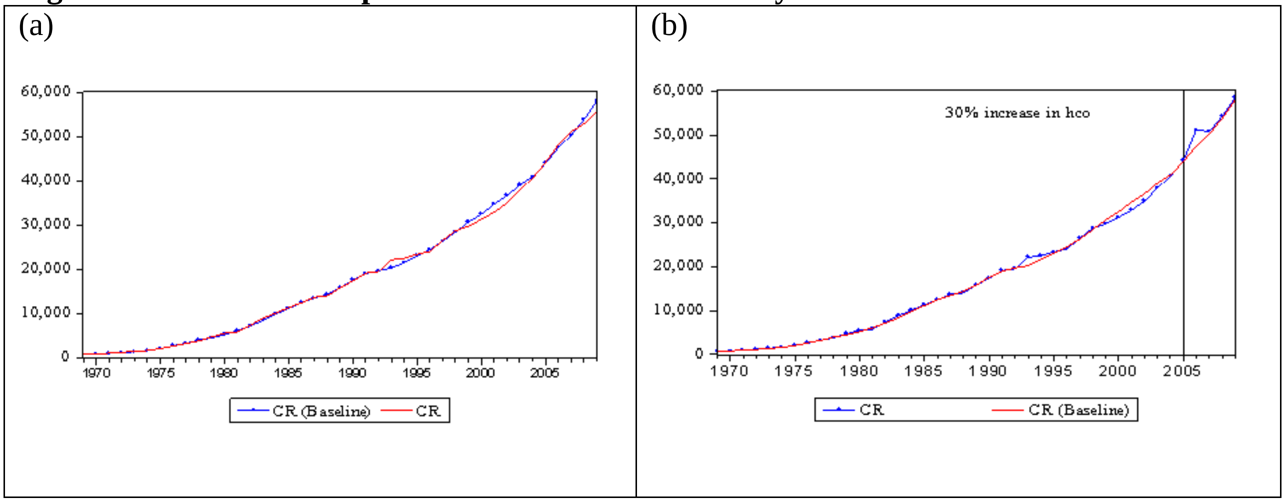
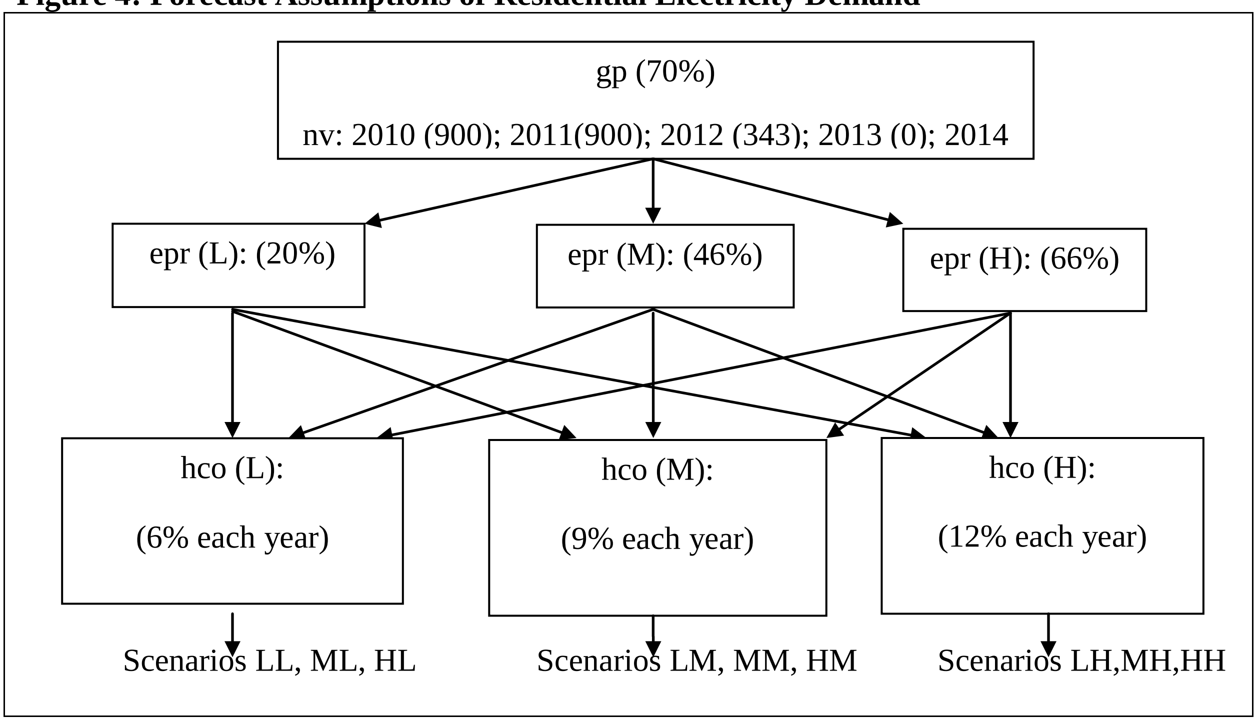


Figure 4: Forecast Assumptions of Residential Electricity Demand



Note: gp, nv, epr and hco denote residential gas price, number of electrified villages, residential electricity price and total household expenditure, respectively.

Figure 5: Scenarios for residential Electricity Demand

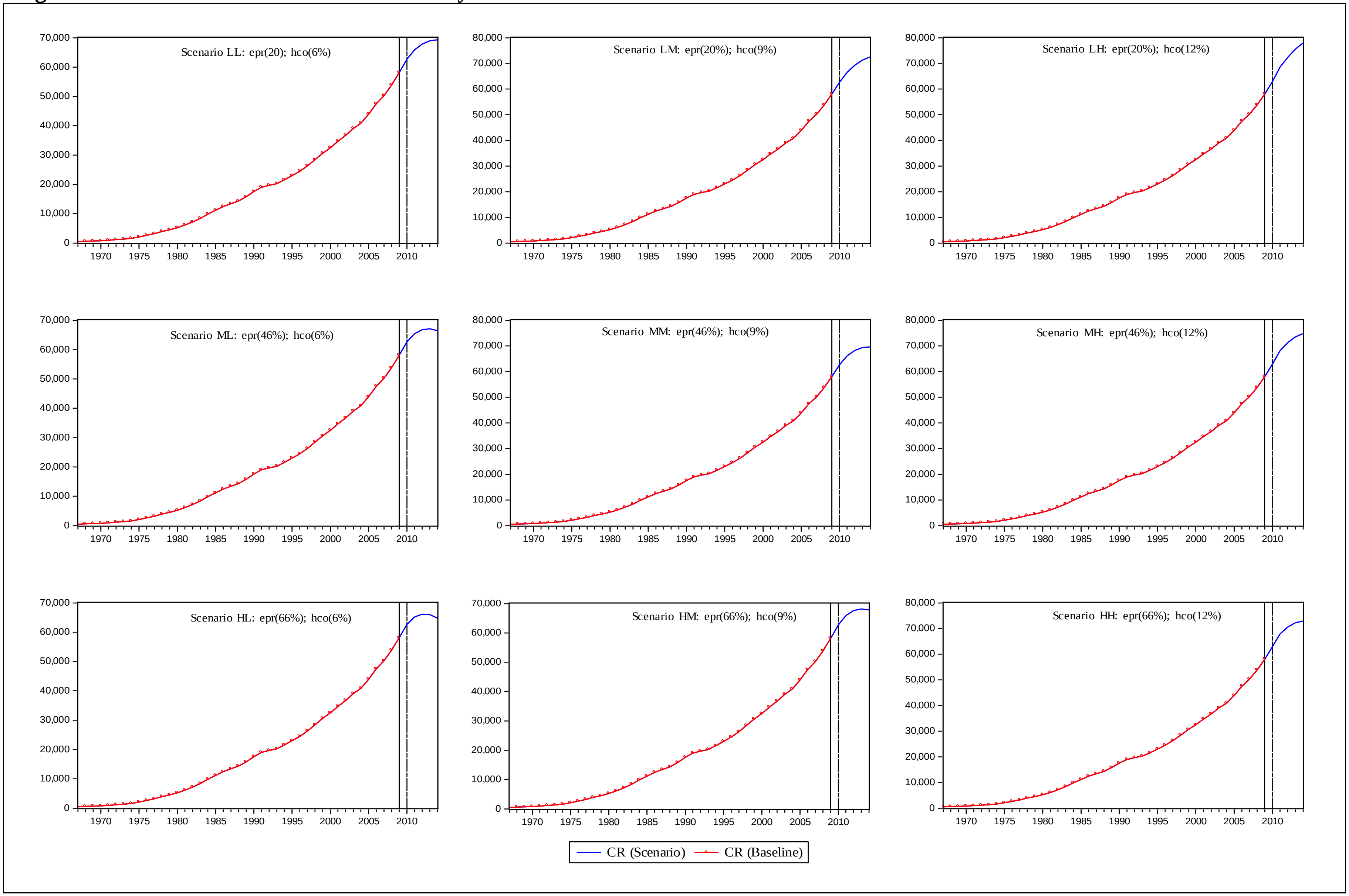


Table 8: Forecast of Residential Electricity Demand

Scenarios / Year	LL		LM		LH		ML		MM		MH		HL		HM		HH	
	GWh	%	GWh	%	GWh	%	GWh	%	GWh	%	GWh	%	GWh	%	GWh	%	GWh	%
2009	58.1		58.1		58.1		58.1		58.1		58.1		58.1		58.1		58.1	
2010	62.7	8	62.8	8	63.0	8	62.7	8	62.8	8	63.0	8	62.7	8	62.8	8	63.0	8
2011	65.8	5	66.5	6	68.5	9	65.4	4	66.1	5	68.1	8	65.1	4	65.9	5	67.9	8
2012	67.8	3	69.3	4	72.4	6	66.8	2	68.3	3	71.3	5	66.2	2	67.6	3	70.6	4
2013	69.0	2	71.3	3	75.6	4	67.1	1	69.4	2	73.5	3	66.0	0	68.2	1	72.2	2
2014	69.2	0	72.6	2	78.0	3	66.5	-1	69.7	0	74.8	2	64.7	-2	67.8	-1	72.9	1
2014 vs. 2009	--	19	--	25	--	34	--	14	--	20	--	29	--	11	--	17	--	25

Table 9: Residential Electricity Demand under MH Scenario

Years	Demand	Annual growth rate (%)	Growth rate compared to 2009 (%)
2010	62,970	8.4	8.4
2011	68,137	8.2	17.3
2012	71,298	4.6	22.7
2013	73,540	3.1	26.6
2014	74,849	1.8	28.8
2015	75,718	1.2	30.3
2016	79,047	4.4	36.1
2017	83,654	5.8	44.0
2018	89,430	6.9	53.9
2019	96,374	7.8	65.9
2020	104,548	8.5	79.9

Appendix A

The utility function of a consumer (U) in any given time period is defined as:

$$U = U\left(Q_e,\ Q_s,\ Q_x,\ G\right) \tag{a. 1}$$

Where Q_e, and Q_s, are the quantity of electricity and its substitute goods, respectively, Q_x is the quantity of other goods, and G is geographical and demographic features which define the household's preference (Filippini, 1999). The household consumer is assumed to maximize the utility subject to a budget constraint, so:

$$L = U\left(Q_e,\ Q_s,\ Q_x,\ G\right) - \lambda(P_e Q_e + P_s Q_s + P_x Q_x - Y) \tag{a. 2}$$

Where λ is the lagrangian multiplier, P_e, P_s and P_x are the prices of Q_e, Q_s and Q_x, respectively and Y is household consumer income.

The assumption is that prices and income are fixed in a given period. Taking the first derivative of Equation (a.2) with respect to Q_e, Q_s, Q_x and λ results in a system of equations. By solving the equations the demand for electricity and other commodities is obtained. The electricity demand function (Q_e) of a single consumer per time period is given by:

$$Q_e = f(P_e, P_s, P_x, Y, G) \tag{a. 3}$$

The total consumption of electricity by all the consumers (Q) can be derived by summing up the individual quantities. Therefore, the demand for n consumers in a given period is:

$$Q = \sum_{i=1}^{n} Q_{ei} = \sum_{i=1}^{n} f_i(P_e, P_s, P_x, Y, G) \tag{a. 4}$$

If the demand function is characterised by constant elasticity of demand, then the total electricity demand of n consumers at time t is:

$$Q_t = P_{et}^{\alpha}\ P_{st}^{\beta}\ P_{xt}^{\tau}\ Y_t^{\gamma}\ G_t^{\delta} \tag{a. 5}$$

Taking the log transformation of Equation (a.5) the demand function can be given by:

$$q_t = \alpha p_{et} + \beta p_{st} + \tau p_{xt} + \gamma y_t + \delta g_t \qquad \text{(a. 6)}$$