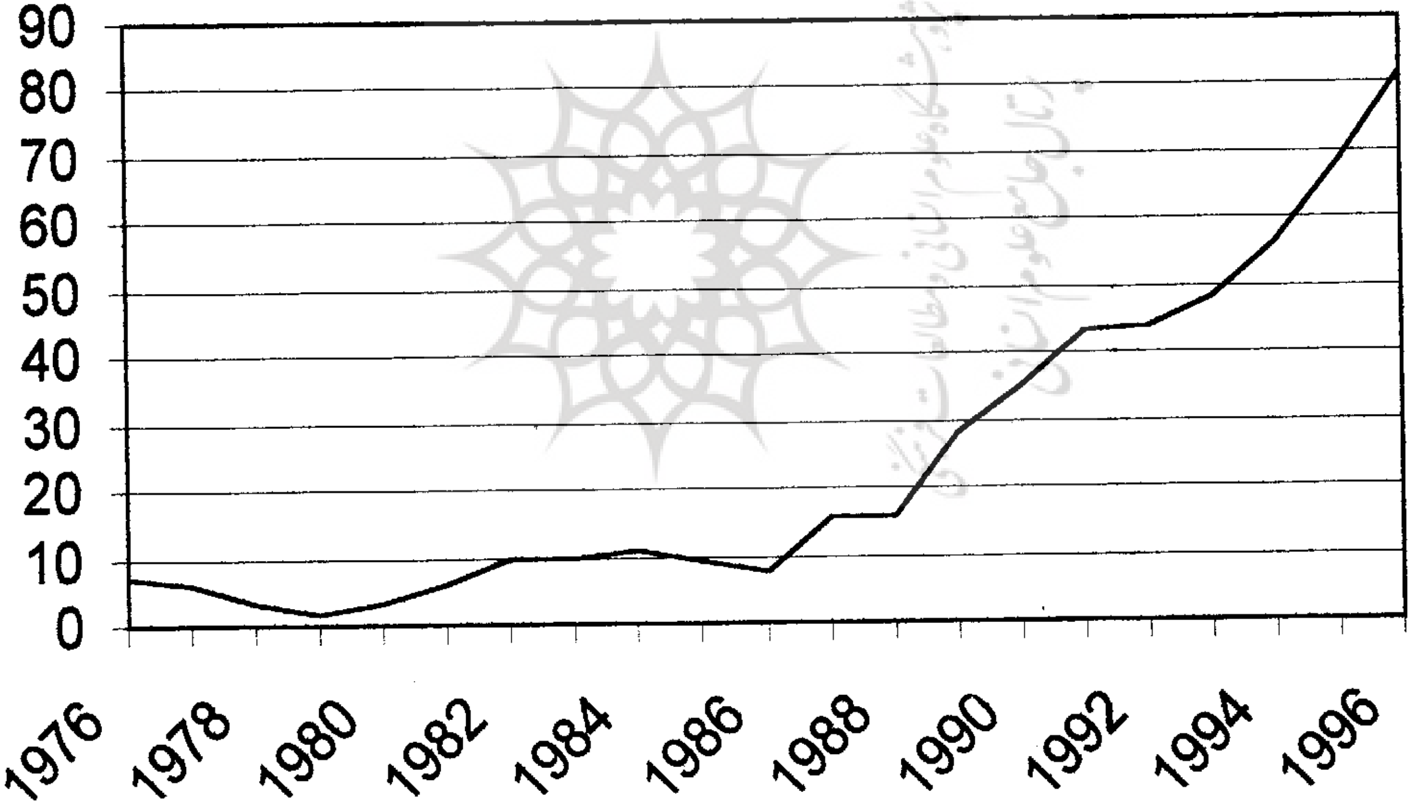
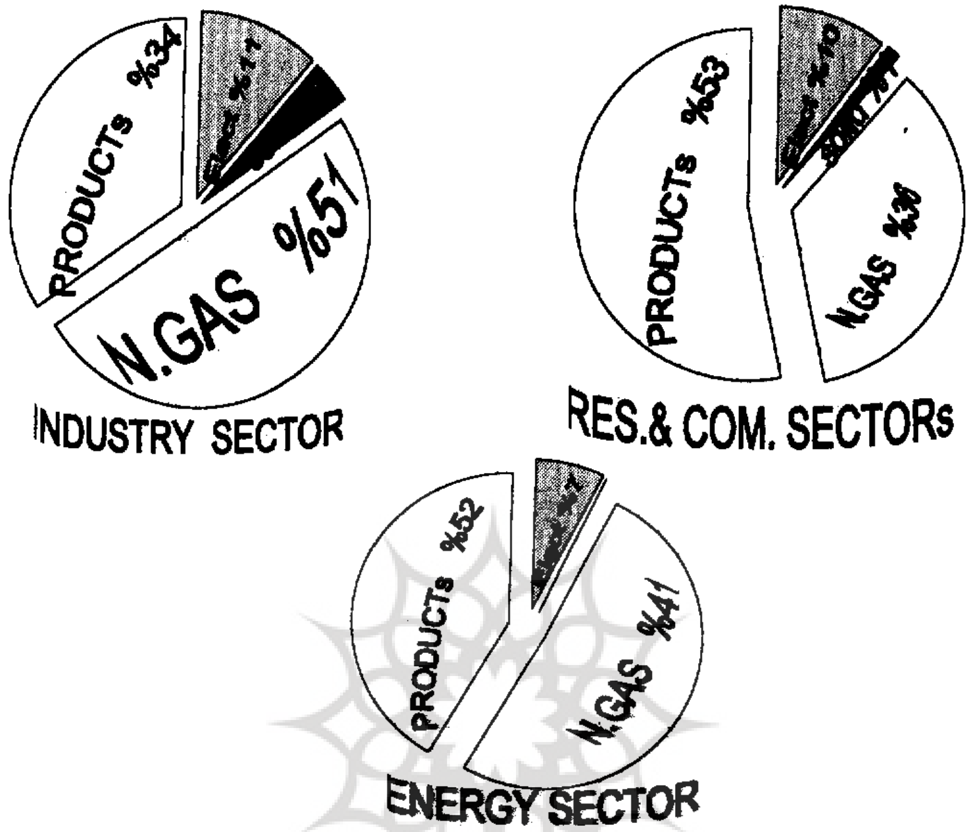
IRAN'S

N.GAS CONSUMPTION

IN INDUSTRY SECTOR (MBOE)



ENERGY CONSUMPTION MIX OF THE ENERGY SECTORs(1996)



RESERVES & PRODUCTION OF N.GAS (1996)

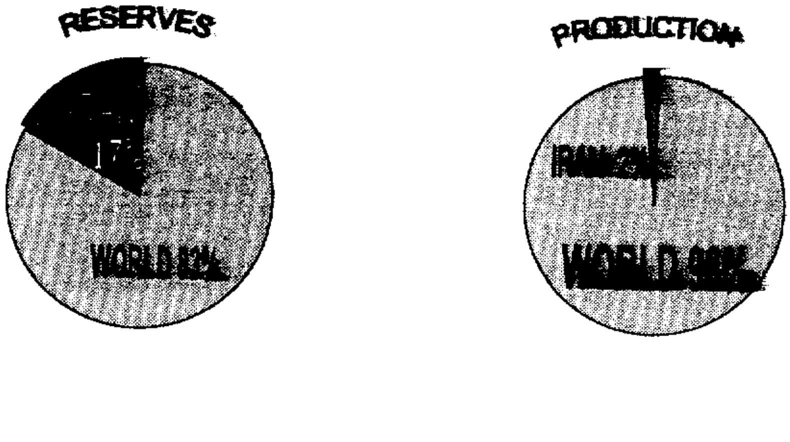


Figure 2

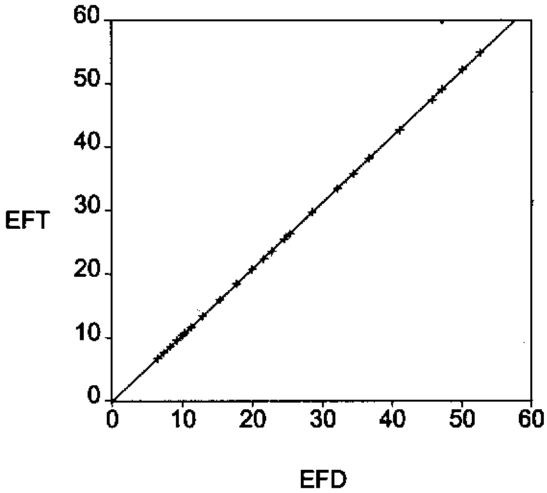


Figure 1

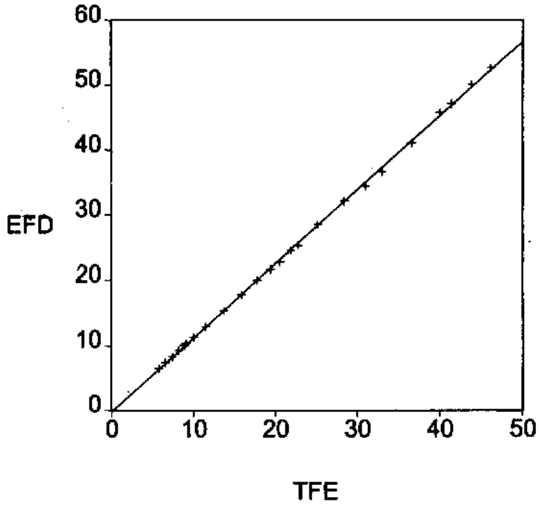


Figure 4

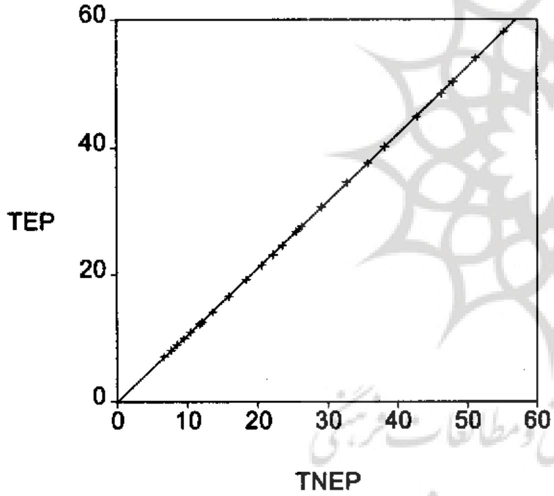


Figure 3

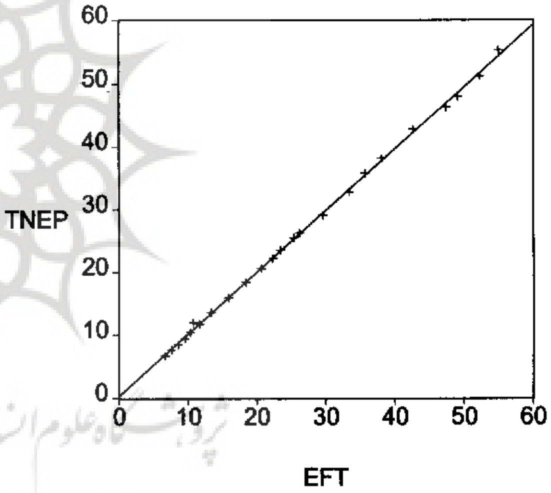
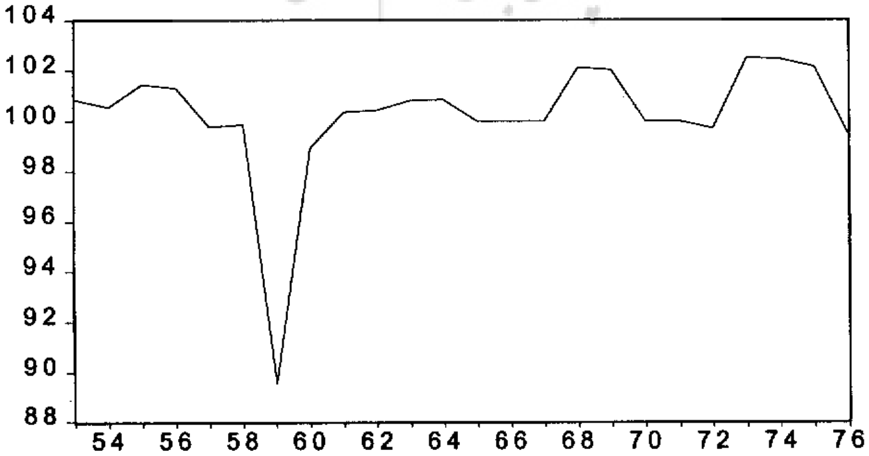
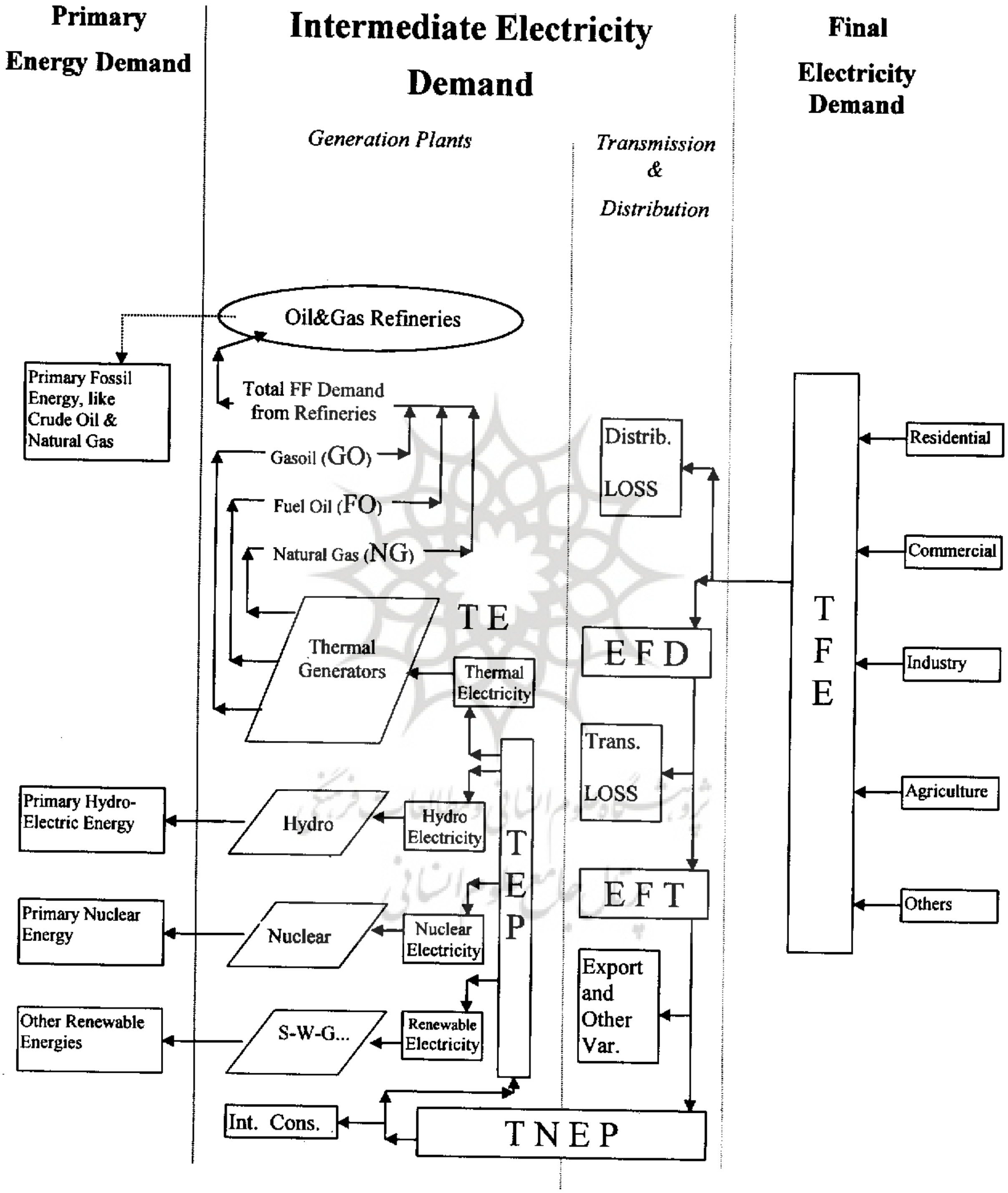


Figure 5



APPENDIX



Flow Diagram 1: Primary (energy), Intermediate and Final Electricity Demand

Cochran- Orcatt method has been used to overcome the first order auto - correlation in estimated equations (9), (10) , and (12). Furthermore, the signs of the estimated coefficients are consistent with theoretical expectations.

5. CONCLUDING REMARKS

This paper has modeled the demand side of the intermediate electricity sector of Iran, using theory and econometric techniques. The empirical results of this study provide policy recommendation in the short and mid terms, because the structure of the electricity industry can not be changed easily in the mid-term. The model is also useful for forecasting the demand of fossil energy inputs for the electricity production sector. This model can be used as a sub-model in an overall energy model, which in turn can be linked to macroeconomic model. This linkage is an important tool in the Iranian national planning efforts. The results of this study are important for the energy sector of Iran, which has suffered from the lack of sufficient and reliable data. The applied approach in this study can also be applied to other developing countries as well.

Using "what if" exercises, the analyst can run several counterfactual simulations to see what would happen to the demand, if policy makers change the exogenous variables. For instance, the planned amount of electricity supply for non - thermal electricity is an exogenous variable in the structural equations. Therefore, by imposing changes of this variable in different scenarios, one can observe its consequences on the development of non - thermal power generation system and evaluate the energy demanded for thermal electricity generation as well. In other words, this paper also addresses those energy carriers for which there are no data history.

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The only remaining part of the intermediate electricity demand model is the sub-model for the thermal electricity power generation [system of simultaneous equation (8)]. It would be useful if we could disaggregate this sub-sector of energy transformation into different types of power generation, such as steam, gas turbine, diesel, and combined cycle. However, there is no sufficient and reliable time series data on these variables in Iran. In developing countries such as Iran we have only data on aggregate variables. Using the causality analysis in this study, as far as the data is concerned, the following model has been selected as the best in explaining the existing relationships between TEP on the one hand and NG, FO and GO on the other;

$$\begin{cases} NG = \alpha_0 + \alpha_1 * FO + \alpha_2 * TE + \alpha_3 * DGO2 + \alpha_4 * NG(-1) + U_1 \\ FO = \beta_0 + \beta_1 * NG + \beta_2 * TE + \beta_3 * DGO3 + \beta_4 * FO(-1) + U_2 \\ GO = \gamma_0 + \gamma_1 * (FO + NG) + \gamma_2 * TE + \gamma_3 * GO(-1) + U_3 \end{cases}$$

Where DGO2 and DGO3 are dummy variables to allow for the substitution of gas oil for natural gas and fuel oil, respectively, and U_1 is the stochastic disturbance term of the i^{th} equation.

As can be seen from the above- specified system of equations, the prices of energy inputs have not been taken into account in the model. The reason for this pertains to the following discussion. Ministry of Petroleum (MP) and Ministry of Energy (ME)[1] are independent and not vertically integrated. Although ME pays for these three fuels, the existing mechanism does not make ME sensitive to fuel prices. Decisions on prices are based on targets specified in the five-year development plans rather than bargaining for prices. Thus the prices are omitted from the relevant equations. This system of simultaneous equations explains the substitutability of three kinds of energy inputs. Substitutability of gas oil for natural gas or fuel oil is indirectly considered by exogeously determined dummy variables DGO2 and DGO3 , while the converse effect is endogenous. This shows that the substitution of gas oil for natural gas or fuel oil has a temporary nature. Because gas oil is a more expensive fuel as compared to other two energy inputs; ME assigns the first priority to the use of fuel oil and natural gas. However, in the special circumstances gas oil is substituted in the system.Therefore, the substitution of gas oil for natural gas and fuel oil is captured by dummy variables. It is, therefore, expected that the substitution effect would be negative and theoretically the estimated α_1, α_3, β_1, β_3 and γ_1 must be negative. The relationship between total thermal electricity production (TE) and energy inputs (NG, FO, and GO) also must be positive, because the higher electricity production needs,the greater energy inputs. Thus, the estimated coefficients of α_2, β_2, and γ_2 ought to have positive signs. The lagged variable in each eqution shows the dynamic behavior and speed of adjustment of the model, which is really important in measuring the dynamic response of dependent variables. The simultaneous equations specified above are identifiable and pass both rank and order conditions. The emperical estimation of the system is summarized as follows:

$$\begin{cases} NG = -0.891 - 0.894 * FO + 2.372 * TE - 2.059 * DGO2 + 0.176 * NG(-1) \\ FO = 0.854 - 0.337 * NG + 1.248 * TE - 2.111 * DGO3 + 0.328 * FO(-1) \\ GO = 1.722 - 0.861 * (FO + NG) + 2.378 * TE + 0.553 * GO(-1) \end{cases}$$

It should be noted that the relevant null hypothesis is rejecred at 5 percent level of signifiance. That is to say, all the reported coefficients are statistically significant and pass a battery of diagnostic tests. The [equation (2)]. As can be seen, the relationship is strictly linear without intercept. Using the annual data for period 1974-1997, the following linear econometric model is estimated for capturing this relationship:

$$EFD=1.1324 * TFE \qquad (9)$$
$$(\mathbf{0.0052})$$
$$R^2 = \mathbf{0.9997} \quad \bar{R}^2 = \mathbf{0.9997} \quad \text{Prob(T-stat)}=\mathbf{0.0000} \quad \text{D.W. stat}=\mathbf{1.8817}$$

Where the number in parenthesis is the standard error of the relevant estimated coefficient. It is noteworthy that no other economic factors such as prices and income have been taken into account in this specification. This is simply because the regional electricity companies in Iran are vertically integrated in production, transmission and distribution affairs and consequently free. This rule also applies for the transmission sub-sector.

Figure 2 in Appendix, shows a scatter diagram of EFT vs. EFD [equation (3)]. From this Figure one can conclude that the electricity demanded for transmission purposes (with the same reason, which were discussed earlier), has a strictly linear relationship with the electricity demanded for distribution sub-sector. The estimation results are as follows:

$$EFT=1.0402*EFD \qquad (10)$$
$$(\mathbf{0.0012})$$
$$R^2 = \mathbf{0.9999} \quad \bar{R}^2 = \mathbf{0.9999} \quad \text{Prob (T-stat)}=\mathbf{0.0000} \quad \text{D.W. stat}=\mathbf{1.8526}$$

Figure 3 in Appendix, shows a scatter diagram of TNEP vs. EFT [equation (4)]. All plotted points are well scattered around a line, which is passing through the origin with only one exception. Figure 5 shows this abnormal observation occurring in 1980. The imposed eight-year Iraq-Iran war was started in this year. This outlier observation has been captured as a qualitative phenomenon by a dummy variable which equals to one in 1980 and zero in other years. As a result, the following linear equation has been estimated to capture the relationship between TNEP vs. EFT:

$$TNEP=0.9906*EFT+1.3622*D59 \qquad (11)$$
$$(\mathbf{0.0026}) \quad (\mathbf{0.3808})$$
$$R^2 = \mathbf{0.9994} \quad \bar{R}^2 = \mathbf{0.9994} \quad \text{Prob (F-stat)}=\mathbf{0.0000} \quad \text{D.W. stat}=\mathbf{1.4856}$$

Finally, Figure 4 in Appendix, shows the relationship between TEP vs. TNEP [equation (5)]. It is crystal clear from this Figure that the relationship is linear without intercept in nature. Using the annual data for the period 1974-1997, the estimated equation is presented below:

$$TEP=1.0516*TNEP \qquad (12)$$
$$(\mathbf{0.0015})$$
$$R^2 = \mathbf{0.9999} \quad \bar{R}^2 = \mathbf{0.9999} \quad \text{Prob (T-stat)}=\mathbf{0.0000} \quad \text{D.W. stat}=\mathbf{1.8892}$$

of technology and different kinds of power generation plants in use. Generally speaking, steam generators have more internal electricity consumption than others, because of high amount of electricity consumption in cooling towers. Thus, there is a technical functional form between total gross electricity production (or simply total electricity production) and total net electricity production, of which internal consumption is deducted. The general form of this relation is written as:

$$TEP = \xi(TNEP) \tag{5}$$

Where TEP is total (gross) electricity production.

TEP is summation of all electricity, which is produced by thermal or non-thermal generations. This simply implies the following identity:

$$TEP \equiv TE + NTE \tag{6}$$

Where TE is thermal electricity production and NTE is non-thermal electricity production. The variable NTE behaves more stochastic and exogenous. The more rainy weather results in higher hydroelectricity production. Also sunny and windy days bring about the greater solar and wind electricity production, respectively. As can be seen, the electricity productions in the above-mentioned sources have a stochastic nature. If we consider NTE as an exogenous variable in the model, the following identity for thermal electricity demand can be written:

$$TE \equiv TEP.\frac{TE}{TEP} \equiv TEP.\alpha \tag{7}$$

Where α is exogenously each year.

The most important part of this study is to construct a model of energy demand for inputs used in thermal electricity generation plants. There are three kinds of energy inputs in the Iranian thermal electricity generation system, including natural gas, fuel oil and gas oil. The implict general linear functional form of this model can be written as:

$$By + \Gamma x = 0$$

or

$$\begin{bmatrix} \beta_{11} & \beta_{12} & \beta_{13} \\ \beta_{21} & \beta_{22} & \beta_{23} \\ \beta_{31} & \beta_{32} & \beta_{33} \end{bmatrix} \begin{bmatrix} GO \\ FO \\ NG \end{bmatrix} + \begin{bmatrix} \gamma_{11} & \gamma_{12} & \gamma_{13} & \cdots & \gamma_{1k} \\ \gamma_{21} & \gamma_{22} & \gamma_{23} & \cdots & \gamma_{2k} \\ \gamma_{31} & \gamma_{32} & \gamma_{33} & \cdots & \gamma_{3k} \end{bmatrix} \begin{bmatrix} \chi_1 \\ \chi_2 \\ \chi_3 \\ \vdots \\ \chi_k \end{bmatrix} = 0 \tag{8}$$

Where,

B and Γ = the coefficient matrices of endogenous and exogenous variable, respectively;

y and x = the vectors of endogenous and exogenous variable, respectively;

GO = the quantity demanded for Gas oil;

FO = the quantity demanded for Fuel oil;

NG = the quantity demanded for Natural Gas;

Given the above system of equations, the intermediate electricity demand model is discussed in this study in the context of the Iranian economy.

4. EMPERICAL RESULTS

In order to find the best functional form of each equation, in addition to the use of theory, various econometric testing have been performed. Figure 1 in appendix, shows scatter diagram of EFD vs. TFE transmission and distribution sub-sectors.

2. THE STRUCTURE OF ELECTRICITY SUBSECTORS

Flow diagram 1 in Appendix indicates how different levels of electricity demand have interactive relationship together. These levels consist of final, intermediate and primary electricity demand. This diagram also shows the structure of electricity sub-sectors in the whole economy.

The intermediate electricity sector is defined as the non-thermal electricity generation plants, including hydroelectric, renewable (wind, solar, geothermal, etc) and thermal power generation plants and transmission and disrtibution networks of electricity. Generally, electricity is produced by thermal or non-thermal power generators. Thermal generators such as steam, gas turbine, diesel and combined cycles plants; and non-thermals like hydroelectric, wind, solar, geothermal and other kinds of renewable generators. Nuclear is known as thermal electricity but here in this study it is classified as a seprate category.

At present, Iran's electricity sector solely contains thermal and hydro electricity. Of course, there are some negligible capacities of other kinds of electricity sources, and there are some plans to develop these capacities, but the bulk of electricity supply is generated by thermal sources.

3. THEORITICAL AND MATHEMATICAL FRAMEWORK

It is assumed that the demand for electricity in the final consumer sectors is already known. That is to say, the demand for total final electricity is given by the following equation:

$$TFE = \sum_{j} f_j(X) \tag{1}$$

Where TFE is total final electricity demand, X is representative vector of explanatory variables (such as sectoral value added and prices, household income, etc.) in demand functions, j is the indicator of the final electricity consumer sector including residential, commercial, industry , agriculture, transportation and others.

The electricity demand for the distribution network (inputs to distribution network) depends upon the kind of technology which has been in use and is most prevalent. So the structural equation of the electricity demanded by this network is shown by the following relation :

$$EFD = \varphi(TFE) \tag{2}$$

Where EFD is the electricity demanded for distribution network.

Electricity demand for the transmission network (input to transmission network) has the same functional behavior as relation (2) which is a technical relation as follows:

$$EFT = \psi(EFD) \tag{3}$$

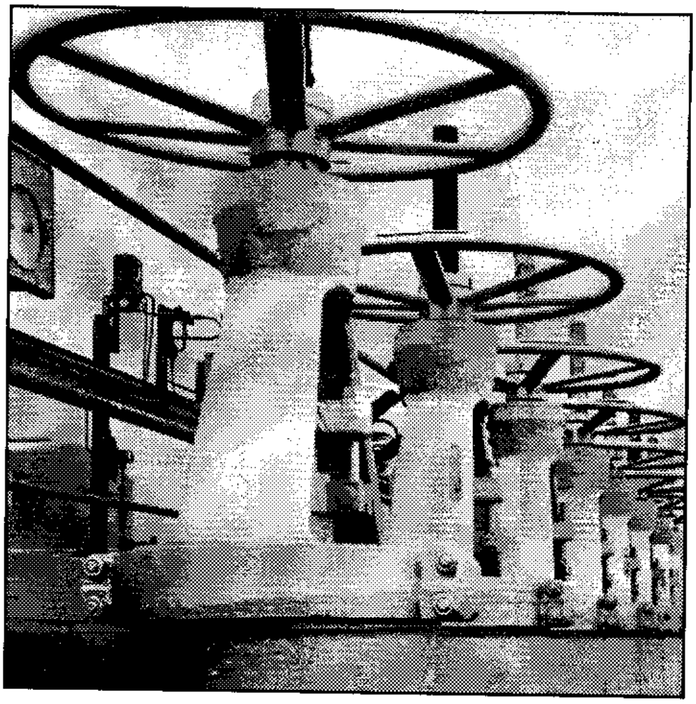
Where EFT is the electricity demanded for transmission sub-sector.

These functional relationships can also be inferred in Flow diagram 1. There is another functional interdependency between total net electricity production (TNEP) and the amount of electricity for transmission (EFT) purposes. This relationship is shown generally by:

$$TNEP = \lambda(EFT) \tag{4}$$

The sub-sector of electricity generation has internal consumption of electricity, which is mainly a function

An Energy Demand Model for Generation, Transmission and Distribution of Electricity in Iran[1]



Reza Fathollahzadeh Aghdam[2]

Abstract

The purpose of this paper is to construct an econometric energy demand model for generation, transmission and distribution (intermediate electricity sectors) of electricity network. In order to substantiate the theoretical framework and structural and behavioral equations of the model, various econometric techniques have been applied. This study provides insightful policy recommendations for the energy authorities in Iran so as to rationalize the use of non-renewable energy resources in the country. The present study can be regarded as a component of a macro energy model for developing countries, which suffer from the lack of sufficient and reliable data.

1. INTRODUCTION

One of the most important objectives of the energy demand modeling at macro level is to forecast the demand for primary energy such as crude oil, natural gas and other primary energy carriers, i.e. hydroelectric, nuclear, solid fuels and other renewable energies. To this end, the demand in various levels of final, secondary and primary energies should be studied separately. In the modeling procedure, instead of estimating an aggregate behavioral equation, the analyst should investigate the disaggregated sectoral demand for energy such as residential, commercial, industrial, transportation and agricultural.

The intermediate energy industries, including oil and gas refineries and power -plants, all as one sector, provide the energy needs for the above-mentioned final energy sectors and thus the study of this sector is of commanding importance for policy makers and planners alike. Using primary and/or secondary energies, this sector supplies various energy carriers to final energy consumers. Modeling the intermediate energy sector is considered as one of the most crucial aspects of energy modeling at macro level.

the empirical analysis of all different kinds of energy carriers is beyond the scope of this study, therefore, our emphasis is confined to the intermediate electricity sector, which consists of the power generation,

1- The text of his speech at the 1999 BIEE Conference entitled "A New Era for Energy? Price signal, industry structure and environment" at St. John's College, Oxford, 20th and 21th September 1999

2- Energy Economist-Iran's Institute for International Energy Studies