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Household Demand for Energy in Kuwait

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Abstract. This paper models and estimates energy demand by the household sector using the top-down or the two-level approach. The discussion has been developed to include a breakdown of household consumption by fuel type. It also simulates the developed model under three scenarios and presents an analysis of the results.

The empirical results indicate that short and long-run energy consumption and the level of economic activity are interrelated. The model simulation shows that energy consumption varies directly with economic growth. It also illustrates that an increase of 100% in all nominal energy prices will lead to a reduction in household energy demand of 28% by the year 2010. Simulation results clearly demonstrate that the potential for energy conservation does exist in Kuwait in the household sector and particularly as regards electricity consumption. Moreover, fuel switching will be in favor of oil products only when energy prices increase substantially as in the case of the extreme scenario.

1. Introduction

Increasing intensity of energy consumption is one of the most striking features of modern lifestyle in Kuwait. As a single resource-based economy, Kuwait has experienced significant structural changes since the beginning of oil exports in 1946. These changes have induced rapid increases in the demand for energy, with the household consumption of energy in Kuwait growing substantially from about 2 million barrels of oil equivalent (mboe) in 1975 to about 7.7 mboe in 2000, at an annual growth rate of about 5%.

The aim of this study is to model and estimate the demand function for energy by the household sector and use the estimated model in forecasting future energy demand under different (pricing) policy options. The model will also be used to explore the conservation potential of this significant sector. The next section reviews the major changes in consumption patterns of the sector followed by a discussion of the model in

Section 3. The empirical results and scenarios are shown in Sections 4 and 5, respectively. Finally, Section 6 presents the conclusions and policy implications.

2. Household Sector: A Background

The residential sector's energy demand represents the demand of households for air conditioning, lighting, and the use of household appliances such as refrigerators, washing machines, stoves, TVs... etc. The main source of data for energy consumption in this sector was obtained from the Ministry of Oil statistics, the Annual Statistical Abstract of the Ministry of Planning and the Statistical Yearbook of the Ministry of Electricity and Water.

In 1980, the residential sector used only about 5.9% of Kuwait's total energy consumption and 7.4% in 1985. This increased to about 7.7% in 1995, and reached about 7.9% in the year 2000. The total energy demand in the sector rose from 3.43 mboe in 1980, to 5.5 mboe in 1985 and reached 7.37 mboe in 1995 and about 7.7 mboe at an annual growth rate of about 5%.

Electricity dominated the consumption of energy in the sector. Its share in total consumption represented about 74% in 1980. It surged to about 82% in 1985 and reached 85 and 88% in 1995 and 2000, respectively.

Electricity consumption ratio rose substantially from 2.53% in 1980 to 4.5% in 1985 and then to 6.27% in 1995 and about 6.8% in 2000 at an annual growth rate of about 5.06% for that period.

Oil products are also used in the residential sector as well as in the government and commercial sectors. However, disaggregated data are not available, thus, data for the governmental and commercial sectors use are included in the data of the residential sector's consumption. That is to say the consumption of LPG and kerosene (oil products) here is for the residential, governmental and commercial sectors, but the residential sector is the dominant one.

Both kerosene and LPG (in the form of butane/propane sold in 12-kg cylinders) are consumed mainly for cooking. The two fuel types together accounted for about 26% of the total energy demanded by the sector in 1980. However, after that, the share declined steadily to represent 18% in 1985, only 15% in 1995 and about 12% in 2000. This decline was mainly due to technical advances in favor of electricity (inter-fuel substitution) such as the introduction of microwave ovens for cooking along with electric stoves.

In spite of the decline in the share of oil products in the total consumption of the sector, the consumption of oil products increased from about 0.9 mboe in 1980 to 1.4 mboe in 2000, at an annual growth rate of 2.2%. The consumption of kerosene as a fuel for cooking has been declined dramatically as LPG substituted kerosene use. LPG consumption increased from 0.61 mboe in 1980 to 1.12 mboe in 2000 at an annual growth rate of 3%. Meanwhile, the demand for kerosene declined from about 0.29 mboe in 1980 to only 0.15 mboe in 2000, a decline of about 50%.

3. The Model

When there are more than one type of fuel consumed by a sector, the conventional approach to model the aggregate energy demand consists of two steps. In the first step, input share equations are derived from some flexible cost function such as the Translog. These share equations are simultaneously estimated. In the second step, the parameters obtained from these share equations are used to construct an aggregate energy price index. This aggregate index is then used to estimate an aggregate demand function.

The aggregate energy demand function is specified as follows:

$$\ln ROTt = \beta_0 + \beta_1 \ln PEt + \beta_2 \ln GDPt + \beta_3 \ln VILLAt + \beta_4 DUMt \quad (1)$$

where:

lnROTt = log of total energy consumption by the residential sector
lnPEt = log of the aggregate energy price index for residential sector
lnGDPt = log of real gross domestic product (base year: 1987=100)
lnVILLAt = the ratio of villas to total dwellings
DUMt = dummy variable representing the period of Iraqi invasion

The demand for a commodity depends on its price and the income of the consumer. This is mainly the rationale for including the GDP and prices as explanatory variables in the demand equation. The ratio of villas to total dwellings has been used to reflect the fact that energy consumption intensity differs by housing structure type, where villas are expected to consume proportionately higher volumes of electricity. A log-linear functional form was assumed. A major advantage of using this functional form is that the estimated coefficients directly yield the demand elasticities. Due to lack in several data for population, growth rate, and number of constructing licenses, we ignored them.

A general observation was made in the first interim report that the values of most of the variables tend to rise over the time period of investigation. The energy demand by the residential demand for electricity, consumer price index, is all valid examples of variables tendency to rise over time. Because of this trended nature of the data, their values through time do not remain constant. It was shown by Engle and Granger [1] that if a time series is not stationary, that is, the mean and the variance increase over time, there always exists the possibility that spurious correlation will result, causing the long run equilibrium to be invalid.

In recent years, cointegartion and error correcting techniques have been proposed as a method of resolving the problem. By cointegrating the long-run model, its errors become stationary. The long run errors are fed into the short run model, which also tend to be stationary - since there is no expected growth in differenced variables. The estimated elasticities do not suffer the unreliability associated with non-stationary data. Thus, Error Correction Model was utilized here in estimating the demand function. The major advantage of this approach is that it gives both the long-run and short-run elasticities which are statistically reliable, and also provides an estimate of the speed of adjustment towards the long run values.

However, before estimating the above demand equation we have to construct an aggregate energy price index. This is done by following the Fuss approach (Fuss [2]). This approach is based on the concept of a unit cost function. The aggregate energy price index is perceived as the cost per unit to the optimizing agent. This unit energy cost function may be represented by some standard cost function. Here, the following translog cost function has been used:

$$\ln PE = \beta_0 + \sum \beta_i \ln P_i + 1/2 \sum \sum \beta_{ij} \ln (P_i) \ln (P_j) \quad (2)$$

where i,j = electricity, and oil products; PE being the aggregate energy price index.

Partially differentiating Eq. (2), invoking Shepard's Lemma, and imposing homogeneity, adding up and symmetry restrictions yields the following input demand equations:

$$S_i = \beta_i + \sum \beta_{ij} \ln (P_j) \qquad \text{where } i=1,2 \text{ and } j=1,2 \quad (3)$$

$$\text{subject to the constraints } \sum \beta_i = 1; \ \sum \beta_{ij} = \sum \beta_{ij} = 0; \ \beta_{ij} = \beta_{ji};$$

where S_i is the share of the ith input.

4. Empirical Results

The share equations are usually estimated simultaneously with Zellner's estimation method, dropping any one of them arbitrarily because the sum of all the shares has to be one. However, because here there are only two fuels, we instead, estimated both the share equations simultaneously for 1975-2000 time period subject to the above restrictions. The estimated equations are as follows:

$$\begin{aligned} SELCR_t = \ & 0.9903 \ - 0.2589 \ln PELCR_t + 0.0349 \ln POILR_t \\ & (10.8) \quad (-10.9) \qquad\qquad (2.15) \\ & R^2 \text{ Adj.} = 0.87 \quad S.E.R = 0.02 \quad D.W. = 1.3112 \end{aligned} \quad (4)$$

$$SOILR_t = 0.0097 + 0.2589 \ lnPELCR_t - 0.0349 \ lnPOILR_t \quad (5)$$
$$(10.8) \quad (10.9) \quad (-2.15)$$
R^2 Adj. = 0.87 S.E.R = 0.02 D.W. = 1.3112

The equations appear to fit the data well with the estimated coefficients being statistically significant. All the variables have expected signs. It shows the cross price elasticity of demand for electricity with respect to oil price is only 0.035, which means that electricity and oil are poor substitutes in the residential sector

The estimated parameters from these equations were substituted in Eq. (2) to obtain the aggregate energy price index. The resulting price index thus obtained was used as one of the explanatory variable in Eqs. (6) and (7).

The next step is to estimate the total energy demand by the sector using the aggregate energy price index as one of the explanatory variables. The results of both long-run (the cointegrating) equation and the short-run (the error-correcting) equation are as follows:

$$lnROT_t = 3.6737 + 0.3833 \ lnGDP_t - 0.5347 \ lnPE_t + 0.9437 \ lnVILLA_t$$
$$(2.54) \quad (3.67) \quad (-2.12) \quad (3.11)$$
$$- 0.2049 \ DUM_t \quad (6)$$
$$(-3.66)$$
R^2 Adj. = 0.93 S.E.R = 0.10 D.W. = 2.0398

$$DlnROT_t^* = 0.1867 + 0.0879 \ DlnGDP_t - 0.2893 \ DlnPE_t + 0.3274 \ DlnVILLA_t$$
$$(6.56) \quad (2.23) \quad (-2.79) \quad (5.69)$$
$$- 0.0945 \ DUM_t - 0.3165 \ U_{t-1} \quad (7)$$
$$(-2.63) \quad (-3.56)$$
R^2 Adj. = 0.86 S.E.R = 0.02 D.W. = 2.1312

* D: denote the first difference.

The equations fit the data well. All the variables have the correct sign and are statistically significant. The coefficients of the price term are high. However, it shows that the demand for energy is price inelastic. It gives about 0.53 elasticity in the long-run and about 0.29 elasticity in the short-run. Also, demand for energy is inelastic for changes in income in the short as well as in the long-run.

The variable corresponding to the ratio of villas performed quite well and was significant in both the short and long-run equations. The dummy variable has a negative sign indicative of the impact of the occupation and the war period in 1990-1991. Furthermore, the coefficient of the error-correction term (U) in Eq. (7) was found to be significant with an adjustment of 0.32, indicating that the demand for energy adjusts only by 32% towards its long-run value in each year.

5. Model Simulation and Forecasts

The model is simulated under different assumptions to evaluate its sensitivity to a variety of inputs. Each simulation exercise represents an experiment performed on the model, determining values of endogenous variables based on alternative assumptions regarding policy variables, stochastic disturbance terms and values of the parameters (Intrilligator [3]).

Three scenarios are chosen to solicit the model's response to long run changes in the key variables. The three scenarios are:

1) **The baseline scenario:** The baseline scenario projects current trends and serves as a benchmark for the remaining scenarios. A set of assumptions is utilized to measure the changes in the key exogenous variables with no changes in domestic energy prices. The main assumptions include:
   * An annual growth rate of 1.5% for the Real Gross Domestic Product (GDP), which is also adopted by the Five Years Economic Development Plan of the Ministry of Planning.
   * An annual inflation rate of about 2% , is also adopted by the Five Years Economic Development Plan.
   * All other exogenous variables are assumed to grow at their historical growth rates.
   * The base year is 2000.

2) **The moderate scenario**: The same set of assumptions, which were used for the baseline scenario, is also utilized here. One major exception is that all domestic nominal energy prices are assumed to increase by 100% immediately in 2000 and then remain constant throughout the forecast period. The aim of this scenario is to examine the consequences of such price adjustments on the various sectors of the economy.

3) **The extreme scenario**: The same set of assumptions that was applied to the moderate scenario is also applied to this scenario, with the only exception that all domestic nominal energy prices are assumed to increase immediately by 200% in 2000 and remain constant throughout the forecast period. The aim of this scenario is to examine the response by various sectors to a deliberate shock in energy prices.

6. Simulation Results

Under the baseline scenario, the energy consumption in the household sector is predicted to significantly increase to about 13.2 mboe in 2010 from 9.1 mboe in 2000, mainly due to the decline in real energy prices. Within the household sector, electricity, which is anticipated to be the fastest growing energy fuel, is projected to sustain most of the growth by 4.2% annually throughout the forecast period as consumer switch from LPG, in cooking, to electricity, the relatively cheaper and easier to use fuel. The share of oil products in the residential sector is expected to decline from about 15% in 2000 to about 11% in 2010. Kerosene is viewed as an inferior commodity and its consumption is expected to decline to negligible by the end of the forecast period where the residential sector's consumption of oil products will be dominated by LPG (see Table 1).

Table 1. Residential sector energy consumption: Simulation of endogenous variables (MBOE)

Baseline Scenario					
Year	**1998**	**2000**	**2005**	**2010**	**Growth rate (%)**
Electricity	7.133	7.781	9.592	11.709	4.22
Oil Product (LPG + Kerosene)	1.260	1.310	1.420	1.505	2.11
Total	**8.393**	**9.091**	**11.012**	**13.214**	**3.94**
Moderate Scenario					
Year	**1998**	**2000**	**2005**	**2010**	**Growth rate (%)**
Electricity	7.133	5.811	7.017	8.565	2.07
Oil Product (LPG + Kerosene)	1.260	0.837	0.870	0.896	(1.36)
Total	**8.393**	**6.648**	**7.886**	**9.461**	**1.65**
Extreme Scenario					
Year	**1998**	**2000**	**2005**	**2010**	**Growth rate (%)**
Electricity	7.133	4.240	5.064	6.189	(0.12)
Oil Product (LPG + Kerosene)	1.260	1.242	0.989	1.064	0.36
Total	**8.393**	**6.358**	**5.229**	**6.128**	**(0.05)**

However, under the moderate scenario, the energy consumption by the household sector is projected to increase to about 9.5 mboe in 2010 from 9.1 mboe in 2000 at annual growth rate of only 1.7% in response to the increase in real energy prices. Within the residential sector, electricity, which was the fastest growing energy fuel type in the baseline scenario (about 4.2), is projected to sustain most of the decline and grow by only 2.1% annually throughout the forecast period. Furthermore, the results show that residential customers are still expected to switch away from oil products (LPG and kerosene) to electricity in cooking.

Finally, under the assumption of this scenario, energy consumption in the residential sector is projected to decline significantly to about 7.4 mboe in the year 2010, which amount to an annual reduction rate of about 0.05%. Within the residential sector, electricity is projected to sustain most of the decline by 0.1% annually throughout the forecast period. Furthermore, under this price structure, the household consumers are expected to switch away from electricity, in cooking, to LPG, the relatively cheaper fuel. LPG consumption in the residential sector is projected to grow by 0.4% from its level in 2000. However, kerosene is viewed as an inferior commodity and its consumption is expected to decline slowly to nothing towards the end of the forecast period.

7. Conclusions and Some Policy Implications

The results of the model simulation based on three scenarios have raised several important issues. With nominal energy prices remaining the same and inflation and economic growth continuing to expand (i.e., baseline scenario), the demand for energy in the household sector, particularly electricity, will continue to grow at historical levels. This result indicates that short and long-run energy consumption and economic activities are interrelated. The model simulation suggests that energy consumption varies directly with economic growth and inflation rates.

Furthermore, based on the results of the baseline scenario, it appears that a lower than historical average economic growth rate, in the short-run, does not reduce the rates of growth in household energy consumption in Kuwait. Rising real income, the affluent living standards, the large stock of automobiles and household appliances and relatively larger dwelling units contribute to extravagant energy consumption patterns. It is unlikely, under the current energy price structure, that short-run economic adjustment will moderate contemporary lifestyles with respect to energy consumption.

Moreover, the economic effects of using a deliberate energy price shock, as in the case of the extreme scenario, in order to produce large reductions in energy consumption, will actually reduce real rates of energy growth but with less marginal reduction. For example, the three-fold price increase in energy prices simulated in the extreme scenario has, on the margin, produced a smaller impact on total residential energy consumption (i.e., 44% versus 28% in the moderate scenario). That is to say an increase of energy prices by an additional 100% will lead to a further reduction of only 16% (down from 44%).

The moderate and extreme scenarios illustrate that an increase in all nominal energy prices will lead to a reduction in household energy demand from the baseline scenario level. These scenarios also demonstrate that the potential for energy conservation exits in Kuwait in the household final demand sector. However, the fuel switching will be in favor of oil products only when energy prices increased substantially as in the case of the extreme scenario.

The results have indicated that changing the price structure of energy types should be done in a comprehensive manner. In other words, electricity prices should be adjusted with the adjustment of oil product prices, otherwise an inter-fuel substitution will occur in the household sectors. The end results of such inter-fuel substitution will not be desirable. This is mainly because it will lead to consuming more crude oil and heavy fuel oil for electricity generation.

Due to the damage to the oil wills during the Iraqi invasion of Kuwait and the upsurge utilization of natural gas by the ever growing petrochemical and LPG industries, Kuwait is currently facing a serious shortage of natural gas. Currently, crude oil and heavy fuel oil are mainly used for power generation. Leaving the environmental impact of such operations aside, the electricity generation consumed at least 75% of Kuwait total energy consumption in year 2000. It is also well known that burning fuel oil / crude oil to generate electricity is very inefficient operation as these are mainly steam turbines. Only between 23-25% at the best of the energy content of a barrel of oil is actually transformed to electricity. Also, keeping in mind that oil is still the main source of income for Kuwait and domestic demand which is used to represent only 6% of total oil production of Kuwait in 1980 represented nearly 20% in 2000. It should be pointed out here that if electricity consumption continued to grow at the rates of the past two decades, this may lead to a critical problem for Kuwait, especially when the needed oil production capacity is not in place. Kuwait Petroleum Corporation has been discussing other options such as importing natural gas via pipelines from Iran or Qatar and most recently from Iraq for that reason.

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طلب القطاع المنزلي على الطاقة في الكويت

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ملخص البحث. تقوم الورقة بنمذجة وتقدير الطلب على الطاقة في القطاع المنزلي باستخدام طريقة الأعلى-الأسفل أو أسلوب المستويين. لقد تم تطوير الدراسة بحيث تتضمن تقسيما للاستهلاك المنزلي حسب أنواع الوقود المستخدم، كما أنها تستخدم أسلوب نموذج المحاكاة بالنسبة للنموذج المستخدم لثلاثة سيناريوهات وقامت باستعراض النتائج.

تبين النتائج التجريبية بأن استهلاك الوقود في كل من المديين القصير والطويل واستهلاك الطاقة يتغير بشكل مباشر حسب وضع النمو الاقتصادي. تبين الدراسة بأن زيادة بنسبة ١٠٠٪ في الأسعار الإسمية لجميع أسعار الطاقة ستؤدي إلى انخفاض في الطلب على الطاقة في القطاع المنزلي بنسبة ٢٨٪ بحلول عام ٢٠١٠م. تبين نتائج المحاكاة بوضوح بأن إمكانات حفظ وبقاء الطاقة متوافرة في الكويت في القطاع المنزلي خاصة فيما يتعلق باستهلاك الكهرباء. بالإضافة إلى ذلك، فقد تبين بأن تغيير نوع الوقود المستخدم سيكون لصالح المنتجات النفطية فقط حينما تزداد أسعار الطاقة بدرجة كبيرة كما اتضح في حالة السيناريو الأكبر.