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Modelling and Forecasting Turkish Residential Electricity Demand

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ABSTRACT

This research investigates the relationship between Turkish residential electricity consumption, household total final consumption expenditure and residential electricity prices by applying the structural time series model to annual data over the period 1960 to 2008. Household total final consumption expenditure, real energy prices and an underlying energy demand trend are found to be important drivers of residential electricity demand with the estimated short run and the long run total final consumption expenditure elasticities being 0.38 and 1.57 respectively and the estimated short run and long run price elasticities being -0.09 and -0.38 respectively. Moreover, the estimated underlying energy demand trend, (which, as far as is known, has not been investigated before for the Turkish residential sector) should be of some benefit to Turkish decision makers in terms of energy planning. It provides information about the impact of the implementation of past policies, the influence of technical progress, the changes in consumer behaviour and the effects of energy market structure. Furthermore, based on the estimated equation, and different forecast assumptions, it is predicted that Turkish residential electricity consumption will be somewhere between 48 and 80 TWh by 2020 compared to 40 TWh in 2008.

JEL Classifications: C22, Q41, Q47.

Key Words: Turkish Residential Electricity Demand, Structural Time Series Model (STSM), Future Scenarios, Energy Demand Modelling and Forecasting.

Modelling and Forecasting Turkish Residential Electricity Demand*

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1. Introduction

Turkey covers an area of just over 780 thousand km², straddling South Eastern Europe and South Western Asia, with an estimated population of just under 72 million people in 2007 (FCO, 2010). The first attempt to produce electricity in Turkey was during the Ottoman Empire era at the beginning of the 20th century. In 1902, electricity was first generated and distributed to households by connecting a 2 KW dynamo to a watermill. Technical knowledge at that time was limited; therefore, the Ottoman Empire targeted foreign investment in order to finance electricity generation. To help facilitate this, the ‘Privileges for Public Wealth’ law was introduced in 1910, giving privileges to electricity generation companies such as the Hungarian Ganz Partnership that, with a Hungarian and Belgium bank, established the ‘Ottoman Electricity Stock Company’. As a result, in 1913 the first large scale electricity power plant (13.4 MW) was built in Silahtaraga, Istanbul. This was followed by construction of further power plants in Anatolia (Dolun, 2002 and TEI, 1972).

* Acknowledgements

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When the Turkish Republic was founded in 1923, the installed electricity capacity for Turkey was 33 MW with production around 50 million kWh. The privileged contracts for foreign electricity generation companies were approved by the new Turkish Republic Administration, but only for a temporary period, acknowledging the lack of technological knowledge within Turkey at that time. The privilege contracts were designed to favour generation companies by indexing the electricity prices to gold prices. Given this, electricity prices were high in the early republican era leading to some electricity intensive industrial factories building their own power generation facilities. This allowed them to produce electricity for their own use and to supply to local households located nearby these facilities¹ (Dolun, 2002 and TEI, 1972).

Given that the foreign private firms involved in the Turkish electricity industry at this time aimed at maximising profits, they were reluctant to invest in rural areas, thus slowing down both the increase in electricity generation and electrification. Therefore, the Etibank (a governmental entrepreneurship) was established in 1935 to operate in the electricity generation and mining sectors. In the same year the Electric Power Resources and Survey Administration was also established with the remit to examine electricity generation opportunities from hydro and other fuels. In addition, starting in 1938 thru 1944 the power plants operating under the control of the foreign concessionary private companies were bought by the Turkish government and were given to the municipal administrations for management. Furthermore, in 1957, the Turkish government established a new organization namely the Energy and Natural Resources Department, responsible for coordinating the activities of electricity generation and distribution companies and the Ministry of Energy and

¹ For example, the Karbuk Iron and Metal Factory and the Izmit Seka and Sumerbank were also known as auto-producers (Dolun, 2002 and TEK, 1972).

Natural Resources was founded in 1963 to administer Turkish energy policies (Dolun, 2002 and TEI, 1972).

In 1970 the Turkish Electricity Institution (TEI)² was established with the main aim of coordinating electricity generation across the country.³ Consequently, the TEI had a monopoly in the generation and transmission of electricity, with distribution undertaken by municipal administrations. However, following the introduction of Law No 2705 in 1982, the distribution function of the municipal administrations was transferred to the TEI giving Turkey a fully vertically integrated state owned monopoly (Dolun, 2002). In 1993, Law no. 513 was introduced, with the stated aim to privatize the TEI. Following this the TEI was divided into two state owned enterprises, the ‘Turkish Electricity Generation and Transmission Co. (TEGTC)⁴’ and the ‘Turkish Electricity Distribution Co. (TEDC)⁵’ but their relationship with the Ministry of Energy and Natural Resources was maintained as before (Dolun, 2002).

In 2001, the Electricity Market Law No. 4628 was introduced, with the aim of regulating the electricity market with the establishment of the Regulatory Body of Electricity Market in the same year. Furthermore, the TEGTC was restructured, being divided into three state owned

² In Turkish, this is known as TEK (Turk Elektrik Kurumu); translated by authors.

³ Although at different times, similar developments occurred across Western Europe (although often for similar reasons) resulting in the establishment of centralised electricity industries and institutions, coupled with nationalization. For example, Electricite de France in France in the mid 1940s, the Central Electricity Generating Board in the UK in the late 1950s and the Ente Nazionale per l'Energia Elettrica (ENEL) in Italy in the early 1960s.

⁴ In Turkish, this is known as TEAS (Turkiye Elektrik Anonim Sirketi); translated by authors.

⁵ In Turkish, this is known as TEDAS (Turkiye Elektrik Dagitim Anonim Sirketi); translated by authors.

public enterprises, the ‘Turkish Electricity Transmission Co. (TETC)⁶’, the ‘Turkish Electricity Generation Co. (TEGC)⁷’ and the ‘Turkish Electricity Trading Co. (TETC)⁸’. Within this new structure TEGC took over and operated the public power plants, TETC was given responsibility for wholesale operations and became the holder of all previous Build-Own-Operate (BOO), Build-Operate-Transfer (BOT) and Transfer of Operating Rights (TOOR) agreements and long term power purchase agreement with Treasury guaranties. TETC was assigned responsibility for transmission and balancing and settlement procedure in order to balance power operation between parties, covering both the physical and financial aspects of transmission operation; hence, TETC became the transmission system operator for Turkey (Dolun, 2002).

The history and development of the Turkish electricity industry, discussed above, has been driven by past governments’ concerns with meeting the growth in electricity demand in order to maintain economic growth and raise the living standards of the Turkish people. This remains true today for the present Turkish government. Therefore, given that the Turkish electricity industry remains under state control, with only, limited genuine market activity, it is vital that Turkish policy makers understand the main characteristics of electricity demand and the key drivers of both past and future of electricity demand. Furthermore, different sectors (such as the residential and industrial sectors) have different characteristics with different drivers and/or different impacts of drivers. This study, therefore, aims to identify

⁶ In Turkish, this is known as TEIAS (Türkiye Elektrik İletim Anonim Şirketi); translated by authors.

⁷ In Turkish, this is known as EUAS (Elektrik Üretim Anonim Şirketi); translated by authors.

⁸ In Turkish, this is known as TETAS (Türk Elektrik Ticaret ve Taahüt Anonim Şirketi); translated by authors.

and forecast Turkish residential electricity demand, which in 2008 represented just under a quarter of total Turkish electricity demand (IEA, 2010).⁹

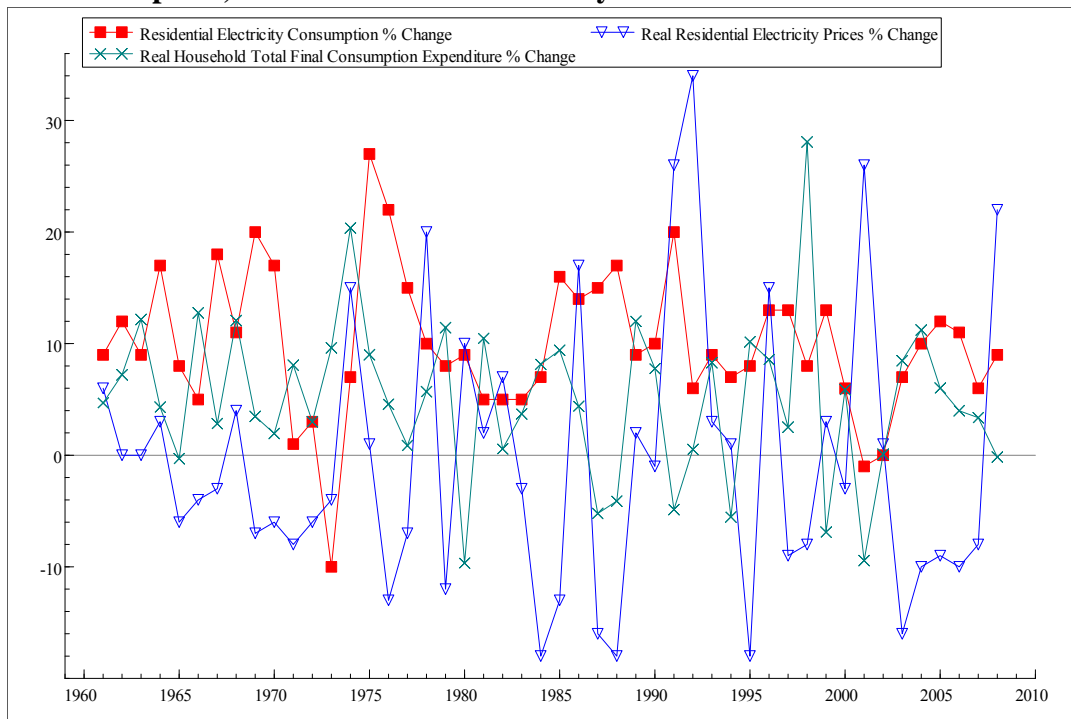
Residential electricity is a ‘derived demand’, not demanded for its own sake but for use with household appliances to produce energy services such as lighting, heating, cooling, etc. In 1970 just over 50% of the Turkish population benefited from accessing electricity but by 1987 it had almost reached 100% (Altas et al., 1994). In the early part of this period, electricity was generally used for lighting but use expanded for a range of other household energy services in the latter part with the installation of new appliances such as TVs, refrigerators, etc. It is commonly expected that higher household income and expenditure will result in higher demand for the services emanating from these kinds of appliances, which use electricity. In the short term, this is likely to boost electricity consumption but in the longer term higher income is likely to result also in households replacing appliances that use old technologies with new more efficient ones that might have a lessening effect on electricity consumption. It is therefore important for policy makers and planners to have some idea of the short and long run income and expenditure elasticities.

From 1960 to 2008, Turkish residential electricity consumption increased by an average of about 10% per year, from 0.5 TWh to 39.5 TWh (IEA, 2010). Whereas from 1960 to 2008 household total final expenditure increased on average by just under 5% per year, from about 53 billion YTL (2005 Constant YTL) to just over 500 billion YTL (2005 constant YTL) (World Bank, 2010). Furthermore, over the period 1960 to 2008 electricity prices were

⁹ This work is part of on-going research analysing Turkish electricity demand; see, for example, Dilaver and Hunt (2010).

mostly controlled by successive Turkish governments despite the Electricity Market Law No. 4628 introduced in 2001 with the aim of creating a liberalized market structure, as discussed above; hence, real electricity prices decreased by an average of about 1% per annum over the estimation period. Figure 1 illustrates the annual changes in residential electricity prices along with the annual changes in electricity consumption and total household expenditure.

Figure 1: Household Total Final Consumption Expenditure, Residential Electricity Consumption, Residential Real Electricity Prices Growth Rates 1960-2008



In 2008, residential electricity consumption accounted for 25% of total Turkish electricity consumption (IEA, 2010). Therefore household electricity consumption has a significant role for energy planners given that over the period 1960 to 2008 electricity was, and remains, predominantly a publicly owned and controlled industry. Therefore, it is increasingly important to investigate the key drivers of Turkish residential energy demand and be able to construct sensible future scenarios. The success or otherwise of these can have a significant impact on the welfare of the Turkish economy and is essential for Turkish sustainable economic development. However, past energy demand studies, discussed in detail in the next section, have arguably not been successful in adequately explaining Turkish energy

demand. One reason being that the previous studies did not attempt to model the underlying energy demand trend to capture the impact of exogenous effects. Whereas, the Structural Time Series approach adopted here does and is therefore arguably a more appropriate tool for electricity demand planning, given it allows for the estimation of a stochastic underlying trend.

Residential electricity consumption is also important in terms of the associated CO₂ emissions. Turkish CO₂ emissions from energy consumption more than doubled from 1990 to 2010. Turkey is a party to the United Nations Framework Convention on Climate Change (UNFCCC) and Kyoto Protocol but is the only Annex-I country that has not put any mitigation targets in place for the post 2012 period. Moreover, Turkey is the only OECD country that does not have a national emission target for 2020 (IAE, 2010). Consequently, Turkey might well face future international pressure to set emission targets. In the short term, the Turkish government's priority is to meet growing energy demand, but in the long term, ignoring these global trends might be costly both politically and economically. However, in order to reach a balance between securing electricity supply to meet demand and transforming the power generation to a more sustainable level, the Turkish government requires sound and reliable electricity demand projections to underpin their planning activities. However, as stated above, this has not always been the case, so that given residential electricity consumption has a significant share in total electricity consumption, it is important that Turkish policy makers understand what drives residential demand and more importantly how it might evolve over the next 10 years or so.

Energy modelling prepares for possible future outcomes, allowing predictions to be made and enabling decisions to be taken for the 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). Furthermore, as stated above, in order to help achieve sustainable Turkish economic growth accurate and reliable energy demand forecasts are very important in order to develop appropriate policies such as electricity price regulation, power investments, long term import contracts, energy efficiency measures etc.

The aim of this study therefore is to investigate how the structural time series methodology performs in terms of modelling past residential electricity demand (by estimating the key household total final consumption expenditure and price elasticities and the underlying energy demand trend) and forecasting Turkey's future residential electricity consumption. The primary motivation is to produce better projections of residential energy demand, to aid policy makers and planners and hence the future welfare of the Turkish economy.

In the next section, the previous Turkish energy demand studies are discussed followed by Section 3, which summarises the key previous literature. Section 4 outlines the methodology used in the paper, followed by Section 5 that discusses the data used for the analysis and presents the results of the estimation. Section 6 presents the future scenarios and the final section concludes.

2. Previous Turkish Energy Demand Studies

There are only a limited number of previous Turkish electricity demand studies, with the majority being undertaken by governmental organizations such as the State Planning Organisation (SPO), the State Institute of Statistics (SIS) and the Ministry of Energy and Natural Resources (MENR) (Ediger and Tatlidil, 2002). The MENR utilized different models in order to determine energy demand functions and to make future projections. For instance, ‘Balance’ models (non-linear equilibrium models that match energy demand with available resources and technologies) and ‘Impact’ models (that focus on the relation between energy consumption and its interaction with the environment) were employed in the framework of the Energy and Power Evaluation Program (ENPEP). Both models were used for producing long-term supply and demand projections between 1981 and 1985. Furthermore, the MENR began to use the simulation models 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 (Energy Flow Optimization Model) was developed by the commission of the European Union starting from 1984 (Ediger and Tatlidil, 2002).

At the same time, the SPO also developed its own models based on sectoral energy demand for different consumer groups and subgroups with mathematical models developed for each sub group by regression. On the other hand, the SIS 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).

Overall, all these Turkish electricity demand forecasts from the above studies foresaw electricity demand being somewhat greater than it actually turned out to be. According to Keleş (2005), this is mainly due to “technical deficiencies of the models used, lack of ability of the relevant authorities in creating precise assumptions and not having transparency and accountability in the relevant processes” (p. vi). As a result of these ‘exaggerated forecasts’, policies that were implemented (such as introducing the guaranteed BOO, BOT and TOOR projects) 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 energy import dependent and therefore more vulnerable to external shocks and prevented energy markets from liberalizing (Keleş, 2005). Furthermore Ediger and Tatlidil (2002) stated that the values of the future predictions of demographic and economic variables used in the MAED models by SPO were significantly manipulated by government policies in line with high economic growth targets rather than reliable forecasts (Ediger and Tatlidil, 2002).

3. Literature Review

In this section, previous Turkish residential electricity demand modelling studies and previous studies using the structural time series model of energy demand are reviewed separately. A more detailed summary of previous energy demand modelling studies can be found at Dilaver and Hunt (2010).

3.1 Electricity Demand Studies for Turkish Residential Sector

There are, as far as is known, only two previous energy demand modelling studies that focused on residential electricity consumption, namely Halicioglu (2007) and Hamzacebi (2007). Halicioglu (2007) investigated Turkish residential electricity demand using the Bounds Testing approach and found a range of estimated elasticities depending upon the number of lags chosen, such as:

- Short and long run price elasticities of -0.33 and -0.52 respectively.
- Short and long run income elasticities of 0.44 and 0.70 respectively.

Halicioglu (2007) argues that the urbanization rate is also a significant variable in determining Turkish residential energy consumption finding estimated urbanization short run and long run elasticities of 0.90 and 0.04 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.

Hamzacebi (2007) is, as far as is known, the only previous academic study to focus on forecasting Turkish residential electricity demand. Based upon 1970-2004 sectoral electricity

consumption data and Artificial Neural Networks, Hamzacebi (2007) predicts future electricity consumption for different sectors, including the residential sector and suggests that residential electricity consumption will reach about 257 thousand GWh in 2020. However, Hamzacebi (2007) took no account of the impact of economic activity and its interaction with residential electricity consumption.

In summary, Halicioglu (2007) investigated the relationship between residential electricity consumption and economic variables whereas Hamzacebi (2007) predicts the future residential electricity consumption. The research undertaken here, attempts to do both of these within a consistent framework and, as discussed above, arguably overcomes some of the shortcomings with both previous studies and hence improve both the understanding of past Turkish residential electricity demand behaviour and also provide better future scenarios. In particular, this study uses real electricity price data rather than the general energy price index and the underlying energy demand trend is explored and illustrated, since this is seen as an important driver of residential electricity consumption. Furthermore, this study allows for the inclusion of economic variables and their impact on residential electricity consumption that arguably allows for a better understanding of residential electricity consumption both in the past and in the future.

3.2 *Review of the Structural Time Series Model (STSM) and its Application to Energy Demand Studies*

3.2.1 *Structural Time Series Models*

The basic concept of structural time series modelling is to decompose a time series into a trend component, seasonal component and irregular component. These models are described by Harvey (1989) as regression models in which explanatory variables are a function of time and parameter change over time. The structural time series model allows for the introduction of either a stochastic or a deterministic trend; however, arguably a stochastic trend is more successful in terms of determining structural changes in time series because of flexible nature of a stochastic trend (Rao, 2010).

The main tool for estimating a STSM is the state space form, which is representation of the system at a given time point with a range of unobserved components including trend.¹⁰ Once the state space form is formulated, unobserved components are estimated using the forward Kalman filter and backward Kalman smoother (Kalman, 1960). This recursive procedure calculates the optimal estimator of the state vector. The hyper-parameters and other parameters of the model are estimated by a combination of maximum likelihood and the Kalman filter.

3.2.2 *STSM in Energy Demand Studies*

According to Jalles (2009), the structural time series models are converted into behavioural models when they are also incorporated with exogenous variables (such as income and price). Furthermore, these models can provide valuable information about underlying trends for

¹⁰ And seasonals if the data frequency is less than a year (but given annual data is used in this study, seasonals are ignored here).

policy makers. Therefore the application of structural time series models are becoming more popular in recent years in energy demand modelling (discussed further below).

Harvey and Koopman (1993) was the first application of the structural time series modelling approach to energy demand modelling, investigating hourly electricity demand for north-west United States. Hunt et al. (2000) by using structural time series approach introduced to the energy demand literature the concept of the ‘Underlying Energy Demand Trend (or UEDT)’¹¹ that summarizes the impact of unobservable exogenous factors that determine energy demand. Hunt et al. (2000) identify the UEDT for different energy types for the UK, including coal, gas, oil, petroleum, electricity and total energy. A range of studies followed this focusing on different energy demand models, including Hunt et al. (2003a 2003b), Hunt and Ninomaya (2003), Dimitropoulos et al. (2005), Amarawickrama and Hunt (2008), and Dilaver and Hunt (2010). Moreover, in almost all cases a stochastic UEDT is favoured over a deterministic UEDT arguing that the stochastic form of the UEDT provides more information about the unobserved components that affect energy consumption. Therefore, the stochastic approach enables the creation of models that should arguably generate more reliable forecasts of energy demand. In the next section, the empirical framework of the STSM and UEDT, used in this study, is explained in detail.

¹¹ A detailed summary of the UEDT can be found Dilaver and Hunt (2010), Hunt et al. (2000) and Hunt et al. (2003a and 3003b).

4. Empirical Methodology

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

$$E_t = f(Y_t, P_t, UEDT_t) \quad (1)$$

Where:

E_t = Residential electricity demand.

Y_t = Household Total Final Expenditure.

P_t = Real residential electricity price.

$UEDT_t$ = Underlying Energy Demand Trend for residential electricity.

For the econometric estimation of equation (1) a dynamic autoregressive distributed lag specification of Turkey's electricity demand function is assumed as follows:

$$A(L) e_t = B(L) y_t + C(L) p_t + UEDT_t + \epsilon_t \quad (2)$$

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 $1 + \phi_1 L + \phi_2 L^2 + \phi_3 L^3 + \phi_4 L^4$; $C(L)$ is the polynomial lag operator $1 + \alpha_1 L + \alpha_2 L^2 + \alpha_3 L^3 + \alpha_4 L^4$ and

$$e_t = \ln(E_t)$$

$$y_t = \ln(Y_t)$$

$$p_t = \ln(P_t)$$

$B(L)/A(L)$ = the long run total household final consumption expenditure elasticity of residential electricity demand;

$C(L)/A(L)$ = the long run price elasticity of residential electricity demand; and

ϵ_t = a random error term¹².

¹² In order to capture any dynamic effects, a four year lag is chosen for the polynomial lag operator since it is seen as a reasonable length.

The UEDT is stochastic and can be estimated by the STSM.

$$\mu_t = \mu_{t-1} + \beta_{t-1} + \eta_t ; \quad \eta_t \sim NID (0, \sigma_\eta^2) \quad (3)$$

$$\beta_t = \beta_{t-1} + \xi_t ; \quad \xi_t \sim NID (0, \sigma_\xi^2) \quad (4)$$

where μ_t and β_t are the level and slope of the UEDT respectively. η_t and ξ_t are mutually uncorrelated white noise disturbances with zero means and variances σ_η^2 and σ_ξ^2 respectively.

The disturbance terms η_t and ξ_t determine the shape the stochastic trend component (Harvey and Shephard, 1993). Where necessary the condition of normality of the auxiliary residuals (irregular, level and slope residuals) can be satisfied, by level and slope interventions (Harvey and Koopman, 1992). These interventions give information about important breaks and structural changes at certain dates with the estimation period. In the presence of such interventions the UEDT can be identified as:

$$\text{UEDT} = \mu_t + \text{irregular interventions} + \text{level interventions} + \text{slope interventions} \quad (5)$$

The software package STAMP 8.10 (Koopman et al., 2007) is used to estimate the model and the results are given in the next section after discussing the data.

5. Data and Estimation

5.1 Data

Annual time series data from 1960 to 2008 for E (residential electricity consumption in KWh), Y (household total final expenditure in 2005 constant Yeni Turk Lirasi, YTL), and P (real electricity prices in 2005 constant YTL) are used for the analysis. E was obtained from the International Energy Agency (IEA, 2010) and nominal household total final consumption

expenditure from the World Bank (World Bank, 2010). Nominal electricity prices were obtained from the archives of the SIS, the MENR and the International Energy Agency (IEA). In order to obtain Y and P the nominal expenditure and prices were deflated by the Consumer Price Index obtained from the World Bank.

5.2 Estimation Results

After eliminating the insignificant variables and including interventions in order to maintain the normality of residuals and auxiliary residuals, a summary of the preferred estimated equation is given by:

$$e_t = 0.758e_{t-1} + 0.380y_{t-1} - 0.092p_t + UEDT_t \quad (5)$$

where $UEDT_{2008} = -4.431$ at the end of the period. The detailed estimation results and the diagnostics tests 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. This includes the STAMP prediction tests over 2001 – 2008, as illustrated in Figure 2.

The previous years' electricity consumption has a significant effect on residential sector electricity consumption the magnitude being just above 75%. In the short run, 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.

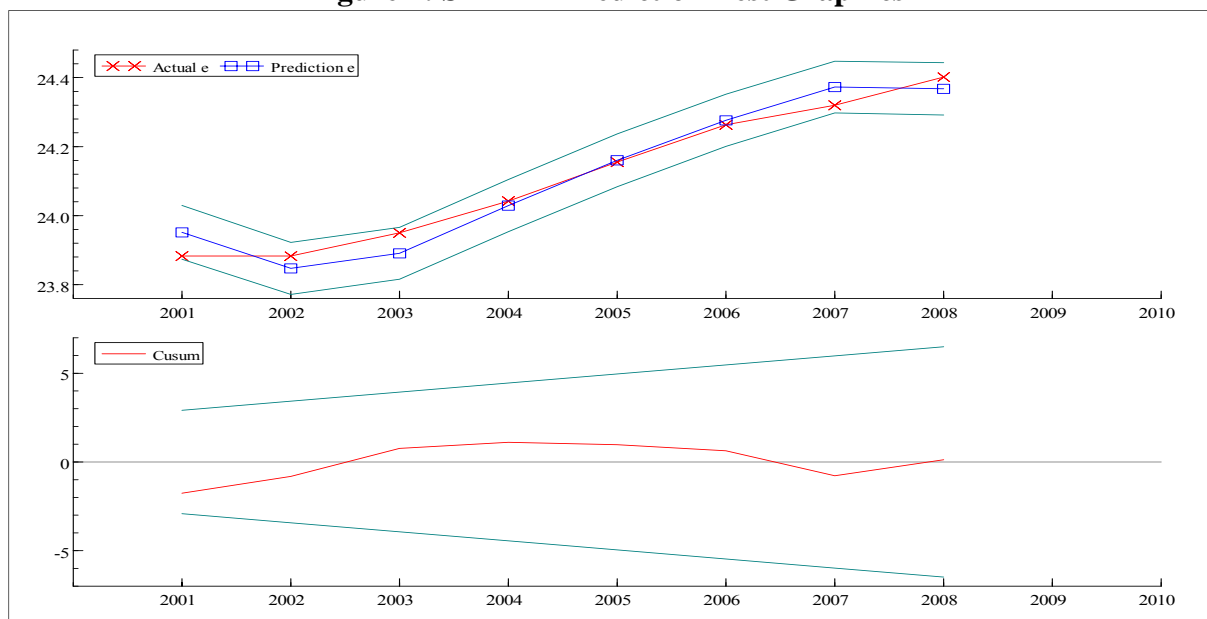
**Table 1: Turkish Domestic Electricity Demand STSM Estimates and Diagnostics
Sample 1960-2008**

Variables	Estimated Coefficients	T Values	Probabilities		
e_{t-1}	0.75767	14.992	0.000		
y_{t-1}	0.37978	4.695	0.000		
p_t	-0.09171	-2.069	0.045		
<i>Irr 1973</i>	-0.1345	-4.471	0.000		
<i>Level 1971</i>	-0.1199	-3.250	0.002		
<i>Level 1975</i>	0.1013	2.576	0.014		
<u><i>Components Of UEDT₂₀₀₈</i></u>			<u><i>Long Run Elasticity Estimates</i></u>		
<i>Level (μ)</i>	-4.4124		Price	-0.38	
<i>Slope(θ)</i>	-		Income	1.57	
			<u><i>Auxiliary Residuals</i></u>		
	<i>Residuals</i>		<i>Irregular</i>	<i>Level</i>	<i>Slope</i>
Std. Error	0.960	Std. Error	0.986	0.969	-
Normality	0.281	Normality	0.816	0.299	-
Skewness	0.111	Skewness	0.827	0.120	-
Kurtosis	0.967	Kurtosis	0.549	0.992	-
H(13)	1.201		-	-	-
R(1)	0.047		-	-	-
R(6)	0.099		-	-	-
DW	1.856		-	-	-
Q(6,5)	1.563		-	-	-
<u>Predictive Test 2001-2008</u>			<u>LR Test</u>		
Failure	0.30		Test (a)	30.507 (0.0000)	
CumSum t(4)	0.97		Test (b)	19.954 (0.0000)	
<u>Goodness of Fit</u>			<u>Hyperparameters</u>		
p.e.v.	0.001		Irregular	0.0007608	
p.e.v./m.d.²	1.134		Level	0.0003398	
R²	0.999		Slope	-	
R_d²	0.720		Nature of Trend:	<i>Local Level Model</i>	

Notes for Table 1:

- Model estimation and all statistics are from STAMP 8.10;
- Model includes a level intervention for the year 1971, an irregular for the year 1973 and a level intervention for the year 1975;
- Prediction Error Variance (p.e.v.), Prediction Error Mean Deviation (p.e.v./m.d.2) and the Coefficients of Determination (R^2 and Rd^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;
- $H(13)$ is a Heteroscedasticity statistic distributed as $F(13,13)$;
- $r(1)$ and $r(7)$ are the serial correlation coefficients at the equivalent residual lags, approximately normally distributed;
- DW is the Durbin-Watson statistic;
- $Q(6,5)$ is the Box – Ljung statistic distributed as $\chi^2(5)$;
- Failure is a predictive failure statistic distributed as $\chi^2(8)$ and Cusum is a mean stability statistic distributed as the Student t distribution; both are STAMP prediction tests found by re-estimating the preferred model up to 2000 and predicting for 2001 thru 2008;
- LR Test(a) represent likelihood ratio tests on the same specification after imposing a fixed level and zero slope hyperparameter and Test(b) after imposing a fixed level and fixed slope; both are distributed as $\chi^2(2)$ and probabilities are given in parenthesis.

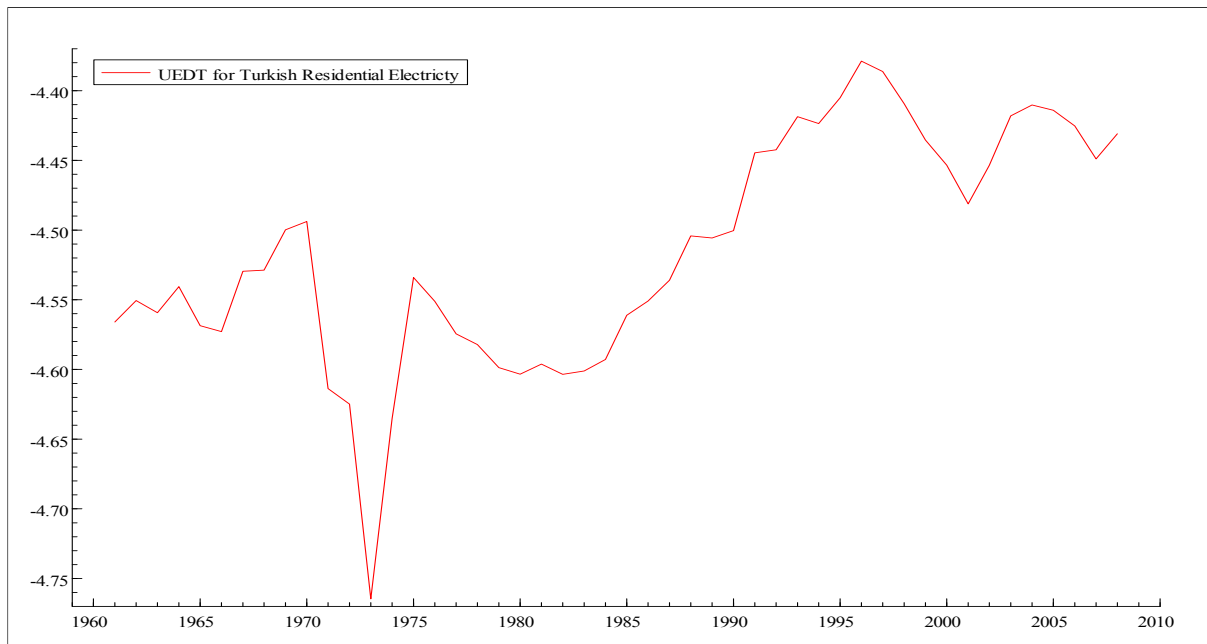
Figure 2: STAMP Prediction Test Graphics



The estimated results suggest that expenditure does not have a significant impact in the current year; that is the ‘impact elasticity’ is estimated to be zero. However, the impact of expenditure is estimated to come through during the next year; hence, this is interpreted here as the ‘short run’ expenditure elasticity of 0.38. This compares to the estimated ‘impact/short

run' price elasticity of -0.09. Whereas the estimated long run residential expenditure and price elasticities are 1.57 and -0.38 respectively.

Figure 3: Underlying Electricity Demand Trend of Turkish Residential Sector 1961-2008

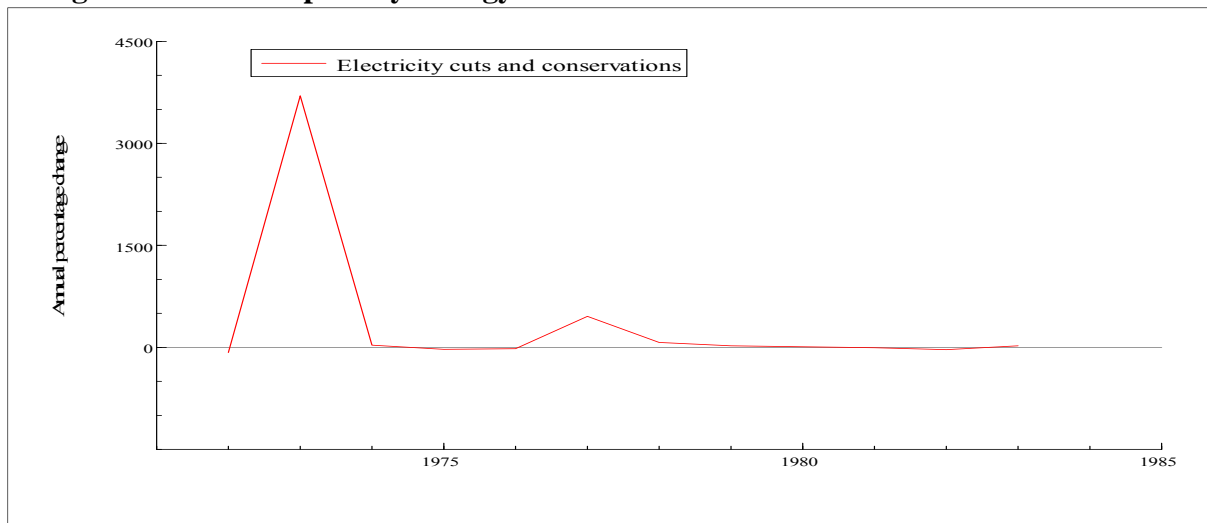


The estimated UEDT is the local level model that consists of a stochastic level but no slope and is shown in Figure 3, which illustrates that the estimated UEDT decreases and increases over the estimation period. This UEDT would appear to reflect the compulsory electricity cuts introduced by the Turkish governments (primarily in the residential sector) aimed at conserving electricity consumption between 1971 and 1983. An irregular intervention in 1973 and level interventions in 1971 and 1975 were required in order to maintain the normality of residuals and auxiliary residuals. The level interventions appear to reflect the

impact of cuts on the behaviours of consumers in 1971¹³ that were almost reversed in 1975 (probably reflecting the way consumers adjusted their behaviour accordingly).

The irregular intervention for the year 1973 probably reflects the impact of the electricity cuts that peaked in 1973 by a factor of 37 from 1972 to 1973 and kept increasing slightly after 1973 (Altas et al. 1994) as illustrated in Figure 4. Thus in 1973 it appears that desired residential demand was severely constrained by the cuts; hence the need for the irregular intervention. Moreover, given the intervention for 1973 represents a ‘pulse effect’ it does not affect the electricity consumption permanently, only in 1973 electricity consumption decrease 14% for the year.

Figure 4: The Compulsory Energy Conservation Measures between 1971 and 1983



*Source: Altas et al. (1994)

¹³ The electricity cuts that were applied for couple of hours during the day decrease the level of total electricity consumption permanently by 12%.

6. Forecasting Scenarios, Assumptions and Results

In this section, the forecast assumptions and future scenarios for Turkish residential electricity demand based on these assumptions are discussed and illustrated.

6.1 Forecast Assumptions and Scenarios

Three scenarios are implemented with different assumptions namely a ‘low’, ‘reference’ and ‘high’ case. In the ‘low’ and ‘high’ case scenarios, a combination of economic variables that drive electricity consumption are chosen in order to ‘minimize’ and ‘maximize’ future electricity consumption respectively. In the ‘reference’ scenario, what is seen as the ‘most probable’ outcome for these economic variables is assumed. However, given the 2009 nominal residential electricity price¹⁴ is known, this is used in all the three scenarios. The detailed information about these scenarios is as follows:

- *In the ‘reference’ scenario*, it is assumed that real residential electricity prices will increase 1% annually from 2010 onwards. The Turkish Parliament ratified the Kyoto protocol and it is likely that the government will introduce some measures such as carbon taxes and incentives for renewables. These new policies will increase the end use prices of electricity. Although improving energy efficiency will reduce the cost, it is assumed that the real prices will still increase 1% annually. The increase of total household final consumption expenditure is assumed to be 1% in 2009 because of the global crises followed by a recovery period with an annual expenditure increasing by 2% per year in 2010 thru 2012, 3% per year in 2013 thru 2016 and 3.5% per year thereafter. Given that the preferred model is a local level model with no estimated slope, this suggests that the UEDT is fixed over the future at the estimated level in 2008. However, given that the estimated UEDT generally rises its average change over the estimation period is utilized for the slope of the UEDT after 2008; it is

¹⁴ In 2009 Turkish residential electricity prices increase d by 19.3 % in nominal terms. The required deflator (the Consumer Price Index from World Bank) is not available for 2009 at the time of writing, although it is known that the inflation rate is around 6.5 % in Turkey for 2009; hence, based on this, the real residential electricity price is assumed to have increased by 12.8% in 2009 for all three scenarios.

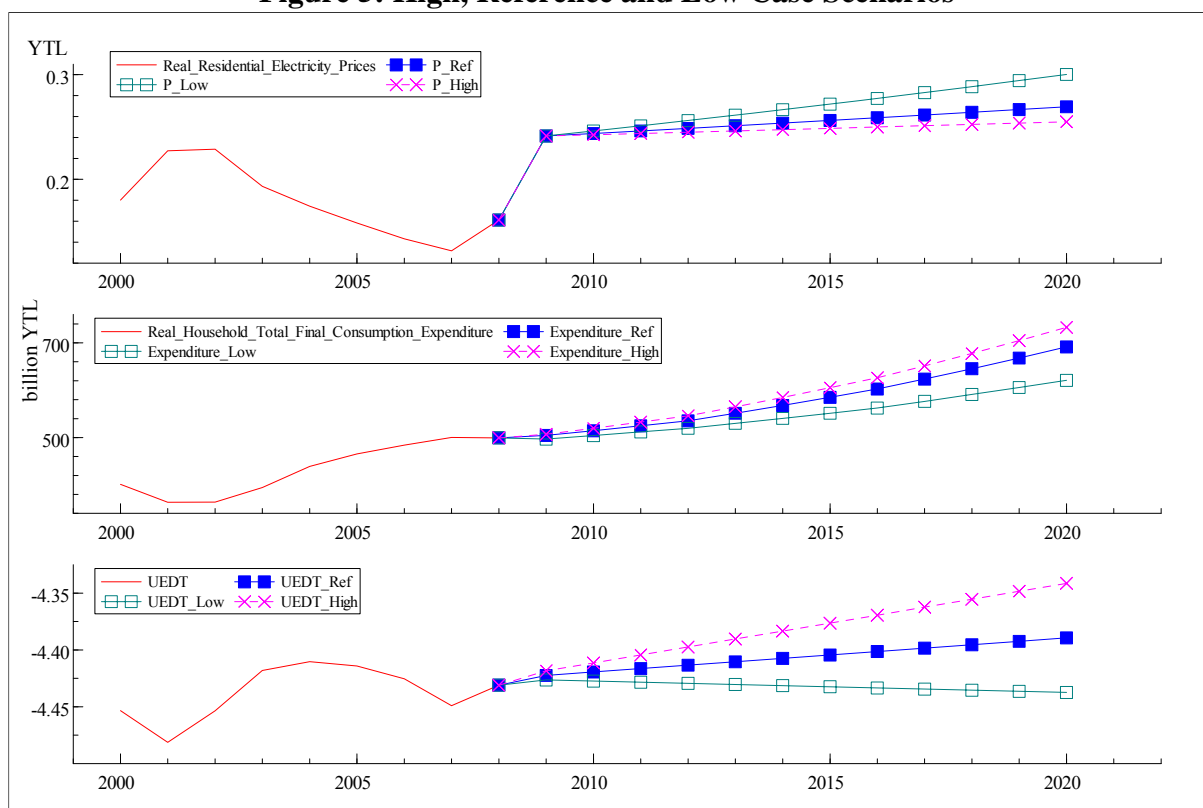
therefore assumed that the slope of the UEDT is 0.003 for the ‘reference’ scenario.¹⁵ This assumption suggests that the general ‘electricity using’ behaviour of the Turkish residential sector by the estimated UEDT will continue into the future.

- *In the ‘low’ case scenario*, it is expected that residential electricity prices will increase by 2% per annum from 2010. It is assumed that measures introduced because of the Kyoto Protocol will increase end use prices and the reduction in the cost as a result of efficiency gains and technical progress will not be reflected in the end use prices. The annual increase of total household final expenditure is assumed to decrease 0.5% in 2009, increase 1.5% per year in 2010 thru 2012 because of the global economic crises, but then increase 2% per year in 2013 thru 2016, and 2.5% per year thereafter. An ‘electricity using’ UEDT with a decreasing slope of 0.001 is introduced from 2009. This assumption reflects the view that the ‘electricity using’ UEDT will continue but at a slower pace than the ‘reference’ scenario because of an increase in energy efficiency.
- *In the ‘high’ case scenario*, even though the Kyoto protocol was ratified by the Turkish parliament, and is likely to result in new carbon taxes, in this scenario it is assumed that the technical 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 increase only by 0.5% per year in real terms. It is assumed that total household total final consumption expenditure will increase by 1.5% in 2009 and 2.5% per year in 2010 thru 2012, followed by a 3.5% per year increase in 2013 thru 2016. It is further assumed that the annual increase of expenditure will be 4% per year thereafter. Additionally, contrary to the ‘low’ case scenario, an ‘electricity using’ UEDT is assumed with a slope of 0.007 from 2009, assuming that the exogenous ‘electricity using’ behaviour for Turkish residential electricity demand increases at an even greater pace.

¹⁵ As opposed to the zero suggested by the estimation results.

The graphical presentation of residential electricity prices, household total final expenditure and UEDT for each scenario is presented in Figure 5.

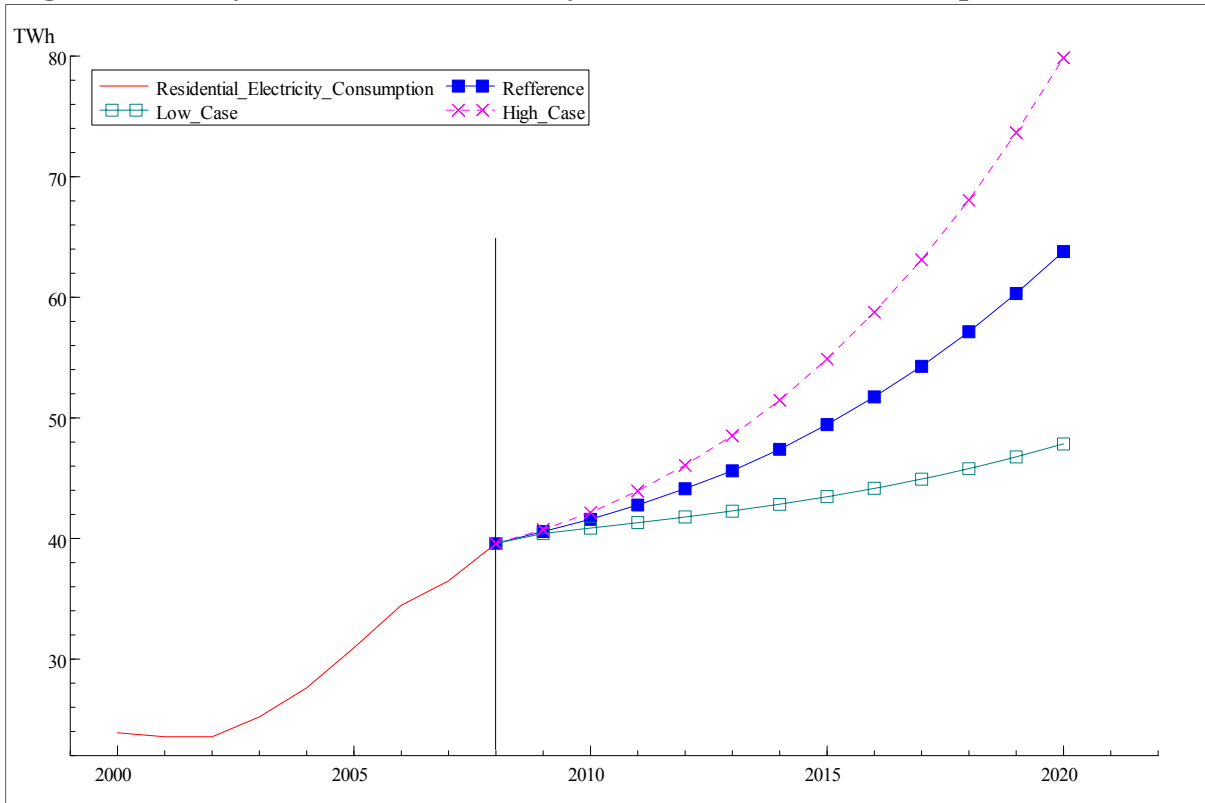
Figure 5: High, Reference and Low Case Scenarios



6.2 Forecast Results of Scenarios:

Given the above assumptions, it is predicted that future residential electricity consumption in 2020 will be 48 TWh, 64 TWh and 80 TWh in the, ‘low’, ‘reference’ and ‘high’ case scenarios respectively. The annual residential electricity consumption forecast scenarios over the period 2009-2020 are given in Figure 6.

Figure 6: Turkey's Residential Electricity Demand Forecast over the period 2009-2020



7. Conclusion and Further Discussion:

Electricity is vitally important for modern economies. It enables consumers to use daily appliances such as computers, medical devices, telecommunication appliances and transport vehicles that increase the quality of life. Most of these appliances are arguably now indispensable in consumers' daily lives and they are powered by electricity. Given its importance, the focus of this paper is to identify and quantify the main drivers of Turkish residential electricity demand: household expenditure, price and UEDT. This is undertaken to assist Turkish policy makers and planners when deciding upon future investment decisions for the Turkish electricity sector. Hence, an understanding of the key drivers of Turkish residential electricity demand and their impact are vital for policy implementation and evaluation. Therefore, given the results here, not only should the estimated price and income

elasticities be incorporated in any policy analysis but also the estimated UEDT to hopefully avoid some of the mistakes made in the past.

Ediger and Tatlidil (2002), Keleş (2005), Ediger and Akar (2007), Hamzacebi (2007), Akay and Atak (2007) argue that previous electricity demand forecasts for Turkey were mostly unsuccessful. A possible reason for this might be that 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 in the models underpinning the forecasts, 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 information 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 electricity 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 0.38 in the short run and 1.57 in long run. Additionally, the short run and long run price elasticities are -0.09 and -0.38 respectively. Furthermore, this paper has uncovered the underlying energy demand trend for the Turkish residential sector, which is highly stochastic with increasing and decreasing periods.

The only previous study focusing on estimating a residential electricity demand function Halicioglu (2007), found estimated short run and the long run price elasticities of -0.33 and -0.52 respectively. Although the estimated short run price elasticity is somewhat different to the -0.09 obtained here, the long run estimate is similar to the estimated -0.38 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) found the estimated short run and long run income elasticities to be 0.44 and 0.70 respectively. Although the estimated short run expenditure elasticity of 0.38 found here is similar to that of the income elasticity in Halicioglu (2007), the estimated long run expenditure elasticity of 1.57 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 trend in Turkish residential electricity consumption was generally diminishing between 1971 and 1983 (except for 1974, 1975, 1976 and 1981) and, as discussed above, probably reflects the compulsory conservation measures (in addition to the impact in 1973 identified by the irregular intervention) that were adopted by the government between 1971 and 1983 and identified by the STSM. This arguably illustrates the power of this approach in distinguishing the structural changes of demand behaviour. In addition, after the end of these compulsory conservation measures starting from 1982, the UEDT follows a generally increasing trend until 1996 and follows a stochastic movement afterwards until the end of estimation period.

Given the analysis undertaken, it is expected under the different forecast assumptions that the Turkish residential electricity consumption will be between 48 and 80 TWh by the year 2020. There is only one previous forecast study, Hamzacebi (2007), which predicted that 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 arguably highly unlikely and unreasonable. Hamzacebi (2007) does not investigate the relation between economic activity and residential electricity consumption but as was explained earlier, electricity demand is 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 in 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 Turkish energy policy that might include the introduction of CO₂ taxes and energy efficiency regulations. With the efficiency regulations expected to have significant impacts on appliances with the introduction of more efficient standards for household appliances leading to less energy consumption in the longer term. However, the 'Copenhagen Accord' did not set any binding targets for developing countries. Therefore, it is not clear in the current situation how Turkey will act.

This study focuses on estimating an energy demand function for the Turkish residential sector, which is used to provide future scenarios of demand. 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.

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