

Price Elasticity of Electricity Demand in Iran Based on Computable General Equilibrium Model

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Abstract

Based on the CGE model and according to Social Accounting Matrix (SAM) 1380, this study simulates the impact of electricity price adjustment on demand for electricity, and the simulation results show the range of electricity elasticity of different consumers. The elasticity of Residential sector is relatively larger. However, the absolute values of the price elasticity are less than one.

Furthermore, this paper quantitatively analyses the price elasticity of different categories of users, which are classified to Resident, Agriculture, Industry and Services. The elasticity absolute value of Residents is around (1.02-0.87), that of Agriculture is around (0.013-0.015), that of Industry is around (0,013-0.032) and that of Services is around (0.02-0.031) in different scenarios.

The analytical results of this paper can provide corresponding support for the formulation of electricity pricing mechanisms for Iran.

Keywords: Electricity price; Price elasticity; CGE

Introduction

Electricity has always been regarded as one of the most essential commodities in the country, as manufacturing industries are not able to produce and households welfare would not be without it as well. In our country all forms of energy, including electricity has had a very low price over the years. Due to the low electricity prices, people did not economize in the use of electricity. Other consumer sectors such as industry used non-efficient technology due to low electricity prices compared to the prices of other factors of production and try to improve the efficiency by continuous usage of electricity power rather than other factors of production. There was no increase in electricity prices since 1384 and the prices had been remained stable in all sectors as previous year (1383) after approval of price-fixing scheme in seventh parliament and listed it in the fourth development plan. After the implementation of targeted subsidies plan from January 1389 to review the policy of subsidizing energy, Energy carriers such as electricity prices in the country rose to consumers in various sectors, especially of residential and industrial sectors and made them more sensitive to prices. This paper is an attempt to consider all economic agents behavior in a context of macroeconomic framework and assess impacts of electricity price increases in consumer demand in the various sectors and examine the use of this valuable resource that plays an important role in production process using a comprehensive model. Therefore, the aim of this paper is to examine the effects of electricity price increase on demand and estimate price elasticities using a Computable General Equilibrium Model (CGE). Since this model can balance all markets (supply and demand of goods and factors of production) and explain the relations between the sectors correctly, has more advantages than other models. Using this model, we can measure the impact of electricity price increase in different economic sectors, including residents, industry, agriculture and services accurately and estimate the price elasticity more accurately that could eventually help in the analysis and evaluation of policies and implementation of next steps in reforming the electricity price.

Questions can be posed in this context include:

- What is the price elasticity of electricity demand in different sectors?

- What is the result of comparing the price elasticity of demand in the residential, industrial and agriculture sectors?
- To answer these questions, the following two hypotheses are proposed:
- Electricity in all sectors is relatively inelastic good.
- The price elasticity of electricity demand in the residential sector is larger than the other sectors.

This paper is organized as follows: Section 2 provides an overview the literature. Section 3 deals with the methodology of the model. In this section Computable General Equilibrium Model and its database is provided. Section 4 contains the results of research, including calibration of the model and Price elasticity analysis and finally, the summary and conclusions of the study are presented.

Literature Review

General equilibrium models define a set of institutions and markets, that revenue and expenditure of each institution is equal and supply and demand in all markets is in equilibrium. It should be noted that the equations in CGE models are based on the assumption of optimizing behavior of consumers and producers in which households seek to maximize utility and producers maximize their profit. Walras equilibrium theory is the theoretical basis of these models.

The corner-stone of Walras's general equilibrium is this rule that all revenue from any activity should be equal to the amount of expenditures.

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According to this rule, all firms' products are demanded by consumers and all stock of capital and labor supplied by households is demanded by firms. Also, for a particular commodity, the firms' product must be equal to the sum of the demands of consumers and other firms. The idea of multi-sector general equilibrium model was presented in Johansen's study in 1960 [1]. The first multi-sector practical model with endogenous prices to estimate the resource allocation was offered by him. After that, extensive studies have been done on the impact of policies such as trade liberalization, fiscal policies and other price shock policies in the form of a system of equations.

Many studies have been done in the field of electricity demand globally. The study of Huathaker [2] by using the method of least squares is one of the first studies in this field. His study suggests that the elasticity of electricity demand in the UK is low. In Atakhanova's study [3] on the electricity market, electricity demand elasticities calculated in three residential, industrial and general in Kazakhstan. Household spending, economic restructuring, electricity prices and consumption in the previous period is considered as the most important variables in the household sector in which price elasticity of demand is very low.

Bianco [4] estimated the electricity demand function in Italy using data for the years 1970-2007. According to the results of this study, the amount of per capita income, electricity prices and the power consumption (with three lags) are involved in electricity demand function. Income elasticity is more than price elasticity and income elasticity of electricity demand is nearly 80%. Also coefficients of structural changes, energy prices and other effective variables are negative and less than one.

Heyongxiu [5] in the study on the price elasticity of electricity demand calculated the effects of price changes on consumer demand in China based on the 2007 social accounting matrix in which the value obtained for the price elasticity is less than 1 in all sectors.

Among internal studies, research carried out by Pajouyan and Mohammadi [6] can be pointed out in which electricity demand assumed as a function of the real price of electricity and substitute energy prices and GDP. The results show that the price elasticity of electricity demand is less than one and the income elasticity is greater than one.

Khiabani [7] evaluated the effects of energy price increases in Iran based on CGE model in the form of three scenarios of gasoline prices increase, all energies price increase and all energies price increase in which the prices of petrol, diesel, fuel oil and electricity prices is equivalent to world prices. The results indicate that the increase of energy prices will reduce energy overuse in the firms and households and increase inflation.

Electricity price policy on the inflation has been investigated by Eslami [8] using a computable general equilibrium model and the results show that electricity prices will increase the general level of prices and inflation and if government cash subsidies are paid from revenues resulting from the global rise in oil prices and increased foreign aid is more efficient and leads to less increase in price index.

Research Methodology

As mentioned in the previous section, the model used in this paper is Computable General Equilibrium Model (CGE). In this model, production activities, which are producing goods in the economy, their revenue earned from the sale of goods and these revenues are used to pay the factors of production and intermediate goods. Goods prices in

this model are a function of the prices of factors and intermediate goods that consumer prices are quite flexible and can change in a competitive atmosphere. So suppliers and demanders in this model are price takers that equate the quantity of supply and demand in a competitive environment.

Households who are the owners of factors earn income from stock of factors (i.e. labor and capital) and spend it to buy goods, pay taxes and savings. Demand function is derived from maximizing utility given the budget constraint.

In the factor market assume the following: (1) For Labor: free mobility across activities, unemployment with fixed, activity-specific real wages and the quantity of labor supply as the market-clearing variable; and (2) For Capital: full employment but no mobility between activities and a flexible market-clearing wage for each factor-activity combination.

Government revenue is obtained from income tax, sales tax, import, and export or activity tax. This revenue is spent on government consumption expenditures or transfer payments to other domestic organs. A part of government revenue may also be transferred abroad to repay foreign debts. The remaining revenue will be saved and positive or negative savings represent the deficit or surplus in the state budget.

Other countries engage in domestic financial markets by lending funds (as loan) or invest in financial markets and receive repayment of loans, attract funds or borrow money from local government. In addition, the interaction with other countries occurs through imports and exports. The assumption of this model is that the economy is small compared with the global economy. Thus, export and import prices are set at the global level. Transfer of workers' income that employed abroad into country and vice versa shows another dimension of relation between domestic and global economy.

Mathematical statement of CGE model

The CGE model is a set of equations describing the balance between supply and demand of the economic system. In this paper, the CGE model is divided into "blocks" for prices, production and commodities, institutions, and system constraints. All endogenous variables are written in uppercase Latin letters, whereas parameters (including variables with fixed or exogenous values) have lower-case Latin or Greek letters. In the model Latin letters a and c represent activities and commodities, respectively.

Price block: This block contains six equations that determine the relation of endogenous prices and other variables.

Import price: On the import and export side, the model incorporates the "small country" assumption that world prices are exogenous.

$$PM_c = (1 + tm_c).EXR.pwm_c \quad (1)$$

Where PM_c is the import price of commodity c in domestic currency, tm_c is the rate of import tariff of commodity c , EXR is the foreign exchange rate (domestic currency per unit of foreign currency), pwm_c is the world import price.

Export price:

$$PE_c = (1 - te_c).EXR.pwe_c \quad (2)$$

Where PE_c is the export price of commodity c in domestic currency, te_c is the export tax rate; pwe_c is the world export price.

Absorption equation: For each commodity, absorption-total domestic spending on the commodity at domestic demander prices—is expressed as the sum of spending on domestic output and imports, including an upward adjustment for the sales tax.

$$PQ_c \cdot QQ_c = [PD_c \cdot QD_c + (PM_c \cdot QM_c)](1 + tq_c) \quad (3)$$

Where PQ_c is the composite price of commodity c , QQ_c is the quantity of commodity c supplied to domestic demanders (composite supply), PD_c is the domestic price of commodity c , QD_c is the quantity of domestic output c sold domestically, QM_c is the quantity of import of commodity c , tq_c is the sales tax rate.

Domestic output value: For each commodity, domestic output value at producer prices is stated as the sum of the value of domestic output sold domestically and the export value.

$$PX_c \cdot QX_c = PD_c \cdot QD_c + (PE_c \cdot QE_c) \quad (4)$$

Where PX_c is the producer price of commodity c , QX_c is the quantity of domestic output, QE_c is the quantity of export of commodity c .

Activity price:

$$PA_a = \sum_{c \in C} PX_c \cdot \theta_{ac} \quad (5)$$

Where PA_a is the price of activity a , θ_{ac} is the yield of commodity c per unit of activity a

Value-added price:

$$PVA_a = PA_a(1 - tx_a) - \sum_{c \in C} PQ_c \cdot ica_{ca} \quad (6)$$

Where PVA_a is the value-added price of activity a , tx_a is the tax rate for activity a , ica_{ca} is the quantity of c as intermediate input per unit of activity a .

Production and commodity block: There are ten equations in this block that describe the supply side of the model.

Activity production function: Cobb-Douglas function is used for producer technology, where QA_a is the level of activity a , ad_a is the production function efficiency parameter, QF_{fa} is the quantity demanded of factor f by activity a , α_{fa} is the value-added share for factor f in activity a .

$$QA_a = ad_a \cdot \prod_{f \in F} QF_{fa}^{\alpha_{fa}} \quad (7)$$

Factor demand:

$$WF_f \cdot WFDIST_{fa} = \frac{\alpha_{fa} \cdot PVA_a \cdot QA_a}{QF_{fa}} \quad (8)$$

Where WF_f is the average wage (rental rate) of factor f , $WFDIST_{fa}$ is the wage distortion factor for factor f in activity a .

Intermediate demand: The assumption of Leontief technology on intermediate inputs means that intermediate commodity demand (QINT) is defined as the product of the fixed (Leontief) input coefficients of demand for commodity c by activity a (ica_{ca}) multiplied by the quantity of activity output (QA).

$$QINT_{ca} = ica_{ca} \cdot QA_a \quad (9)$$

Output function: This equation aggregates the commodity outputs by each activity.

$$QX_c = \sum_{a \in A} \theta_{ac} \cdot QA_a \quad (10)$$

Composite supply (Armington) function: Imperfect substitutability between imports and domestic output sold domestically

is captured by a CES (constant elasticity of substitution) function in which the composite commodity that is supplied domestically is produced by domestic and imported commodities Economically, this means that demander preferences over imports and domestic output are expressed as a CES function

$$QQ_c = \alpha q_c \left[\delta_c^q QM_c^{-\rho_c^q} + (1 - \delta_c^q) QD_c^{-\rho_c^q} \right]^{-1/\rho_c^q} \quad (11)$$

Where αq_c , δ_c^q and ρ_c^q are respectively the shift parameter, the share parameter and the exponent ($1/\rho_c^q$) for Armington function.

Import-domestic demand ratio: This equation defines the optimal mix between imports and domestic output.

$$\frac{QM_c}{QD_c} = \left[\frac{PD_c}{PM_c} \cdot \frac{\delta_c^q}{(1 - \delta_c^q)} \right]^{1/(1 + \rho_c^q)} \quad (12)$$

Composite supply for non-imported commodities:

$$QQ_c = QD_c \quad (13)$$

For commodities that are not imported, the Armington function is replaced by the above statement.

Output transformation (CET) function: Imperfect transformability between domestic output for exports and domestic sales is captured by a CET (constant elasticity of transformation) aggregation function. In economic terms, the difference between the Armington and CET functions is that the arguments in the former are inputs, those in the latter are outputs.

$$QX_c = \alpha t_c \left[\delta_c^t QE_c^{\rho_c^t} + (1 - \delta_c^t) QD_c^{\rho_c^t} \right]^{1/\rho_c^t} \quad (14)$$

Where αt_c , δ_c^t and ρ_c^t are respectively the shift parameter, the share parameter and the exponent ($1/\rho_c^t$) for CET function.

Export-domestic supply ratio: This equation defines the optimal mix between exports and domestic sales as below:

$$\frac{QE_c}{QD_c} = \left[\frac{PE_c}{PD_c} \cdot \frac{1 - \delta_c^t}{\delta_c^t} \right]^{(1/\rho_c^t - 1)} \quad (15)$$

Output transformation for non-exported commodities:

$$QX_c = QD_c \quad (16)$$

For commodities that are not exported, the CET function is replaced by a statement imposing equality between domestic output sold domestically and domestic output.

Institution block: This block contains six equations that define income and expenditure of institutions of the model; households (h), government (g) and rest of world (row).

Factor income:

$$YF_{hg,f} = shry_{hg,f} \left(\sum_{a \in A} WF_f \cdot WFDIST_{fa} \cdot QF_{fa} + tr_{f,row} \cdot EXR \right) \quad (17)$$

Where $YF_{hg,f}$ is the transfer of income to institution hg from factor f , $shry_{hg,f}$ is the share of the income from factor f in institution hg , $tr_{f,row}$ is the income of factor f from rest of world and hg refers to domestic institutions (households and government).

Household income:

$$YH_h = \sum_{f \in F} YF_{hf} + tr_{h,gov} + EXR \cdot tr_{h,row} \quad (18)$$

Where YH_h is the income to household h , YF_{hf} is the transfer of

income to household h from factor f, tr_{if} is the transfer from institution i to institution i.

Household consumption demand:

$$QH_{ch} = \frac{\beta_{ch}(1 - mps_h)(1 - ty_h)YH_h}{PQ_c} \quad (19)$$

Where QH_{ch} is the quantity of consumption of commodity c by household h, β_{ch} is the share of commodity c in the consumption of household h, mps_h is the share of disposable household income to savings, ty_h is the rate of income tax.

Investment demand:

$$QINV_c = \overline{qinv_c} \cdot IADJ \quad (20)$$

Where $QINV_c$ is the quantity of investment demand, $qinv_c$ is the base-year investment demand; IADJ is the investment adjustment factor.

Government revenue:

$$YG = \sum_h ty_h YH_h + \sum_{c \in C} tq_c (PD_c \cdot QD_c + (PM_c \cdot QM_c)) + \sum_c tm_c \cdot EXR \cdot pwm_c \cdot QM_c + \sum_c te_c \cdot EXR \cdot pwe_c \cdot QE_c + \sum_a tx_a \cdot PA_a \cdot QA_a + \sum_f YF_{g,f} + EXR \cdot tr_{g,row} \quad (21)$$

Where YG is the government revenue, $YF_{g,t}$ is the transfer of income to government from factor f

Government expenditures:

$$EG = \sum_h tr_{h,g} + \sum_c PQ_c \cdot qg_c \quad (22)$$

Where EG is the government expenditure, qg_c is the government commodity demand.

Market clearing conditions and system constraint block: This block defines the constraints that are satisfied by the economy as a whole without being considered by its individual agents. The model's micro constraints apply to individual markets.

Factor markets:

For the two factors, the closure rules are: unemployment with fixed, activity-specific real wages for labor and fixed capital use for each activity.

$$\sum_a QF_{fa} = QFS_f \quad (23)$$

Where QFS_f is supply of factor f.

Composite commodity markets:

$$QQ_c = \sum_a QINT_{ca} + \sum_h QH_{ch} + qg_c + QINV_c \quad (24)$$

Current account balance: The current-account equation imposes equality between the country's earning and spending of foreign exchange. Foreign savings (FSAV) is equal to the current-account deficit

$$\sum_c pwe_c \cdot QE_c + \sum_{hg} tr_{hg,row} + FSAV = \sum_c pwm_c \cdot QM_c \quad (25)$$

Savings-investment balance: This equation imposes equality between savings and investment, where the left hand side of equation refers to the total savings, the right hand refers to investment and WALRAS is a dummy variable that is zero at equilibrium.

$$\sum_{a \in A} mps_a \cdot (1 - ty_a) \cdot YH_a + (YG - EG) + EXR \cdot FSAV = \sum_{a \in C} PQ_a \cdot QINV_a + WALRAS \quad (26)$$

Price normalization:

$$\sum_c PQ_c \cdot cwtsc = cpi \quad (27)$$

Where cpi is the consumer price index and cwtsc is the commodity weight in CPI.

Basic data base of CGE-SAM

Data organizing for using the CGE model is of initial important steps to build the models. The required data for these models is provided in a matrix called Social Account Matrix (SAM) in which cash flow of goods and services and also payment between sectors is reflected. SAM matrix used in this study is macro-social accounting matrix of Iran 2001 (Table 1), which is the last matrix in this field. The matrix consists of seven accounts of goods and services, activities, factors, institutions, saving-investment, taxes and rest of world. To facilitate the calculation and tracking simulation results, in this paper the matrix is aggregated regarding following characteristics.

- Account of goods and services, which includes 22 commodity groups, is aggregated to two groups of electricity and other goods that are identified by subscript c.
- Account of activities, including 21 activities, is aggregated to three activities of agriculture, industry and mining, services that are marked with subscript a.
- Account of factor in both original social accounting matrix and aggregated matrix consists of two factors, labor and capital which will be shown with subscript f.
- Account of households is introduced in two forms of rural and urban households and since the merging of enterprises and government does not create disturbance in our discussion, these two institutions have been merged. So the institutions of model are urban households, rural households, government and rest of world. This part is shown with subscript i.

Commodities		417436		397376	104733	206214				157720
Activities	1149118									
Factors		722717								1003
Households			439332		46427					15
Government			284388				37040	8965	9386	1020
S-I				51358	189639					
Income Tax				37040						
Sale Tax		8965								
Import Tax	9386									
Rest of World	124975					34783				
Total	1283479	1628125	801304	485774	349846	240997	37040	8965	9386	159762

Table 1: Macro-SAM of 2001 (unit: Billion Rials).

Sectors	5%	10%	15%	20%
Residents	-1.029	-0.958	-0.91	-0.871
Agriculture	-0.015	-0.014	-0.013	-0.013
Industry	-0.033	-0.021	-0.016	-0.013
Services	-0.031	-0.024	-0.022	-0.02

Table 2: Values of price elasticity of electricity demand.

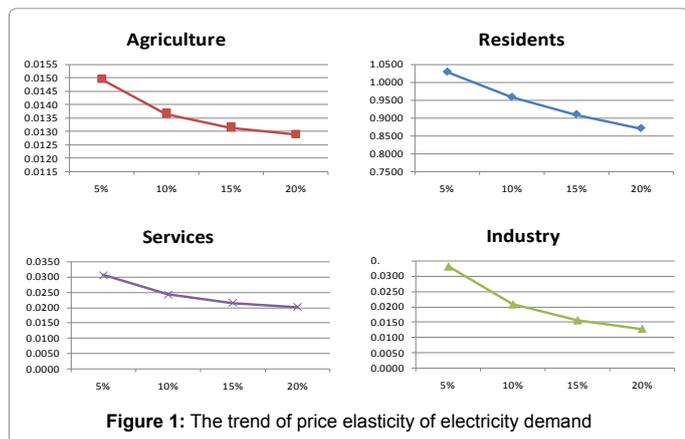


Figure 1: The trend of price elasticity of electricity demand

- Saving-Investment account represents institutions savings and on the other hand, investment demand for different goods.
- Taxes as well as production factors remained unchanged and consist of three types of taxes (income tax, sales tax, and taxes on imports).

Simulation Results

Model calibration

One of the important steps in modeling general equilibrium models is to calibrate the model. Calibration is a process of determining the parameter values so that the values of the endogenous variables for the base year to be reproduced. In fact, the aim of calibration is that general equilibrium that is presented in the form of mathematical equations should be reproduced the values of the SAM in the first run. In other words, when the general equilibrium model is solved, the same amount of social accounting matrix is obtained as the answer of the model.

CGE model has two types of parameters: the first type such as share of households and government consumption of different goods, savings rates, tax rates and etc., is called share parameters. These parameters which derived from the SAM are obtained using the GAMS software. The second type is behavioral parameters, including Armington function's elasticity and CET function's elasticity. To obtain these parameters previous studies and past research in the country or similar countries are used. In this paper import substitution elasticity (Armington function elasticity of substitution) and export elasticity of substitution (CET function elasticity of substitution) respectively 0.5 and 2 is assumed by Heyongxiu¹.

Analysis of price elasticity of electricity demand

Generally, electricity demand is in form of final demand from households and in form of intermediate demand from the firms. This section introduces the scenarios (Four Scenarios: 5%, 10%, 15% and 20% increase in electricity prices) and the effects of energy price

increases on demand based on the equation $E = \frac{\Delta Q/Q}{\Delta P/P}$ in all sectors is investigated.

By calibrating the model and obtained parameters and also applying above mentioned scenarios using GAMS software for the price elasticity of electricity demand the results obtained are presented in Table 2. According to this table, the price elasticity of electricity demand in all sectors is negative. It indicates the establishment of demand law for electricity. The absolute value of the elasticity in all sectors and all scenarios (except residential sector in the first scenario) is less than one and we can say electricity relatively inelastic good in all sectors. Thus, the first hypothesis of this paper is accepted. In addition, price elasticity of households demand for electricity in all scenarios is larger than the other sectors. This may be due to low price of electricity and using luxury accessories at homes that with rising prices the incentive to save and reduce the use of these materials occurs. So, the second hypothesis based on the higher price elasticity of electricity demand in the household sector relative to other sectors is accepted.

The high volatility of electricity prices results lower price elasticity in all consumption sectors. This indicates that in the early stages of rising prices greater capacity is in available for saving power consumption for people and with subsequent price increases the capacity will be decreased. This is illustrated in Figure 1.

As reference [7] Khiabani mentioned the price elasticity of electricity demand in most countries is less than one. It should be noted that the price elasticity of electricity demand in the residential sector in developed countries is usually larger, that is due to high level of welfare and use of facilities and luxury equipment. In this study the price elasticity in the residential sector is around one. From this point of view we can say that the results for the household sector are similar to studies conducted on developed countries. The results show the low electricity elasticity in other sectors in this study and similar studies as well.

Summary and Conclusions

This paper attempts to investigate the effects of electricity price increase on its demand based on the Computable General Equilibrium (CGE) model by using the 2001 social accounting matrix. Therefore, after designing the general equilibrium model and calibrating it in the GAMS software, four scenarios include 5%, 10%, 15% and 20% increase in electricity price for different consumer sectors (household, industry and mining, agriculture and services) was introduced. The results suggest that: First, the price elasticity of electricity demand in all sectors and all scenarios is negative. Second, absolute value in all sectors and all scenarios (except the residential sector in the first scenario) is less than unity that Indicates low elasticity of electricity demand. Third, elasticity in the household sector is greater than other sectors and is close to one. A comparison of these results with similar results in different countries suggests that the elasticity in the household sector in our country is very similar to developed countries. It can be due to the low price of electricity and the use of luxury equipment in this section.

Based on the above analysis it is recommended:

- As general equilibrium models provide more reliable results than other models, it is recommended that policymakers in electricity industry to increase the electricity price consider the results of this survey.
- Since more increase in electricity price leads to reduction of elasticity (compared to the past), policymakers should not expect further savings in power consumption in the second phase of targeted subsidies in comparison with first phase.

¹For this purpose we use Heyongxiu [5] and Naderan and Fouladi (2006).

- National accounts Classification is based on the International Standard ISIC, while cost and power consumption statistical classification is based on Supplementary Regulations electricity tariffs (to separate residential, industrial, agricultural, commercial and public) that there is no connection between these two. Therefore, it is recommended that policymakers in power industry offer the electrical industry statistics in accordance with the international standards as possible.
 - As this study used data from 2001 and we did not succeed to provide results in detailed breakdown of the electricity tariff, it is hoped that further research in the future provide these results producing required and up to date data.
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