Residential Electricity Demand for Turkey:  
A Structural Time Series Analysis  
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Abstract  

The aim of the research is to investigate the relationship between residential electricity consumption, household total final consumption expenditure and residential electricity prices for Turkey. This is achieved by applying the structural time series modelling (STSM) technique to annual data over the period 1971 to 2006. It is found that household total final consumption expenditure, real energy prices and an underlying residential energy demand trend are important drivers of residential electricity demand; consequently, these drivers should be included in any model of Turkish residential electricity demand. Furthermore, the estimated short run and the long run household total final consumption expenditure elasticities are 0.41 and 2.29 respectively whereas the estimated short run and long run price elasticities are -0.10 and 0.57 correspondingly. Moreover, the underlying energy demand trend for the Turkish residential sector is estimated, which, as far as is known, has not been investigated before for Turkey. This should therefore be of some benefit for Turkish decision makers in terms of energy planning since it provides information about the impact of past policy implementation, influence of technological progress, changes in consumer behaviour and effects of energy market structure so that they can evaluate the past policies and plan new ones.
1. Introduction:

In 1970, only 51.5% of the population benefited from electricity in Turkey but by 1987, 99.7% of the Turkish population had access to electricity. The demand for energy is a derived demand rather than a demand of its own sake. In the early part of the period, electricity was generally used for lightening by householders. However, later on, with an increase in household income and technological improvements, new appliances take place in the daily life of households such as TV, refrigerator, etc. It is commonly expected that higher household income and expenditure will result in higher demand for these kinds of appliances that use electricity. In the short term, this increase will boost electricity consumption but in the longer term, higher income level will also lead households to replace the appliances that use old technologies with new and much more efficient ones which might have a lessening effect on electricity consumption in the long term (Hunt et al. 2003).

The domestic electricity consumption of Turkey increased by an average of 10% per year from 658 GWh to 49,293 GWh over the period 1960-2006 (IEA, 2009) (Figure 1). In 2006 residential electricity consumption accounted for 35% of the total electricity consumption. This figure was 31% in 1960 and 20% in 1974 (Figure 2). The high growth rate of the domestic electricity consumption would appear to result mainly from the increasing number of applications of energy intensive technologies in the daily life of Turkish households. Residential electricity consumption has an increasing share in overall electricity consumption and therefore has a significant impact in energy planning. The share of Turkish residential electricity consumption is increasing, as it becomes more energy intensive in line with global trends. Additionally household total final expenditure has increased from about 95 billion (2000 constant $ PPP) in 1968 to just over 370 billion (2000 constant $ PPP) in 2006, an average annual increase of 3.7% (World Bank, 2009 and Centre for International Comparisons of Production, 2009) (Figure 1).
Although the Electricity Market Law No. 4628 was introduced in 2001 in Turkey with the aim of creating a liberalized market structure, electricity prices were controlled by governments over the period 1960 to 2006. As discussed above, the share of residential electricity in total electricity has increased over the period 1974 to 2006 (Figure 2); therefore, it is becoming increasingly important to investigate the main drivers of residential energy demand and be able to construct sensible scenarios for the future.

**Fig 1: Household Total Final Consumption Expenditure, Residential Electricity Consumption, Residential Real Electricity Prices Growth Rates 1960-2006**

**Fig 2: The Share of Residential Electricity Consumption in Total Electricity Consumption**
Although essential for Turkish sustainable economic development, past energy demand studies, discussed in the next section, have arguably not been successful in adequately explaining Turkish energy demand. One reason put forward for this here is that the previous studies did not adequately model the underlying energy demand trend to capture the impact of exogenous effects. Therefore, the Structural Time Series approach adopted here is arguably a solution for electricity demand planning, given it allows for the estimation of a stochastic underlying trend. Moreover, electricity demand planning has a significant impact on the welfare of the Turkish economy.

Energy modelling prepares us for the possible future outcomes, allows predictions to be made and enables us to take decisions about preparation and financing of measures including development of necessary natural resources, utilization of new technologies, evaluation of energy generating and energy consuming assets (McVeigh and Mordue, 1999). For the sustainable economic growth of Turkey, accurate and reliable energy demand forecasts are very important in order to develop appropriate policies such as electricity price regulations, power investments, long term import contracts, energy efficiency measures etc.

The aim of this study therefore is to investigate how structural time series methodology performs in terms of modelling past residential electricity demand, estimating the key household total final consumption expenditure and price elasticities and forecasting Turkey’s future residential electricity consumption. The primary motivation is being the need to achieve better projections of residential energy demand, which has an important role for welfare of the Turkish economy.

In the second section, the background of Turkish energy demand studies will be discussed and in the third section, a summary of the associated literature will be considered. The fourth section will discuss the method of the study and the fifth section discusses the data used for
the analysis. The sixth and the seventh sections illustrate the estimated results and forecasting results respectively. Finally, in the eighth and final section the outcome of this study is discussed.

2. Background of Energy Demand Studies in Turkey

Turkish electricity demand studies are very limited, being generally carried out by governmental organizations namely State Planning (SPO), State Institute of Statistics (SIS) and the Ministry of Energy and Natural Resources (MENR) (Ediger and Tatlıdil, 2002). The Ministry of Energy and Natural Resources utilize different models in order to determine energy demand functions and to make future projections. For instance, ‘Balance’ models that are non-linear equilibrium models that match the energy demand with available resources and technologies and ‘Impact’ models that focus on the relation between energy consumption and its interaction with environment were employed in the framework of Energy and Power Evaluation Program (ENPEP). Both models were used for the long-term supply and demand projections between 1981 and 1985. The Ministry of Energy and Natural Resources (MENR) began to use the simulation models namely MAED, WASP III and EFOM-12 C Mark. MAED (Model for Analysis of Energy Demand) and WASP III (Wien Automatic System Planning) were originally developed by the International Atomic Energy Agency (IAEA) and Energy demand model EFOM-12 C Mark was developed by the commission of the European Union starting from 1984 (Ediger and Tatlıdil, 2002).

At the same time, the State Planning Organization (SPO) also developed its own models based on sectoral energy demands for different consumer groups and subgroups. Finally, the mathematical models were developed for each sub group by regression. On the other hand, the State Institute of Statistics explored the relationship between demographic factors and economic parameters with energy demand in its models. Both of the models explored by SIS
and SPO verified the relationship between energy demand and GDP (Ediger and Tatlidil, 2002).

The MAED was applied six times over the period, in the years 1986, 1990, 1994 1997, 2000 and 2005. The difference between the predicted electricity consumption by the studies based upon MAED and the actual electricity consumption is magnified when the time period increases between the date when the forecasts were made and the target forecast year.

For instance; in MAED’86, the predictions that were made for the period 1986 and 1999 are bigger than the actual electricity consumption with a range of about 2.5 and 26.9 million tons of oil equivalent (toe). In addition, in MAED’90 a similar type of difference can be observed with a range of 1.7 and 26 million toe for the period 1990 and 1999. These prediction errors were also observed in MAED’90 and MAED’97 which vary between 4.295 and 6.939 million toe (over period 1994-1999) and -2.200 and 4.972 million toe (over period 1997-1999) relatively.

As an example, if we take the year 1999 as a target forecast year in order to evaluate the prediction power of MAED models; MAED’86 projected 34% higher than the outturn figures, MAED’90 33% higher, MAED’94 9% higher and MAED’97 6% higher. From this example, it can be inferred that MAED applications are relatively successful for the near future but fluctuate enormously in long periods. The MAED model is criticized because of its unsuccessful long term projections commonly observed all around the world (Ediger and Tatlidil, 2002). The application of MAED models in Turkey is also criticized widely in number of studies including; Ediger and Tatlidil (2002), Keles (2005), Ediger and Akar (2007), Hamzacebi (2007), Akay and Atak (2007). The estimations of the economic parameters for the future that are used in the MAED model are predicted by SPO, but these estimates are generally targets which are considerably influenced by the government’s
optimistic policies rather than scientific projections. The success of the MAED models varies from country to country which might be a sign that every country has its own and unique energy demand behaviour and elasticities. Ignoring these unique features arguably leads to misspecification of energy demand functions and wrong projections.

In the overall assessment of Turkish electricity demand forecasts, these studies always foresaw electricity demand as being greater than it actually is. According to Keles (2005), the reasons for this outcome are mainly: technical shortcomings of the models applied; lack of capability of the authorities in establishing accurate assumptions and not having transparency and credibility during the application of the selected model. The future predictions of demographic and economic variables that were used in MAED models are identified by SPO, however these values significantly have been manipulated by government policies rather than reliable forecasts (Ediger and Tatlidil, 2002). Because of these exaggerated forecasts, policies that are implemented such as introducing the guaranteed BO, BOT and TOOR projects, have caused a significant proportion of electricity generation capacity of public power plants to remain idle, increasing the primary energy imports which Turkey does not need. These policies lead Turkey to be import dependent and much more vulnerable to external shocks and prevent energy markets from liberalizing (Keles, 2005).

3. Literature Review:

In this section the literature related to energy modelling studies for Turkey and the structural time series modelling are reviewed separately.
3.1 Energy Demand Studies for Turkey:

There is only two previous energy demand modelling studies that focused on residential electricity consumption therefore all known existing Turkish energy demand studies to evaluate the previous progress in this field.

There has been a significant increase in the number of energy demand modelling studies focusing on Turkey, carried out since the late 1990s. Within these, some attempt to establish whether causality between economic variables and energy consumption exists (discussed in Section 3.1.1 below); some attempt to identify the relationship between energy consumption and economic drivers (discussed in Section 3.1.2 below); whilst others attempt to forecast future energy demand by using different approaches (discussed in Section 3.1.3 below).

3.1.1 Causality Studies:

Previous studies focussing on the causality between energy consumption and economic variables (namely Erdal, Erdal and Esengun, 2008; Karanfil, 2008; Erbaykal, 2008; Jobert and Karanfil, 2008; Soytas and Sari, 2007; Lise and Montfront, 2007; and Altinay and Karagol, 2005) all applied different techniques. These include Vector Auto Regression (VAR), Granger Causality, Instantaneous Causality, Bounds Testing, Johansen Cointegration, Pair-wise Granger Causality and Vector Error Correction Model (VECM). However, they all test whether or not there is a causal relationship between economic variables (mostly GDP) and energy consumption and the direction of this relationship.

3.1.2 Relationship Studies:

The studies aiming to identify the relationship between variables including Erdogdu (2007), Halicioglu (2007) and Bakirtas et al (2000) employ a range of different methods such as; Engle-Granger two step procedure, Johansen Cointegration Procedure, Auto Regressive
Moving Average, Bounds Testing, Partial Adjustment Model (PAM). However, again there is consistency in their aim. They attempt to identify and measure the effects of economic variables, primarily price and income, on energy consumption.

Bakirtas et al (2000), using price, income, population and energy consumption data over the period 1962 to 1996, investigated the long run economic relation between total electricity demand per capita, income per capita and prices by using Engle and Granger’s two step procedure. They failed to find significant price elasticity and stated that this was to be expected given electricity prices were subsidised by Turkish governments. On the other hand, they concluded that the long and short run income per capita elasticities were about 0.7 and 3.1 respectively. Furthermore, they also carried out a univariate ARMA process in order to forecast the electricity consumption between 1997 and 2010 and concluded that total electricity consumption per capita will reach about 2222 KWh.

A recent study by Erdogdu (2007) can also be separated into two parts. In the first part, the PAM is employed with quarterly data including real GDP per capita, price and net total electricity consumption per capita between 1984 and 2004. Erdogdu (2007) found that the price elasticity is not significantly different from zero and that the short and long run income elasticities are 0.01 and 1.09 respectively. In the second part, Erdogdu (2007) undertook ARIMA modelling with a simple regression model for his forecast and annual data for electricity consumption data for the period 1923 to 2004. He concluded that there will be an annual 3.3% percent increase until 2014 with electricity consumption gradually increasing to about 156 thousand GWh in 2010 and about 160 thousand GWh in 2014.

As discussed above, both Erdogdu (2007) and Bakirtas (2000) attempt to explain past electricity demand by exploring the relationship and/or causality between income, total electricity consumption and electricity prices by using the PAM, the Johansen procedure and
the Engle and Granger two step procedure. It is somewhat surprising, therefore, that to produce their forecasts these relationships are ignored, instead preferring to predict the future, they both used univariate models, as described above. This is arguably a weakness in their approach, which this paper attempts to correct.

By using only previous years’ electricity consumption values in their forecasts, Erdogdu (2007) and Bakirtas (2000) ignore the interactions between energy consumption and economic variables and their forecasts both rely on the underlying process of electricity consumption. Consequently, the forecasts are arguably not reliable, since it is commonly expected that the change in the income, prices and the underlying energy demand trend factors will have an effect on the future energy consumption and not taking into account these interactions might lead to misleading outcomes.

Halicioglu (2007) investigates Turkish residential electricity demand using the Bounds Testing approach and finds a range of estimated elasticities depending upon the number of lags chosen, such as:

- Short and long run price elasticities vary from -0.33 to -0.46 and -0.52 to -0.63 respectively.
- Short and long run income elasticities vary from 0.49 to 0.70 and 0.37 to 0.44 respectively.

Halicioglu (2007) also argues that the urbanization rate is a significant variable in determining Turkish residential energy consumption, and finds that urbanization has a 0.90 and 0.04 effect in the short and long run respectively. He also finds that the short run income and price elasticities are lower than the long run elasticities and argues that policy makers should consider this when implementing policy. He claims that in the short term the response to policy changes will be limited because of the fixed energy appliances.
Although Halicioglu (2007) contributes significantly to the exploration of the residential sector electricity demand modelling, it can arguably be improved in two main ways. Firstly, Halicioglu (2007) uses an energy price index rather than real electricity prices. Secondly, Household Total Final Expenditure probably represents household consumption capability better than Gross National Product per capita, which Halicioglu uses.

3.1.3 Forecast Studies:

In the last group researchers focus on predicting future Turkish energy demand, these include Hamzacebi (2007), Ediger and Akar (2007), Erdogdu (2007), Akay and Atak (2006), ceylan and Ozturk (2004), Ozturk et al (2005) and Ediger and Tatlidil (2002). Again, various methodologies are employed, including: Univariate Cycle Analysis; Genetic Algorithm Approach; Grey Prediction with Rolling Mechanism; Auto Regressive Integrated Moving Average (ARIMA); and Artificial Neural Networks. In predicting future Turkish energy demand, none of these studies takes into account real electricity prices in their forecasts. Most of them take into account GDP and some of them are based only their prediction of the previous year’s electricity consumption.

Among these studies, Hamzacebi (2007) is, as far is known, the only previous study to focus on residential electricity demand forecasting. He uses 1970-2004 sectoral electricity consumption data and Artificial Neural Networks to estimate the electricity consumption for different sectors, including the residential sector. Hamzacebi concluded that in 2020 residential electricity consumption will reach about 257 thousand GWh However, no account was taken of the impact of economic activity and its interaction with residential electricity consumption.

There are two prior studies focused on Turkish residential electricity demand namely Halicioglu (2007) and Hamzacebi (2007). On the one hand Halicioglu investigates the
relationship between residential electricity consumption and economic variables on the other hand Hamzacebi predicts the future residential electricity consumption. As discussed above arguably the shortcomings with these two prior studies which this study attempts to improve upon the shortcomings of the both studies. First, in this research real electricity price data used rather than the energy price index. Additionally the underlying energy demand trend is explored and illustrated, since this is seen as an important driver of residential electricity consumption. Furthermore, the inclusion of economic variables and their impact on residential electricity consumption, should allow for a better understanding of future residential electricity consumption.

3.2 Review of Technological Progress and Underlying Energy Demand Trend:

Technological progress is an important factor that influences energy demand. Energy is a derived demand rather than being a demand for its own sake, a demand for the services it produces with the capital and appliance stock in place at a certain time. The amount of energy consumed is connected to the technology level of the energy appliances to assure the demanded level of services. Therefore, according to Hunt et al. (2003) technology is an important factor that determines energy demand. Beenstock and Wilcocks (1981, 1983) stated that technological progress must be taken into account in energy modelling studies and used a simple deterministic trend in their studies. However, Kouris (1983a, 1983b) criticized this view because, even though technology is an important determinant in energy demand, there is no sufficient way to identify its effect on energy demand unless a sufficient way to measure it can be addressed. Furthermore, Kouris stated that the effect of technological progress could be observed from price changes so it is also related to price elasticity. In response, Beenstock and Willcocks (1983) mentioned that is an important issue to capture technological progress as an exogenous factor and that although using a linear trend is not an adequate way it is basically better than ignoring technological progress. Jones (1994) stated
that even if the technological progress is induced by price changes, it is important to
distinguish the effect of technology on price and normal “price effects” for policy
implementation.

Hunt et al (2000) underlined another important issue related to technological progress and
stated that income and output expansion might have a boosting effect on technological
progress. Hunt et al (2003) stated that the effect of technological progress on income and
output could lead to an increase in energy demand in the short term with the existing
appliance and capital stock. However, in the long term the increase in output and income will
also accelerate the process of replacing the existing appliance and capital stock with much
more efficient ones. There is a need for distinguishing the effect of technological progress on
income and output as it can affect the energy demand. Furthermore Hunt et al (2003) stated
that there are other exogenous factors, which should be taken in to account; including
consumer tastes and economic structure.

The Underlying Energy Demand Trend can therefore be described as a factor that identifies
the exogenous factors, which determine energy demand and it is necessary to determine its
effects on energy demand. As an example if income is rising but the UEDT is downward
sloping then the income elasticity will be underestimated by not taking the UEDT into
account. The UEDT is expected to be non-linear and arguably it is important to model it in
the most general and flexible way possible. Structural Time Series Models that were
introduced by Harvey et al. (1986), Harvey (1989), Harvey and Shephard (1993), Harvey and
Scott (1994) and Harvey (1997) are debatably the only sufficient approach to capture UEDT.
3.3 Review of STSM and Application of STSM to Energy Studies:

3.3.1 Structural Time Series Models:

The structural approach determines the series as the sum of trend and irregular components. Although it is possible to establish a model based on a deterministic trend, the preferred flexibility can be achieved by letting the trend change over time and therefore introducing stochastic trend. A basic univariate STSM can be explained as regression in which the parameters are changing over time and explanatory variables are functions of time. State space form of a STSM is a presentation of the state of a system with unobserved components including trend. By introducing new observations to the system, the estimate of unobservable components can be updated by means of a filtering procedure. Predictions are made based on carrying these estimated parameters into the future while smoothing the algorithms in order to obtain the best estimate of the state at any point. The stylized facts can be determined as well under structural time series model (Harvey and Shephard, 1993). Further explanation of the STSM will be given in Methodology section.

3.3.2 The STSM in Energy Demand Studies:

The STSM is a relatively new method; hence, there are few applications to energy demand. Hunt et al. (2000) is the first example of this approach, which estimates UK final consumption of coal, gas, oil, petroleum, electricity and total energy by using quarterly data over period 1972 to 1995. It is concluded that the UEDT has a stochastic, rather than deterministic, form as previously used in conventional models. Furthermore, the estimated UEDT is found to be fluctuating over time, which illustrates that energy consumption is affected by exogenous variables. Hunt et al. (2003) investigates UK aggregate energy demand using the STSM for various sectors of the UK using quarterly data over period 1972 to 1997 and concludes that stochastic trends and seasonals are better when modelling energy
consumption. Similarly, Dimitropoulos et al (2005) demonstrates once more that the STSM approach is superior because of implementing the stochastic trend rather than deterministic by investigating sectoral aggregate energy demand using annual UK data over period 1967 to 2002. Hunt and Ninomaya (2003) investigates transportation oil demand for the UK and Japan by using the STSM with quarterly data over period 1971 and 1997 and test their results against conventional deterministic trends and argue that the stochastic trend from the STSM is more appropriate than a deterministic one.

4. Methodology:

It is assumed that Turkey’s residential electricity demand is identified by:

\[ E_t = f(Y_t, P_t, \mu_t) \]  \hspace{1cm} (1)

where;

\[ E_t = \text{Residential electricity demand.} \]
\[ Y_t = \text{Household Total Final Expenditure.} \]
\[ P_t = \text{Real residential electricity price.} \]
\[ \mu_t = \text{Underlying Energy Demand Trend} \]

For the econometric estimation of equation (1) the dynamic autoregressive distributed lag specification for the long run equilibrium of Turkey’s electricity demand function is as follows:

\[ A(L) e_t = B(L) y_t + C(L) p_t + \mu_t + \epsilon_t \]  \hspace{1cm} (2)
where; \( A(L) \) is the polynomial lag operator \( 1 - \lambda_1 L - \lambda_2 L^2 - \lambda_3 L^3 - \lambda_4 L^4 \), \( B(L) \) is the polynomial lag operator \( 1 + \phi_1 L + \phi_2 L^2 + \phi_3 L^3 + \phi_4 L^4 \) and \( C(L) \) is the polynomial lag operator \( 1 + \phi_1 L + \phi_2 L^2 + \phi_3 L^3 + \phi_4 L^4 \) and;

\[
e_t = \ln (E_t)
\]

\[
y_t = \ln (Y_t)
\]

\[
p_t = \ln (P_t)
\]

\[
B(L)/A(L) = \text{the long run total household final consumption expenditure}
\]

\[
electricity demand;\]

\[
C(L)/A(L) = \text{the long run price elasticity of residential electricity demand}; \text{and}
\]

\[
\mu_t = \text{the value of UEDT at period } t
\]

\[
e_t = \text{a random error term.}
\]

The UEDT (\( \mu_t \)) is stochastic and can be estimated by the STSM.

\[
\mu_t = \mu_{t-1} + \beta_{t-1} + \eta_t ; \quad \eta_t \sim \text{NID} (0, \sigma^2_{\eta}) \tag{3}
\]

\[
\beta_t = \beta_{t-1} + \xi_t ; \quad \xi_t \sim \text{NID} (0, \sigma^2_{\xi}) \tag{4}
\]

\( \eta_t \) and \( \xi_t \) are the mutually uncorrelated white noise disturbances with zero means and variances \( \sigma^2_{\eta} \) and \( \sigma^2_{\xi} \) respectively. Larger variances cause greater stochastic movements in the trend. The term \( \eta_t \) allows the level of trend to shift up and down on the other hand term \( \xi_t \) allows the slope to change (Harvey and Shephard, 1993). The shape of the underlying electricity demand trend is determined by these hyper-parameters including \( \sigma^2_{\xi} \), \( \sigma^2_{\eta} \) and \( \sigma^2_{\xi} \). The hyper-parameters and other parameters of the model are estimated by combination of maximum likelihood and Kalman filter. By smoothing the algorithm of the Kalman filter, the
optimal estimation of trend through the sample period is obtained. Equation residuals and a set of auxiliary residuals are estimated in order to evaluate the model. The auxiliary residuals consist of smoothed estimates of model disturbances (identified as irregular residuals, \( \epsilon_t \)), smoothed estimates of the level disturbances (identified as level residual, \( \eta_t \)), smoothed estimates of the slope disturbances (identified as slope residuals, \( \xi_t \)). In order to maintain the normality of the auxiliary residuals, some slope and level interventions can be identified. These interventions generally give information about important breaks and structural changes at certain dates with the estimation period (Koopman et al. 2004). The insignificant variables will be eliminated after introducing the necessary interventions. The software package STAMP 6.3 is used to estimate the model.

5. Overview of Data:

Annual time series data from 1971 to 2006 for E (residential electricity consumption in KWh), Y (household total final expenditure in 2000 constant Yeni Turk Lirasi, YTL), and P (real electricity prices in 2000 constant YTL) are used for the analysis. E is obtained from the International Energy Agency. Nominal household total final expenditure is obtained from the World Bank and nominal electricity prices are obtained from the archives of the State Institute of Statistics (SIS), the Ministry of Energy and Natural Resources (MENR) and the International Energy Agency (IEA). In order to obtain Y and P the nominal expenditure and prices are deflated by the Consumer Price Index obtained from the International Energy Agency.

6. Estimation Results:

After eliminating the insignificant variables and including interventions in order to maintain the normality of residuals and auxiliary residuals. The preferred estimated equation is given by:
\[ e_t = 0.81911e_{t-1} + 0.41457y_{t-1} - 0.10271p_t - 0.15617D73 + \mu_t \]

where \( \mu_t = -6.26901 \) at the end of the period. The detailed estimation results and the diagnostics test are given in Table 1.

The model passes all the diagnostic tests including the additional normality tests for the auxiliary residuals generated by the STSM approach. Real total household expenditure does not have an ‘impact elasticity’, so that a change in expenditure does not have a significant impact in the current year. However, the impact of the expenditure does come through in the next year, which is therefore interpreted here as a short run expenditure elasticity; estimated to be 0.41. This compares to the estimated ‘impact/short run’ elasticity of -0.10. The estimated long run residential expenditure and price elasticities are 2.29 and -0.56 respectively.

The previous years’ electricity consumption has a significant effect on residential sector electricity consumption and the magnitude of this effect is just below 82%. In the short term, household appliances are fixed and given the derived demand nature of residential electricity, the short run impact of changes in prices and income is limited. However, in the long run households are able to change the appliances so that the household expenditure and price elasticities will be greater in the long run.

The estimated UEDT is shown in Figure 5, which shows that it is decreasing and increasing over the estimation period. The year 1973 was introduced as a dummy in order to maintain the normality of the auxiliary residuals. The Turkish government introduced compulsory electricity cuts mainly from residential sector, aiming conservation between 1971 and 1983 however these electricity cuts hike by 37 factor from 1972 to 1973 and kept increasing slightly after 1973 (Figure 4). This conservation effort identified by the UEDT; however, the annual change in year 1973 was enormous which is assumed to create an artificial effect on
energy demand function. By introducing the 1973 dummy, the model is more successful in capturing the features of residential electricity demand. On the other hand, the estimated UEDT captures the compulsory electricity cuts to aid conservation between 1971 and 1983; since starting from 1975 the UEDT follows an energy saving path and by the end of this period, starting from 1984, it is generally upwards sloping.

**Fig-4: The Compulsory Energy Conservation Measures between 1971 and 1983**

![Electricity cuts and conservations](image)

**Fig-5: Underlying Electricity Demand Trend of Turkish Residential Sector 1971-2006**

![Underlying Electricity Demand Trend for Turkish Residential Sector](image)
Table 1: Turkish Domestic Electricity Demand STSM Estimates and Diagnostics
Sample 1971-2006

<table>
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<th>Estimated Coefficients</th>
<th>T values</th>
<th>Probabilities</th>
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**Long run Elasticity Estimates**

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**Goodness of fit**

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**Diagnostics**

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<tr>
<td>Kurtosis</td>
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<td>H(1)</td>
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</tr>
<tr>
<td>r(1)</td>
<td>-0.09063</td>
<td></td>
<td></td>
</tr>
<tr>
<td>r(7)</td>
<td>-0.06202</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DW</td>
<td>2.1235</td>
<td></td>
<td></td>
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<tr>
<td>Q(7,6)</td>
<td>2.7517</td>
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</tbody>
</table>

**Predictive Tests 2003-2006**

<table>
<thead>
<tr>
<th>Variables</th>
<th>Estimated Coefficients</th>
<th>T values</th>
<th>Probabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Failure</td>
<td>0.8285</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cumsum t(4)</td>
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**LR TEST**

<table>
<thead>
<tr>
<th>Variables</th>
<th>Estimated Coefficients</th>
<th>T values</th>
<th>Probabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test(a)</td>
<td>23.494</td>
<td>(0.0000)</td>
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</tr>
<tr>
<td>Test(b)</td>
<td>6.2443</td>
<td>(0.0125)</td>
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</tr>
</tbody>
</table>

**Notes:**
- Model estimation and t-statistics are from STAMP 6.3;
- Model includes a dummy for the year 1973;
- Prediction Error Variance (p.e.v.), Prediction Error Mean Deviation (p.e.v./m.d.2) and the Coefficients of Determination ($R^2$ and $R_d^2$) are all measures of goodness-of-fit;
- Normality (corrected Bowman - Shenton), Kurtosis and Skewness are error normality statistics, all approximately distributed as $\chi^2 (2)$; as $\chi^2 (1)$; as $\chi^2 (1)$ respectively;
- $H(11)$ is a Heteroscedasticity statistic distributed as $F(11,11)$;
- $r(1)$ and $r(7)$ are the serial correlation coefficients at the equivalent residual lags, approximately normally distributed;
- *DW* is the Durbin-Watson statistic;
- *Q(7,6)* is the Box–Ljung statistic distributed as $\chi^2(6)$;
- Failure is a predictive failure statistic distributed as $\chi^2(4)$;
- Cusum is a mean stability statistic distributed as the Student $t$ distribution;
- LR Test(a) represent likelihood ratio tests on the same specification after imposing a zero level hyperparameter and Test(b) after imposing a fixed level hyperparameter distributed as $\chi^2(1)$ and probabilities are given in parenthesis.
- Prediction test are performed after estimation process completed by simply employing the estimation equation for last 4 observations namely 2003, 2004, 2005, 2006.

The years 2003, 2004, 2005 and 2006 are used in order to test the forecast reliability of the model. The model is passed from the prediction tests. The prediction test graphics are provided in Figure 6.

**Fig-6: Prediction Test Graphics**

![Prediction Test Graphics](image)

7. **Forecasting Scenarios, Assumptions and Results:**

In this section, the forecast assumptions, scenarios and the forecast results based on these assumptions and scenarios will be illustrated.
7.1 Forecast Assumptions and Scenarios:

Three scenarios are implemented with different assumptions namely high case, reference and low case. In the high case and the low case scenario a combination of the economic variables were chosen which maximize and minimize the electricity consumption respectively. In the reference scenario, what is seen as the ‘most probable’ outcome of these economic variables is assumed. Furthermore, an increasing, decreasing and constant UEDT is presumed for the high case, low case and reference scenarios respectively. The detailed information about these scenarios is as follows:

In the reference scenario, it is assumed that the real residential electricity prices will increase 1% annually. The Turkish Parliament ratified the Kyoto protocol and it is likely that the government will introduce some measures such as carbon taxes and substitutes for renewables. These new policies will increase the end use prices of electricity. Although the improving energy efficiencies will reduce the cost it is assumed that the real prices will increase 1% annually. The increase of total household final consumption expenditure is expected to be 1%, -1.5% and 1.5% in 2008, 2009 and 2010 respectively because of the global crises. There would then follow a recovery period with an annual expenditure increasing of 3.5%, 2.5%, 2.5% and 2.5% for 2011 to 2014 and a 2% per annum thereafter. Additionally, a constant UEDT that has the same value as the last estimation period is assumed. Although it appears that UEDT is diminishing from 2004, there is not a sufficient number of observations to conclude that it will follow this path. Because of this, the UEDT is assumed constant over the forecast period in the reference scenario.

In the high case scenario, the real residential electricity price is assumed constant over the period 2007-2020. Even though the Kyoto protocol is ratified by Turkish parliament, and will result in new carbon taxes, in this scenario it is assumed that the technological progress and
increasing efficiency standards in electricity generation will decrease the cost. Consequently, it is assumed that these two factors balance each other out and the electricity price will remain constant in real terms. Furthermore, in the high case scenario, because of the global economic crisis, it is assumed that total household total final consumption expenditure will increase by only 1.5% and 1% in 2008 and 2009 respectively, followed by a recovery period with 5% and 4% increase in 2010 and 2011. It is further assumed that the annual increase of expenditure will fall back slightly to 3% per year between 2012 and 2014 and to 2.5% per year thereafter to 2020. Additionally, energy consuming UEDT with a slope of 0.005 is introduced between 2007 and 2020. Although, as mentioned above, UEDT appears to have ‘peaked’ in 2004, the UEDT from 1983 to 2004 for residential electricity consumption is increasing. Therefore, in order to take into account of the possibility that it will return to the increasing despite the downturn in 2004, it is assumed to increase in high case scenario.

In the low case scenario, it is expected that residential electricity prices will increase 2% annually. In this scenario, it is assumed that the measures that will be introduced as a result of Kyoto Protocol will increase the end use prices and reduction in the cost as a result of efficiency and technological progress will not be reflected in end use prices. The annual increase of total household final expenditure is assumed to increase 0.5%, -2.5% and -3% in 2008, 2009 and 2010 because of the global economic crises and increase 2% between 2011 and 2014 then increase annually 1.5% until 2020. In the low case scenario contrary to the high case scenario, an energy saving UEDT with a slope of -0.005 is introduced. It is assumed that the peak and the decreasing UEDT for residential electricity consumption is permanent and therefore continues on a diminishing path.

The graphical presentation of residential electricity prices, household total final expenditure and UEDT according to the related scenarios can be found in Figure 7.
7.2 Forecast Results of Scenarios:

Given the above assumptions, future residential electricity consumption will be 248 TWh, 147 TWh and 84 TWh in the high, reference and low case scenarios respectively. The annual residential electricity consumption forecasts over period 2007-2020 are given in Figure 8.
8. Conclusion and Topics for Further Discussion:

Previous energy forecasts for Turkey were mostly not successful (Ediger and Tatlidil, 2002), (Keles, 2005), (Ediger and Akar, 2007), (Hamzacebi, 2007), (Akay and Atak, 2007). The underlying energy demand trend, structural changes and breaks in energy consumption behaviour, and the impact of previous shocks were not adequately taken into account, and arguably they should be in order to make useful and usable forecasts. Since structural time series modelling, enables the underlying energy demand trend to be estimated it provides valuable knowledge about the structural change and breaks in electricity consumption behaviour and adjustment process related to shocks to the system. It is therefore concluded that the STSM approach is the right solution for determining forecasts of future energy demand.

This paper estimates the residential electricity demand function by using STSM approach. It is found that the estimated household total final expenditure elasticity is 0.41 in short run and 2.29 in long run. Additionally the short run and long run price elasticity is -0.10 and -0.57 respectively. Furthermore, this paper has uncovered the underlying energy demand trend for the Turkish residential sector.

The only previous study focusing on residential electricity demand Halicioglu (2007) finds the short run and the long run price elasticities, which vary from -0.33 to -0.46 and -0.52 to -0.63 respectively. Although these estimated short run price elasticities are somewhat different to the -0.10 obtained here, the long run estimates are similar to the estimated -0.6 found here. This is probably due to firstly, the different real price variable used and secondly the inclusion of the UEDT in this study. Arguably, the more relevant price variable and the inclusion of the UEDT in this study render it more appropriate and therefore more reliable. Additionally, Halicioglu (2007) produces estimated short run income elasticity between 0.37
and 0.44 and an estimated long run income elasticity between 0.49 and 0.70. Although the estimated short run expenditure elasticity of 0.4 found here is similar to that of the income elasticity in Halicioglu (2007), the estimated long run expenditure elasticity of 2.3 differs considerably. These differences are probably due to first, the different activity variables used and second, as with price, the inclusion of the UEDT in this study. It is believed that the expenditure variable used for economic activity here is more appropriate.

The residential electricity demand has a diminishing trend between 1976 -1983, which might be just because of compulsory conservation measurements that were adopted by government between 1971 and 1983 and identified by Structural Time Series Modelling that arguably illustrates the power of STSM approach distinguishing the structural changes of demand behaviour. In addition, after the end of these compulsory conservation measurements starting from 1984, the UEDT follows an increasing trend until 2004. Furthermore, it can be argued that there is a structural change in 2004 when it appears that the trend reached a peak and might follow a diminishing path, perhaps transforming the Turkish residential sector to being ‘energy saving’.

It is expected under the different forecast assumptions that the Turkish residential electricity consumption is expected to be between 84 and 248 Terawatt-hour by the year 2020. There is only one previous forecast study Hamzacebi (2007) which predicted that the residential electricity consumption would be 257 TWh in 2020, which is noticeably greater than even the high case scenario of this study. This forecast is highly unlikely and arguably unreasonable. Hamzacebi (2007) does not investigate the relation between economic activity and residential electricity consumption but as was explained earlier, the electricity demand is derived demand and highly affected by economic activity. Thus, any forecast that ignores this effect will arguably lead to a misleading outcome.
On the other hand, the Kyoto protocol was ratified by the Turkish Parliament on 05/02/2009. The Kyoto protocol legally introduces compulsory commitments for the reduction of greenhouse gases. It is commonly expected that there will be a change in the energy policies of Turkey that might include CO₂ taxes and energy efficiency regulations. The efficiency regulations are expected to have significant impacts on appliances. Introducing more efficient standards for household appliances will lead to less energy consumption in long term. Another expected result of ratification of the Kyoto protocol might be the structural change in the Turkish residential sector electricity demand that should be tested by a later study.

This study focuses on estimating an energy demand function for the Turkish residential sector, which is used to provide future scenarios of consumption. Previous Turkish electricity demand forecasts always projected greater electricity demand than the actual outturn. It is argued here that this is mainly because of the shortcomings of the applied models, the inability of the authorities in establishing accurate assumptions and not having transparency and credibility during the application of the selected model. This study addresses some of the shortcomings of models by introducing the UEDT, which has an important impact on electricity consumption behaviour.

Having better knowledge about future demand, it will be possible to finance and develop the necessary measures with an optimum cost and over an optimum period that enables sustainable and cost efficient solutions for future electricity needs. For the sustainable economic growth of Turkey, accurate and reliable energy demand forecasts are very important in order to develop accurate policies.
References:


