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AN ESTIMATION OF NATURAL GAS DEMAND IN HOUSEHOLD SECTOR OF IRAN; THE STRUCTURAL TIME SERIES APPROACH

Abstract:

Natural gas is one of the most important energy for household sector in entire the world. Iran has rich gas reserves and after Russia, Iran has the largest natural gas reserves in entire the world. A study of natural gas demand is very important and crucial for policy makers of energy sources in Iran. With a good estimation of natural gas demand as a result a good forecasting of natural gas demand, policy makers of energy sources can to plan an accurate energy planning. The aim of this paper is analyzing the effective factors on natural gas demand in household sector of Iran. For do it, we have used structural time series method with Kalman Filter algorithm during 1974-2010 period. Results indicate that time trend as a proxy for technology and non-economic factors is non-linear process and the elasticity of demand to price of natural gas is -0.50. Also, the elasticity of natural gas demand to price of electricity as a substitute commodity for natural gas is 0.48. The elasticity of gas demand to gas splits and real GDP per capita is 2.37 and 0.72 respectively. Conclusion: The elasticity of demand to price of natural gas is -0.50 that it shows that natural gas is an essential commodity for household sector in Iran.

Keywords:

Gas Demand, Household Sector, Structural Time Series, Kalman Filter

JEL Classification: Q41, C19, D19

INTRODUCTION

In first decade of 1970s, because of oil crisis, politicians and economist have attracted to energy debates. Many researchers have investigated the demand of energy for understanding effective factors on energy demand. The controversies between economist and engineers in this subject have caused development in methodology of demand modeling. Modeling energy demand is one of the most tasks for energy programming in each country. This task is important for both development and developing countries. Because of some limitations in energy modeling as structural limitations and hypothesis limitation, energy demand modeling is a complex process. So, modeling the energy demand with advanced methods would be suitable for estimation the model correctly. Energy is a vital input for social and economic development of any nation Jebaraj and Iniyan (2006). In the past decade energy consumption has increased exponentially globally Suganthi and Samuel (2011). Energy management is crucial for the future economic prosperity and environmental security Suganthi and Samuel (2011). Natural gas is one of the most important energy for household sector in entire the world specifically Iran. Iran has rich gas reserves and after Russia, Iran has the largest natural gas reserves in entire the world. A study of natural gas demand is very important and crucial for policy makers of energy sources in Iran. With a good estimation of natural gas demand as a result good forecasting of natural gas demand, policy makers of energy sources can to plan an accurate energy planning. Many researchers have investigated the demand of natural gas as Toksari&Toksari (2012), Payne, Loomis& Wilson (2011), Toksari(2010), Sun and *et al* (2011), Sun and *et al* (2012), Toksari (2010) and Aras (2008).

In our study, the important property in modeling natural gas demand is applying trend variable as a proxy for technology and non-economic factors that it has assumed time varying. This variable has ignored in previous studies of natural gas demand in Iran. So, our contribution is using trend variable that this fact was our incentive for writing the paper, also, there is no study about natural gas demand with structural time series in Iran.

The aim of this paper is estimation of natural gas demand with structural time series method in Iran during 1974-2010 period.

This paper is organized by five sections. The next section is devoted to literature review. Section 3 shows research method. Section 4 implies empirical results and final section is devoted to conclusion.

2. Theoretical Base:

In this section, we review some theoretical model for modeling energy demand.

End-use approach:

This method has identified the role of each end-use towards the aggregate energy consumption. Chateau and Lapillonne (1978) introduced this method based on estimating the energy demand in different sectors or industries using the technical relationship between output and energy use. The data needed for end-use modelling approach is collected through energy surveys, technical studies, and energy audits and focuses on dividing the sectoral demand into homogeneous parts, so that the energy demand for each part can be easily related to the technical and economic factors - the key factors that determine the energy demand for each sector Dilaver (2012).Therefore, a number of models have been produced; such as MARKAL, MARKAL MACRO, EFOM, MAED that all use the general end-use modelling approach but differ from each other in terms of the structure of chosen determinants Dilaver (2012).

Input-Output Models:

This analyses the process in which inputs from one industry produce output for consumption or input for another industry. From an input-output table it is possible to identify the change in demand for inputs from a change in production of a final good. The application of this approach to energy demand enables the estimation of the direct energy demand as well as indirect energy demand via inter-industry transactions (Bhattacharyya and Timilsina, 2009).

The Econometric Modelling Approach:

The econometric modelling approach of energy demand is a quantitative approach that generally aims to analyse statistically relationships usually based on econometric theory or intuition between a dependent variable and independent variables using historical data. The identified relationships can be used for analysing the past, estimating the effect of changes of the independent variables on the dependent variable and for prediction over the future Dilaver (2012).

The Log Linear Models and Their Applications:

The demand for energy is not a final demand; the energy demand is generated because of the demand for goods and services which needs energy in order to be utilized; such as heat, light, transport, etc. (Nordhaus, 1977). Therefore, the stock of appliances and its capacity usage are important factors that contribute to determining energy demand Dilaver (2012).

2.1. Literature Review:

Azadeh, Asadzadeh, &Ghanbari (2010) have presented an adaptive network-based fuzzy inference system (ANFIS) for estimation of NG demand. Standard input variables are used which are day of the week, demand of the same day in previous year, demand of a day before and demand of 2 days before. Their proposed ANFIS approach is equipped with pre-processing and post-processing concepts. Moreover, input data are pre-processed (scaled) and finally output data are post-processed (returned to its original scale). The superiority and applicability of the ANFIS approach is shown for Iranian NG consumption from 22/12/2007 to 30/6/2008. Their results have shown that ANFIS provides more accurate results than artificial neural network (ANN) and conventional time series approach. Their results of their study provide policy makers with an appropriate tool to make more accurate predictions on future short-term NG demand Azadeh, Asadzadeh, &Ghanbari (2010).

Aydinalp-Koksal & Ugursal (2008) have investigated the use of conditional demand analysis (CDA) method to model the residential end-use energy consumption at the national level. There are several studies where CDA was used to model energy consumption at the regional level; however the CDA method had not been used to model residential energy consumption at the national level. The prediction performance and the ability to characterize the residential end-use energy consumption of the CDA model are compared with those of a neural network (NN) and an engineering based model developed earlier. The comparison of the predictions of the models indicates that CDA is capable of accurately predicting the energy consumption in the residential sector as well as the other two models. The effects of socio-economic factors are estimated using the NN and the CDA models, where possible. Due to the limited number of variables the CDA model can accommodate, its capability to evaluate these effects is found to be lower than the NN model Aydinalp-Koksal & Ugursal (2008).

Murata and *et al* (2008) have presented the results of estimating how much electricity is currently used and would be used in future in China's urban household-sector. Conclusions are derived from an analysis of data obtained from a questionnaire survey recently conducted in 13 cities in China. Electricity used for various purposes in China's urban-households is evaluated, considering climate conditions specific to the target regions and the possession of end-use appliances. How much electricity could be saved in the future by improving the efficiency of end-use lighting equipment, room air-conditioners, refrigerators, and TV sets is estimated. It is demonstrated that about 28% reduction could be achieved in the year of 2020 by means of improving the efficiency of these end-use appliances Murata and *et al* (2008).

Athukorala& Wilson (2010) have investigated the short-run dynamics and long-run equilibrium relationship between residential electricity demand and factors influencing demand – per capita income, price of electricity, price of kerosene oil and price of liquefied petroleum gas – using annual data for Sri Lanka for the period, 1960–2007. They have used unit root, co integration and error-correction models. The long-run demand elasticities of income, own price and price of kerosene oil (substitute) were estimated to be 0.78, − 0.62, and 0.14 respectively. The short-run elasticities for the same variables were estimated to be 0.32, − 0.16 and 0.10 respectively. Liquefied petroleum (LP) gas is a substitute for electricity only in the short-run with an elasticity of 0.09. The main findings of the paper supported the following (1) increasing the price of electricity is not the most effective tool to reduce electricity consumption (2) existing subsidies on electricity consumption can be removed without reducing government revenue (3) the long-run income elasticity of demand shows that any future increase in household incomes is likely to significantly increase the demand for electricity and (4) any power generation plans which consider only current per capita consumption and population growth should be revised taking into account the potential future income increases in order to avoid power shortages in the country Athukorala & Wilson (2010).

Chang &Serletis (2013) have investigated the demand for gasoline in Canada using recent annual expenditure data from the Canadian Survey of Household Spending, over a 13-year period from 1997 to 2009, on three expenditure categories in the transportation sector: gasoline, local transportation, and intercity transportation. In doing so, they have used three of the most widely used locally flexible functional forms, the Almost Ideal Demand System (AIDS) of Deaton and Muellbauer (1980), the quadratic AIDS (QUAIDS) of Banks *et al*. (1997)—an extension of the simple AIDS model that can generate quadratic Engel curves—and the Minflex Laurent model of Barnett (1983), which can also generate quadratic Engel curves [Chang &Serletis (2013)]. They have paid explicit attention to economic regularity, argue that unless regularity is attained by luck, flexible functional forms should always be estimated subject to regularity as suggested by Barnett (2002), and impose local curvature to produce inference consistent with neoclassical microeconomic theory. Their findings indicated that the curvature-constrained Minflex Laurent model is the only model that is able to provide theoretically consistent estimates of the Canadian demand for gasoline. Their estimates have shown that the own-price elasticity for gasoline demand in Canada is between −0.738 and −0.570 —less elastic than previously reported in the literature Chang &Serletis (2013).

Al-Nasser (2011) has evaluated the economics of establishing a residential natural gas network in Saudi Arabia's Eastern Province (EP) to cater to the household demand for natural gas. He focused primarily on household use of natural gas for cooking. Additional economic analysis of other household uses – as air conditioning, space and water heating – is incorporated. Demand streams of various consuming segments are analysed to estimate the volume of the daily natural gas supply by the network. Economic analysis has employed financial net present value methodology to define the cost effectiveness of the proposed network. Economic rent and opportunity costs of utilizing other sources of energy and their efficiency differences are plugged into the economic equation. The quantity of natural gas supply for the targeted 322,000 households located in the EP is estimated at 23.2 MMscfd. The effect of the government subsidy of natural gas prices is quantified. He concluded that the project has a positive net present value – at a range of natural gas fuel prices and required rate of returns of future incomes – during the life span of the project Al-Nasser (2011).

Yoo, Lim, & Kwak (2009) have estimated households' demand function for natural gas by applying a sample selection model using data from a survey of households in Seoul Yoo, Lim, & Kwak (2009). Their results have shown that there exists a selection bias in the sample and that failure to correct for sample selection bias distorts the mean estimate, of the demand for natural gas, downward by 48.1% Yoo, Lim, &Kwak (2009). In addition, according to the estimation results, the size of the house, the dummy variable for dwelling in an apartment, the dummy variable for having a bed in an inner room, and the household's income all have positive relationships with the demand for natural gas Yoo, Lim, &Kwak (2009).

In Iran, some researchers have investigated the energy demand such as Mousavi (2010), Ahmadian, M., M. Chitnis and L.C. Hunt (2007), Sohfi, M., and M. Paknejad (2001). For instance, Mousavi (2010) has analyzed energy demand in transportation sector of Iran with structural time series method.

Our contribution in this paper is applying structural time series method for estimation natural gas demand in household sector of Iran for representation more accurate estimation of parameters for policy makers in energy sector of Iran.

Research Method:

In this paper, we have extracted the Gas demand from maximization utility function of consumer in household sector of Iran. According to Weyman-Jones (1986), we can suppose that a consumer consumes two groups of goods consist of energy goods (q_e) and non-energy goods (q_{ne}) as following utility function (u_1):

$$u_1 = u_1(q_e, q_{ne}) \tag{1}$$

The aim of a consumer is maximization of the utility function with following restriction:

$$y = p_e q_e + p_{ne} q_{ne} \tag{2}$$

Where y is income of consumer, p_e is price of energy, p_{ne} is price of non-energy goods, q_e is quantity of energy goods and q_{ne} is quantity of non-energy goods. By maximization of the utility function of equation (1) with restriction of equation (2), demand functions are extracted as following equations:

$$q_e^* = q_e^*(p_e, p_{ne}, y)$$
$$q_{ne}^* = q_{ne}^*(p_e, p_{ne}, y) \tag{3}$$

Where q_e^* is demand of energy goods that is function of price of energy (p_e), price of non-energy goods (p_{ne}) and income (y). Also, q_{ne}^* is demand of non-energy goods that is function of price of non-energy goods (p_{ne}) and income (y). Allocation of expenditure of energy goods by consumer (y_e) is calculated by following equation:

$$y_e = p_e q_e^* \tag{4}$$

Expenditure of energy goods by consumer (y_e) consist of four groups including Petroleum products, Natural Gas, Electricity and Coal. For modeling purpose, we have divided these four groups to two groups consist of natural gas (g) and other energy goods (oe). So, we can write the utility function of energy goods by each consumer as following equation:

$$u_2 = u_2(q_g, q_{oe}) \tag{5}$$

Where q_g is quantity of consumption of natural gas and q_{oe} is quantity of consumption of other energy goods by each consumer. The restriction for U_2 function is:

$$y_e = p_g q_g + p_{oe} q_{oe} \tag{6}$$

Where p_g is price of natural gas and p_{oe} is price of other energy goods. By maximization of equation (5) with restriction of equation (6), the demand functions of energy goods are extracted as following:

$$q_g^* = q_g^*(p_g, p_{oe}, y_e)$$
$$q_{oe}^* = q_{oe}^*(p_g, p_{oe}, y_e) \tag{7}$$

We can suppose that the utility functions are as following shape:

$$u_1 = q_e^{\alpha_1} q_{ne}^{\alpha_2} \tag{8}$$

$$u_2 = \exp(q_g^{\gamma_1} q_{oe}^{\gamma_2})$$

So, we can prove that when equations (8) are utility functions, then the demand function of Natural Gas as following:

$$q_g = h\, p_{oil}^{\varphi_1}\, p_g^{\varphi_2}\, p_{el}^{\varphi_3}\, p_{gasoil}^{\varphi_4} y^{\varphi_5} en^{\varphi_6}$$

We know that the elasticity of natural gas demand is function of price range $p_2 = g(p_g)$ and if we suppose that $p_2 = \eta_0 + \eta_1 \ln(p_g)$ so we can write the models as following form:

$$q_g = h\, p_{oil}^{\varphi_1}\, p_g^{\eta_0+\eta_1 \ln(p_g)}\, p_{el}^{\varphi_3}\, p_{gasoil}^{\varphi_4} y^{\varphi_5} en^{\varphi_6}$$

By taking logarithm from the model, we can write the model as logarithm form:

$$\ln q_g = \psi_t + \varphi_1 \ln p_{oil} + \eta_0 \ln p_g + \eta_1 (\ln p_g)^2 + \varphi_3 \ln p_{el} + \varphi_4 \ln p_{gasoil} + \varphi_5 \ln y + \varphi_6 \ln en + \varepsilon_t \tag{9}$$

$$\psi_t = \psi_{t-1} + \phi_{t-1} + \nu_t$$
$$\phi_t = \phi_{t-1} + \omega_t$$
$$\nu_t \approx NID(0, \sigma_\nu^2)\,,\ \omega_t \approx NID(0, \sigma_\omega^2)$$

where q_g is demand quantity of natural gas, p_{oil} is price of oil, p_g is price of natural gas, p_{el} is price of electricity, p_{gasoil} is price of gas oil, y is real GDP per capita and en is number of Gas splits. ψ_t is trend variable and $\sigma_\omega^2, \sigma_\nu^2$ are super-parameters of the model. Trend variable or ψ_t is as a proxy for technology and non-economic factors that it has assumed time varying. Some factors are invisible but have impact on the natural gas demand, so we have used trend variable for explain unknown variables that affect on the demand.

The model is a state-space model which the trend variable is invisible. We can estimate parameters of the model with Kalman-Filter algorithm. The method of estimation is Maximum Likelihood by using recursive algorithm of Kalman-Filter approach.

The super-parameters can be constant or stochastic and we have tested stochastic hypothesis of the super-parameters by using LR test as following:

$$LR = \frac{Log\ Likelihood\,(\hat{\theta}_R)}{Log\ Likelihood\,(\hat{\theta}_{UR})} \approx \chi^2(k)$$

Where the $Log\ Likelihood\,(\hat{\theta}_R)$ is restricted model of the demand and the $Log\ Likelihood\,(\hat{\theta}_{UR})$ is unrestricted model of the demand. For estimation the model, we have used the state-space approach with Oxmetrics software and stamp application. The method of estimation is Maximum Likelihood. The sample of this research is household sector of Iran during 1974-2010 period.

Estimation Results:

We collected the data from some official reports of ministry of energy and oil in Iran during 1974-2010 period. First of all, we have tested unit root for all of the variables. Table 1 indicates unit root test:

Table 1: Unit Root Test (KPSS*).

Variables	LM (kpss)	Results
$\ln q_g$	0.16	Stationary
$\ln p_{oil}$	0.14	Stationary
$\ln p_g$	0.17	Stationary
$\ln p_{el}$	0.15	Stationary
$\ln p_{gasoil}$	0.15	Stationary
$\ln y$	0.18	Stationary
$\ln en$	0.19	Stationary

*KPSS is Kwiatkowski-Phillips-Schmidt-Shin test statistic

KPSS test indicate that all of the variables are stationary, so we can estimate the model. In this section, we have estimated the model with stamp (Oxmetrics software). Table 2 indicates Method of estimation; Table 3 indicates Log-Likelihood and Prediction error variance, Table 4 shows some summary statistics, Table 5 shows Variances of disturbances, Table 6 indicates State vector analysis at period 2010, Table 7 indicates the estimation results after eliminating redundant variable, Table 8 shows Normality test for Residuals, Table 9 shows Goodness-of-fit based on Residuals, Table 10 shows Serial correlation statistics for Residuals.

Table 2: Method.

Estimation done by Maximum Likelihood (exact score)
The database used is G:\new04.in7
The selection sample is: 1353 - 1389 (T = 37, N = 1 with 2 missings)
The dependent variable Y is: Lqgas
The model is: Y = Trend + Irregular + Explanatory vars
Steady state. Found

Table 3: Log-Likelihood and Prediction error variance

Log-Likelihood is 55.3703 (-2 LogL = -110.741).
Prediction error variance is 0.012513

Table 4: Summary statistics.

Lqgas	
T	35.000
p	2.0000
std.error	0.11186
Normality	3.6514
H(8)	0.27193
DW	2.1005
r(1)	-0.20944
q	6.0000
r(q)	-0.051000
Q(q,q-p)	7.7196
Rd^2	0.84541

Table 5: Variances of disturbances:

	Value	(q-ratio)
Level	0.000000	(0.0000)
Slope	0.00682934	(2.889)
Irregular	0.00236367	(1.000)
Table 6. State vector analysis at period 2010		
	Value	Prob
Level	-28.13863	[0.13656]
Slope	-0.15504	[0.20922]

Table 4 indicates that there is no serial correlation in error term. Also the error term has not heteroskedasticity. Table 5 indicates the variances of disturbances that it shows that the slope is significance but level is not significance.

Figure 1. Trend of logarithm of natural gas demand (Level and Slope)

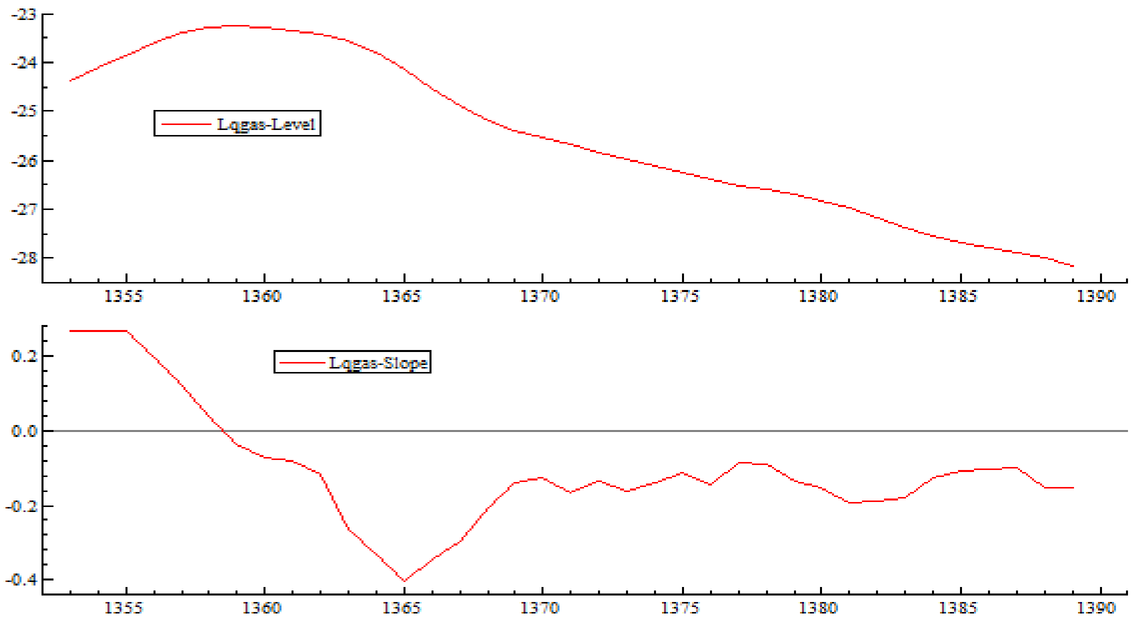

Fig. 1: Indicates trend variable (level and slope) of natural gas demand in Iran. This shape indicates that the trend variable is non-linear. The level of trend increased during 1976-1981. Then the level decreased during 1981-2010. The slope of trend decreased during 1976-1986 period then it increases during 1986-2010 period. the slope had volatility during 1986-2010.

Table 7: Regression effects in final state at time 2010.

	Coefficient	RMSE	t-value	Prob
$\ln p_g$	-1.04344	0.36995	-2.82050	[0.00906]
$(\ln p_g)^2$	-0.33212	0.13148	-2.52599	[0.01797]
$\ln p_{el}$	0.48359	0.16639	2.90641	[0.00738]
den	-0.53241	0.07263	-7.33042	[0.00000]
Len_2	2.37108	1.16640	2.03281	[0.05240]
Lpgdp	0.72680	0.38900	1.86838	[0.07302]
d60	0.22065	0.07801	2.82831	[0.00889]

Table 8: Normality test for Residuals Lqgas.

Value	
Sample size	26.000
Mean	-0.068476
St.Dev	0.88874
Skewness	-0.71546
Excess kurtosis	-0.20648
Minimum	-2.3521

Maximum	1.0914
Chi^2	prob
Skewness	2.2181 [0.1364]
Kurtosis	0.046188 [0.8298]
Bowman-Shenton	2.2643 [0.3223]

Table 9: Goodness-of-fit based on Residuals Lqgas.

	Value
Prediction error variance (p.e.v)	0.012513
Prediction error mean deviation (m.d)	0.0091042
Ratio p.e.v. / m.d in squares	1.2026
Coefficient of determination R^2	0.9967
... based on differences Rd^2	0.84541
Information criterion Akaike (AIC)	-3.8404
... Bayesian Schwartz (BIC)	-3.4051

Table 10: Serial correlation statistics for Residuals Lqgas.

Durbin-Watson test is 2.1005				
Asymptotic deviation for correlation is 0.196116				
Lag	df	Ser.Corr	Box Ljung	prob
1	-1	-0.20944	1.2774	[1.0000]
2	0	0.3229	4.4401	[1.0000]
3	1	-0.15854	5.2357	[0.0221]

Table 7 indicates the estimation results of the model after eliminating redundant variables. Estimation results indicate that:

1. Price of natural gas has a significant negative impact on demand of natural gas. So, demand right has confirmed in household sector of Iran. The elasticity of demand to price of natural gas is -0.50 that it shows that natural gas is an essential commodity for household sector in Iran.

2. square of price of natural gas has a significant negative impact on demand of natural gas.

3. Price of electricity has a significant positive impact on demand of natural gas. In other word, electricity is a substitute commodity for natural gas. The elasticity of natural gas demand to price of electricity is 0.48. The elasticity in equation (9) is calculated as following:

$$e_{gas} = \frac{dlnq_t}{dlnp_t} = \eta_0 + 2\eta_1(\ln p_g)$$

We used average of $(\ln p_g)$ in above equation, η_0 and η_1 are coefficient of the model.

4. Dummy variable for Islamic revolution in 1979, has a significant negative impact on demand of natural gas.

5. The variable of number of Gas splits with two lags has a significant positive impact on natural gas demand. The elasticity of gas demand to gas splits is 2.37 that it indicates high elasticity.

6. Real GDP per capita has a significant positive impact on natural gas demand. The elasticity of gas demand to real GDP per capita is 0.72.

7. Dummy variable for War of Iraq-Iran has a significant positive impact on natural gas demand.

Table 8 indicates the normality test for residual of the research model. The result shows normality of the residuals for the model. Table 9 indicates some goodness of fit criteria of the model. In Table 10, Durbin-Watson test indicates that there is no serial correlation between residual series of the model.

Conclusion:

Natural gas is one of the most important energy for household sector in entire the world. Iran has rich gas reserves and after Russia, Iran has the largest natural gas reserves in entire the world. A study of natural gas demand is very important and crucial for policy makers of energy sources in Iran. With a good estimation of natural gas demand as a result a good forecasting of natural gas demand, policy makers of energy sources can to plan an accurate energy planning. There are lack studies about estimation of natural gas demand in Iran and this problem was incentive us for writing the paper, also, there is no study about natural gas demand with structural time series in Iran. The aim of this paper is estimation of natural gas demand with structural time series methodin Iran during 1974-2010 period.

The result of analysis of variances of disturbances shows that the slope is significance but level is not significance. Price of natural gas has a significant negative impact on demand of natural gas. The elasticity of demand to price of natural gas is -0.50 that it shows that natural gas is an essential commodity for household sector in Iran. Also, square of price of natural gas has a significant negative impact on demand of natural gas. Price of electricity has a significant positive impact on demand of natural gas. In other word, electricity is a substitute commodity for natural gas. The elasticity of natural gas demand to price of electricity is 0.48. Also, the variable of number of Gas splits with two lags has a significant positive impact on natural gas demand. The elasticity of gas demand to gas splits is 2.37 that it indicates high elasticity. Finally, real GDP per capita has a significant positive impact on natural gas demand. The elasticity of gas demand to real GDP per capita is 0.72.

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