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Modeling and Forecasting the Electricity Demand for Major Economic Sectors of Iran

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Abstract: The demand for electricity has been modeled in major economic sectors, industry and agriculture in this study, Also the demand for electricity has been forecasted in the both sectors until 2011. According to heterogeneity of industries with respect to equipment, products, technologies, processes and energy consumption, they are classified in two general groups of high energy and low energy consuming industries and the demand model has been separately presented for each group. The most important difference between high and low energy consuming industries is to consider the electricity intensity variable which is an index to the level of technology. Other variables of this model are price of industrial electricity, price of the substitute fuels and number of customers. According to the final model, electricity intensity and price of the substitute have positive impact on electricity consumption in this group. The demand model of electricity in low energy consuming industries consist number of the customers, price of electricity and electricity consumption in the last period that the significance of number of the customers variable came to the result in the proposed model. Also demand of electricity in the agricultural sector has been considered as a function of price, number of customers and consumption of the previous period. Results verify the significance of the above variables and it has been found that consumption of energy in the previous period plays a major role in this model.

Key words: Modeling, forecasting, electricity, industry, agriculture

INTRODUCTION

Energy effectiveness and its importance are manifest for everybody these days. Different economic sector necessities of a country to energy can put a non recoverable shock on the trend of reclamation and development of a country if they are not paid much attention. Acceptance of energy sovereignty on the current and future economy of the country and the substantial need to currency incomes and its usage for interior consumption makes the necessity of immunization and economical exploitation of energy. The realization of a stable economic promotion needs the production and exploitation of energy to be programmed compatibly along the other associations such as human, resources, raw materials, financial sources and etc.

The recent energy deliberations made many countries to be more concern on their limited resources of energy. Electricity as a clean source of energy and its supply and demand is a challenge among policy makers. The productivity of the industries from demand side and the price mechanism from supply side could be considered as powerful tools for decision making, managing and controlling the demand of the electricity consumption in industries.

The usage of electricity is different in the energy consuming sectors like residential, commercial, industrial and agricultural as the economically productive sectors which use electricity in order to increase the value added, are considered very significant. In general, the consumption of electricity can be divided into two parts. Energy consumption in the building component at the aim of heating, cooling, etc and in manufacturing component at the aim of providing the required energy in the operational process, mechanical drivers, electronic processing, metals processing etc. Also in agricultural sector, electricity consumption in order to start the water pumps wells and heating and light of green houses and domesticated animal breeding centers.

In this study, according to the electricity consumption in both industrial and agricultural sectors, the variables affecting the electricity demand has been determined. Also the demand for electricity is modeled by the means of Time Series Data (TSD) and the amount of which is predicted until 2011. According to the heterogeneity of industries in equipment, products, technologies, processes and energy consumption, they are classified in two general groups in the model of demand for industrial electricity, namely, high energy consuming industries and low energy consuming

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industries and the demand model has been separately presented for each sector.

A number of electricity forecasting models have been developed using economic, social, geographic and demographic factors. Egelioglu[1] studied the influence of economic variables on the annual electricity consumption in Northern Cyprus by using multiple linear regression analysis. It was found that the number of customers, the price of electricity and the number of tourists correlate with annual electricity consumption. Harris and Liu[2] found that price plays a major role in explaining conservation behavior by electricity consumers. Yan[3] proposed residential electricity consumption using climatic variables for Hong Kong. Rajan and Jain[4] expressed energy consumption patterns for Delhi as functions of weather and population. Fung and Tummala[5]. Concluded that it was reasonable to use electricity price, Gross Domestic Product (GDP), deflated domestic exports and population to forecast electricity consumption in Hong Kong. Liu *et al.*[6] used GDP, real electricity price and population in forecasting electricity consumption of Singapore. Lakhani and Bumb[7] used residential price of electricity, per capita income and the estimated long run elasticity of demand in forecasting demand for electricity in Maryland. These findings suggest that a multiple linear regression model using GDP, price and population would provide an appropriate forecasting model for electricity consumption. Makridakis and Wheelwright[8] state that either a simple model that may not completely duplicate reality can be constructed, or a complex model that is more accurate can be built, but this requires a large amount of effort and resources to be developed and manipulated. Even the most sophisticated model would have some part of reality that could not be explained, as the number of factors in real life phenomena is infinite.

For estimating energy demand, especially electricity, in Iran, we can point to the introductory report of establishing energy model in Iran that plan and budget organization[9] has investigated energy carrier's demand. In addition, plan and budget organization[10] has formulated econometrics model for forecasting energy supply and demand. Also supreme research institute in planning and development[11] has conducted study by the name of energy demand estimation. In this study, the oil product, electricity and natural gas demand models has estimated for various sectors and total economy. In addition, Zamani[12] has investigated and have estimated electricity demand in residential and industry sectors in Lorestan province. Sadeghi[13] has investigated the stability of demand for energy and effective factors on it and Sadeghi[14] has forecasted electricity consumption by econometric methods.

Theoretical and methodological framework: The main purpose of this study was to estimate the function of demand for electricity in the major economic sectors. First step in this way is to become familiar with the specifications of energy consuming sectors in order to determine the variables affecting electricity consuming in that sector. Therefore pursuant to this section, first the specifications of the industrial and agricultural sectors in Iran are introduced and then the theoretic modeling approach is presented.

Industrial and agricultural electricity consumption: In Iran, industrial sector with the consumption of 32.9% from the total consumption of electricity is placed in the first place[15]. Iron, steel products, aluminum, petrochemical, cement and glassware industries are high energy consuming industries. In industry, electricity is used both in building component for cooling, heating and light which varies according to the workforce increase, building extension and weather condition and in the operational process for mechanical drivers, electronic processing and for metals processing.

One of the overriding characteristics in the industrial sector is the heterogeneity of industries, products, equipment, technologies, processes and energy uses. Adding to this heterogeneity is that the industrial sector includes not only manufacturing, but also agriculture, mining and construction. These disparate industries range widely from highly energy-intensive activities to non-energy-intensive activities.

Industrial model has classified the industries in two general groups' i.e., high energy consuming industries and low energy consuming industries. Three kinds of industries out of all industries are placed in the first group namely, high energy consuming industries. These industries consist of chemicals, basic metals and non metal minerals. Also the second group of industries, low energy consuming industries, consists of food, textile, paper and machinery producing industries. According to the type of consumption, in each class the variables affecting the demand for electricity are determined different.

Electricity in the agricultural sector is used to commission the agriculture water pumps and for heating and light of greenhouses and domesticated animal breeding centers. In 2003, agricultural sector with the consumption of 13858.6 million KWH used 12.1% of total electricity consumption.

Modeling approach: There are plenty of methodologies available for modeling demand. An appropriate method is chosen based on the nature of the data available and the desired nature and level of detail of the models. An approach often used is to employ more than one method. In this study, we use Econometric methods to model demand functions. This approach combines economic theory with statistical methods to produce a system of equations for estimating energy demand Taking time-series or cross-sectional/pooled data, causal relationships could be established between electricity demand and other economic variables. The dependant variable, in our case, demand for electricity, is expressed as a function of various economic factors. To model electricity demand, economic investigation and theories propose various variables to explain electricity demand. These variables are also different according to the type of consumer such as residential, industrial users. In the most of studies and investigations, industrial electricity demand is considered as function of average price of industrial electricity, industrial value added, the number of industrial consumers and some times electricity consumption in the previous period.

Because in high energy consuming industries, the level of technology can effect the consumption in great extent, this variable (technology variable) is considered in the model. Since technology is a qualitative variable, the energy intensity index is used in the model as the representation of technology. Also the variables such as electricity price, the number of customers and the price of the substitute fuels in industries (fossil fuels) is considered in the model. The mean weighted price fossil fuels are used as the variable of the price of the substitute energies. This variable entered the model with three yours lags, it is assumed that if the price of electricity increases in an extent that industries are forced to use the substitute fuels, in average it takes three years for industries to change their technologies or reconstruct them for using fossil fuels. According to the direct relationship between the number of customers (number of factories) and industrial value added (in fact their role is same in the model) so only the number of customers is considered in the model. According to the last researches, this variable presents better results.

The primary demand model of low energy consuming industries is defined on the basis of a function by the variables of electricity price, the number of industrial users and the previous period consumption (it is assumed that the consumption between two sequential periods is not very different unless in the cases of events like war, recession, etc that in these cases Chow testing is used). Because these industries are low electricity consuming and it is often used in the cases when there is no better substitute (light, air conditioning), the variable of substitute energies prices is not entered in the model.

Since the main consumption of electricity in the agricultural sector relates to the water pumping, the primary demand model for this sector can be identified by a function through real customers. This variable has a direct and close relationship with the value added and so there is no need to add this variable. Also the price of agricultural electricity is another variable which is assumed to affect the electricity demand. The variable of previous period consumption of electricity is used in order to determine the general pattern of electricity demand model.

In both of the above mentioned sectors, industry (high energy consuming and low energy consuming) and agriculture, the primary models are specified as Eq. 1-3.

Industrial models

$$\begin{aligned}\mathrm{Ln}(EC_{high}) &= \alpha_0 + \alpha_1 \mathrm{Ln}(NC_{high}) + \alpha_2 \mathrm{Ln}(PR_{high}) + \\ &\quad \alpha_3 \mathrm{Ln}(PRs_{high}) + \alpha_4 \mathrm{Ln}(ET_{high})\end{aligned} \quad (1)$$

$$\begin{aligned}\mathrm{Ln}(EC_{low}) &= \beta_0 + \beta_1 \mathrm{Ln}(NC_{low}) + \beta_2 \mathrm{Ln}(PR_{low}) + \\ &\quad \beta_3 \mathrm{Ln}(EC_{(-1)low})\end{aligned} \quad (2)$$

Agriculture model

$$\begin{aligned}\mathrm{Ln}(EC_{agr}) &= \gamma_0 + \gamma_1 \mathrm{Ln}(NC_{agr}) + \gamma_2 \mathrm{Ln}(PR_{agr}) + \\ &\quad \gamma_3 \mathrm{Ln}(EC_{(-1)agr})\end{aligned} \quad (3)$$

Where:

EC : Electricity consumption in each sector (KW/hours);

NC : The number of electricity consumers in each sector;

PR : Electricity price in each sector (RLS and fixed prices of 1997);

PRs : The price weighted mean of fossil fuels (RLS and fixed prices of 1997);

$EC_{(-1)}$: Electricity consumption in the previous period (KW/hours);

ET : Electricity intensity in high energy consuming industries (KW/hours*RLS);

$VA_{(t-1)}$: Value added in each sector (RLS and fixed prices of 1997);

α_i β_i γ_i : Coefficient of variables and model intercept

And subscripts high, low and agr indicate high energy consuming, low energy consuming and agriculture sectors in sequence. Several functional forms and combinations of these and other variables may have to be tried until the basic assumptions of the model are met and the relationship is found statistically significant.

Table 1: ADF tests for variables used in model of high energy consuming industries

Variables	Ln (EC_{high})	Ln (ET_{high})	Ln (NC_{high})	Ln (PR_{high})	Ln (Prs_{high})
level	1.99 (−1.96)	0.03 (−1.96)	1.29 (−1.96)	−0.98 (−1.96)	−5.04 (−3.76)
1st difference		−2.46 (−1.96)	−0.93 (−1.96)	−3.04 (−1.96)	
2nd difference			−2.46 (−1.96)		

Estimating the electricity demand function: In order to estimate the electricity demand model in productive sectors of economy, industry and agriculture and to predict the electricity, econometric models has been used. Therefore time series data of 1979 to 2003 has been collected from statistic center of Iran[16] and after doing statistical tests in relation with verifying and identifying the validity, the final results has been presented in the form Eq. 4-6.

Many economic time series are non-stationary. Today, stationary of time series is an accepted feature for economic variables. Therefore applying common methods of econometrics like OLS method in most cases lead to incorrect results for non stationary series. The importance of non-stationary of time series in regression at studies is the reason that in most cases which are assumed to have relatively normal distributions, assumption of normal distribution rejects the estimating factors when non-stationary variables appeared in the model.

So the specification of these time series will have an identifying role in selecting the method of estimation and statistic under standing. A common method to change non stationary series to stationary is to make differentiate them. If a time series changed to stationary by one time of differentiation, it is called first difference co integration I (1) and if by d time of differentiation, it will be d difference co integration I (d). So the first step in estimating the models is to determine the co integration degree of time series. One of the common methods to determine the co integration degree is Fuller and Dickey test. In this test, the ADF test statistic is compared to the Mackinnon table quantity. Table 1 to 3 show ADF test results about the variables of model in each consuming sector. After examining the stationary of data, the classical theories of econometric model should be investigated to validate the models. These theories including lack of Autocorrelation, variance Heterogeneity and lack of Co linearity are examined by tests of LM, WHITE and adjusted coefficient of determination R^2 and t respectively and after assuring about all of the assumptions, the final results has been presented in Table 4 to 6.

Table 2: ADF tests for variables used in model of low energy consuming industries

Variables	EC_{low}	Ln (ECP_{low})	Ln (NC_{low})	Ln (Pr_{low})
level	2.29 (−1.96)	1.05 (−1.96)	1.99 (−1.96)	2.41 (−1.96)
1st difference		−3.01 (−1.96)		−3.04 (−1.96)

Table 3: ADF tests for variables used in agriculture model

Variables	Ln (EC_{agr})	Ln (NC_{agr})	Ln (VA_{agr})	Ln (Pr_{agr})
level	3.52 (−3.65)	1.98 (−1.96)	−0.12 (−1.96)	−2.03 (−1.96)
1st difference	−0.82 (−3.67)		−1.00 (−1.96)	
2nd difference	−5.42 (−3.62)		−2.76 (−1.96)	

Table 4: Electricity demand estimation in high energy consuming industries

Variables	Model 1	Model 2	Model 3
Ln (ET_{high})	0.76* (5.70)**	0.78 (6.11)	0.75 (5.88)
Ln (NC_{high})	0.24 (0.5)	-	-
Ln (PR_{high})	-2.91 (0.94)	-2.99 (-0.99)	-
Ln (PRs_{high})	3.7 (1.21)	3.84 (1.28)	0.89 (5.42)
Intercept	9.3 (4.02)	11.20 (8.79)	10.82 (8.50)
D-W***	1.94	1.93	1.96
F-value	47.83	59.83	74.49
R^2	0.984	0.986	0.977

Table 5: Electricity demand estimation in low energy consuming industries

Variables	Model 1	Model 2	Model 3
Ln (NC_{low})	1.20 (2.74)	1.5 (3.44)	1.2 (3.04)
Ln (PR_{low})	−0.93 (-2.54)	−0.84 (-1.63)	-
Ln (VA_{low})	−0.18 (0.56)	-	-
Intercept	−7.21 (-1.12)	−5.3 (−1.49)	−6.7 (−1.86)
****Dum	−1.69 (-3.44)	−1.64 (−3.09)	−1.07 (−2.48)
Dum 91	8.81 (21.12)	8.83 (26.26)	9.03 (27.56)
D-W	1.89	1.83	1.79
F-value	82.18	65.51	79.79
R^2	0.992	0.988	0.985

Table 6: Electricity demand estimation in agriculture sector

Variables	Model 1	Model 2	Model 3
Ln (ECP_{agr})	0.56 (7.14)	0.57 (7.31)	0.56 (7.29)
Ln (NC_{agr})	0.46 (4.81)	0.46 (5.05)	0.47 (5.22)
Ln (PR_{agr})	−0.01 (−0.31)	-	-
Intercept	2.10 (5.29)	2.04 (6.18)	2.08 (6.42)
Dum 82	0.06 (0.87)	0.06 (0.86)	-
D-W	2.07	2.05	1.98
F-value	2134	2944	4457
R^2	0.996	0.996	0.9937

*Coefficients of variables in model, **The t-statistics appear in parentheses, *** Dummy variables, **** Durbin-Watson statistic

For high energy consuming industries

$$\begin{aligned} Ln(EC_{high}) = 0.7Ln(ET_{high}) + 0.24Ln(NC_{high}) - \\ 2.91Ln(PR_{high}) + 3.7Ln(PRs_{high}) + \\ 9.3 + 0.9MA(1) \end{aligned} \tag{4}$$

For low energy consuming industries

$$\begin{aligned} (EC_{low}) = 0.1*10^6 Ln(ECp_{low}) + 1.2*10^6 Ln(NC_{low}) - \\ 0.8*10^6 Ln(PR_{low}) - 4.8*10^6 - 1.6*10^6 Dum + \\ 8.9*10^6 Dum91 + 1.34MA(1) \end{aligned} \tag{5}$$

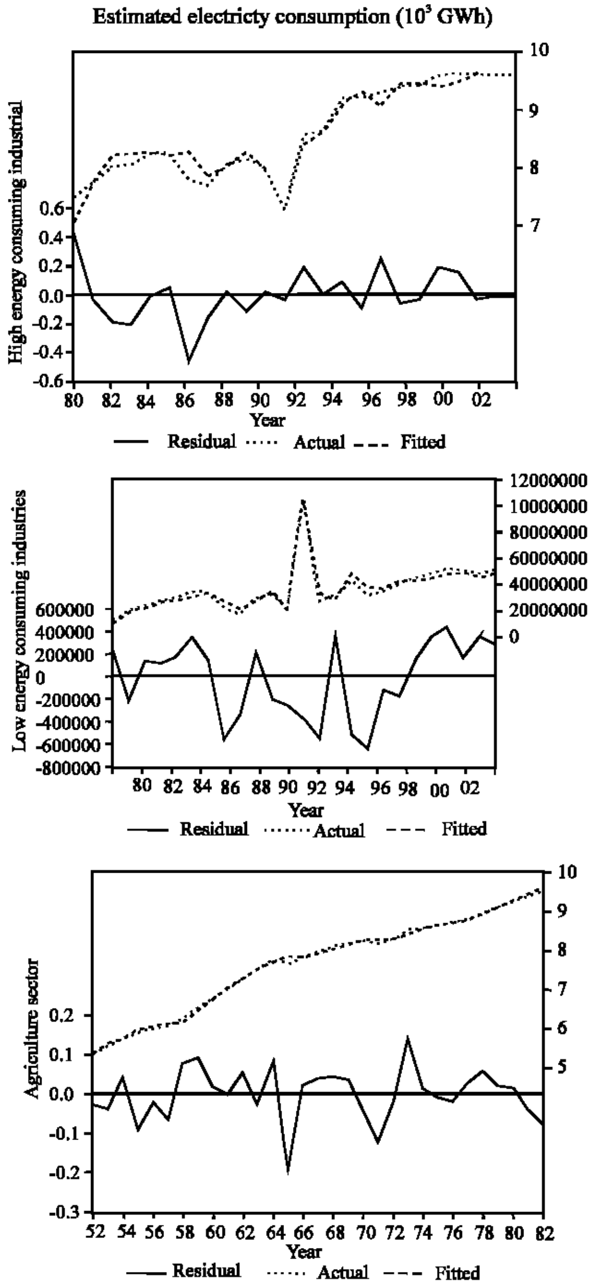

Fig. 1: Actual and estimated electricity consumption for Iran

For agriculture sector

$$\begin{aligned}\mathrm{Ln}(EC_{agr}) = &-0.01\mathrm{Ln}(PR_{agr}) + 0.46\mathrm{Ln}(NC_{agr}) + \\ &0.56\mathrm{Ln}(ECp_{agr}) + 2.1 + 0.06\mathrm{Dum}82 + \\ &2.1 + 0.06\mathrm{Dum}82\end{aligned} \quad (6)$$

Various statistical tests are used to validate the models. They include the adjusted coefficient of determination R^2 to determine how well the model explains the actual consumption data, an F-test for overall significance of the model and a t-test for testing the strength of each of the individual coefficients of the model[17]. The residual plots of the error, u, is also studied to determine the appropriateness of the model. Fig. 1 shows actual and estimated electricity consumption for Iran.

Analyzing the final models of electricity demand: Above electricity demand function was estimated in each industrial and agricultural sector. Pursuant to the final model of demand for energy will be analyzed in each sector.

Electricity demand in high energy consuming industries has been considered as a function electricity price, the price of substitute fuels, the number of customers and the energy intensity (index of technology level). Regarding the model we understand that there is a direct relationship between electricity consumption and electricity intensity variables and the number of customers which is in accordance with theoretic principles. It is obvious that the growth of electricity intensity and the number of customers will increase the electricity consumption. Also the significant of electricity price negative coefficient indicates that electricity consumption in this group of industries can be affected by pricing policies and the government can control electricity consumption in these industries by increasing the electricity price and direct them toward efficient consumption (by promoting the technology and other effective factors). Also positive and big coefficient of substitute energy price confirms this matter that the reduction of the substitute fuels cause industries to use these kinds of fuels, therefore electricity consumption will be reduced.

High level of statistic F verifies the significance of coefficient of all independent variable in the model. Also according to the fact that the amount of statistic D.W. is near to 2, the lack of autocorrelation is confirmed in the model. Adjusted coefficient of determination R^2 shows how well the model explains the actual consumption data (Eq. 4).

In the model of low energy consuming industries, Chow breakpoint test is used to examine the effect of war on electricity consumption. This test has indicated the effect of war on electricity consumption. This test indicated the lack of breakpoint in the high energy consuming industries, but in the low energy consuming industries, electricity demand has been affected by above mentioned shocks and in order to omit the shocks due to the war and recession of 1991 dummy variables (Dum and

Dum91) have been used. The final model indicates that all of the variables of the primitive model (the number of customers, price and the previous period consumption) are significant in the consumption of electricity in this sector and the number of customers plays the most important role in the above mentioned model. The estimation results of this model indicates the weak sensitivity of low energy consuming industries energy consumption to price changes, so the price is not a good tool for policy makers to control the electricity consumption in this sector (Eq. 5).

As mentioned, electricity demand in the agricultural sector is considered as a function of electricity price, previous period consumption and the number of customers. Also the above model once was performed by value added variable but because of the bad results, it has been omitted and replaced by the number of customers. Because of a general change in electricity tariff in 1982 which cause basic changes in the trend of electricity price changes in the agricultural sector, Dum 82, dummy variable was added to the model. Electricity demand in this sector is not sensitive to the price and the reason is supposed the low tariff of electricity and its little change (Eq. 6).

Forecasting electricity demand: To predict the short and medium term forecasting of electricity demand in each economic sector, VAR model estimation method has been used. VAR methodology to a great extent is similar to me simultaneous equations in which all of the variables are considered endogenous. In this method, the value of a variable is described as a linear function of previous data and all of the existing variables in the model.

In this study electricity demand has been estimated in industrial and agricultural sectors until 2011. The above mentioned estimation results has been presented in Table 7 and Eq. 8-10 show VAR prediction model in each sector. Each VAR equation has been obtained by the means of OLS method and 2 lags. The primitive model of VAR is like following.

$$EC_t = \alpha + \sum_{j=1}^{2} \beta_j EC_{t-j} + U_t \quad (7)$$

In Eq. 8-10, VAR estimation model is presented in each industrial high energy consuming, low energy consuming and agricultural sectors.

$$EC_{high} = 0.8798269015*EC_{high}(-1) + 0.1114505355*EC_{high}(-2) + 681.0879367 \quad (8)$$

$$EC_{low} = 0.0001897800499*EC_{low}(-1) + 0.4786678823*EC_{low}(-2) + 3222530.931 \quad (9)$$

$$EC_{agr} = 1.230616708*EC_{agr}(-1) - 0.1188050387*EC_{agr}(-2) + 6.886500683 \quad (10)$$

CONCLUSIONS

In this study, the demand for electricity has been modeled in major economic sectors, industry and agriculture, also the demand for electricity has been forecasted in the both of the above mentioned sectors until 2011. According to the heterogeneity of industries in equipment, products, technologies, processes and energy consumption, they are classified in two general groups in the model of demand for industrial electricity, namely, high energy consuming industries and low energy consuming industries and the demand model is separately presented for each sector. Above 60% consumption of the total consuming electricity by 3 industries i.e., chemical industry, basic metals, non-metal minerals and also the main difference at the level of technology in this group of industries in comparison to other industries caused these industries to classify in a separate group which is referred to as the high energy consuming industries with different variables. The most important difference between high energy consuming industries and low energy consuming industries is to consider the electricity intensity variable which is an index to the level of technology. Other variables of this model are the price of industrial electricity, price of the substitute fuels (this variable is the price weighted mean of fossil fuels which entered the model with three years lags) and the number of customers that according to the final model, electricity intensity and price of the substitute have positive impact on electricity consumption in this group.

The demand model of electricity in low energy consuming industries consist number of the customers, price of electricity and electricity consumption in the last period that the significance of number of the customers variable came to the result in the proposed model.

Also demand of electricity in the agricultural sector has been considered as a function of price, number of

Table 7: Forecasting of electricity demand in each economic sector

	2004	2005	2006	2007	2008	2009	2010	2011
EC_{high}	15106	15596	16086	16573	17055	17533	18008	18479
EC_{low}	5380	5498	5584.	5636	5674	5697	5714	5723
EC_{agr}	15584	17539	19739	22214	24999	28132	31657	35622

customers and consumption of the previous period. Results verify the significance of the above variables and it has been found that consumption of energy in the previous period plays a major role in this model.

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