International Journal of Energy Economics and Policy
Vol. 2, No. 3, 2012, pp. 159-166
ISSN: 2146-4553
www.econjournals.com

How Can We Assess the Relation Between Equipment, Price and Electricity Demand in Tunisia?

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ABSTRACT: Economists and analysts of electricity demand sector believed for a long time that equipment is a key factor. They try to determine the performance of Equipment policy instrument on energy demand. For lack of reliable data, they use in most cases the variable "urbanization rate" as proxy to the variable "equipment". To assess the effectiveness of this policy as a tool to decrease electricity demand in Tunisia, we estimate a Translog production function "KLEM" using annual data spanning the period 1990-2007. The results suggest that an Equipment policy like a price policy play a crucial role in reducing electricity demand. Furthermore, those results highlight the complementary relation between electricity and equipment in the economic sense.

Keywords: Electricity demand; Equipment policy instrument; Price policy; KLEM model; Complementary
JEL Classifications: Q41

1. Introduction

During the last decades, Tunisian society had undergone many important changes: increase of the gross domestic product, demographic development moreover many climatic changes. All those changes led to an upward trend in the electricity demand.

The electricity is generally the subject of a special treatment, and it satisfies a very specific uses with low substitution possibilities. Seeing the importance of this subject, therefore, it should be treated with a meticulous manner.

The knowledge of the main factors that influence the electrical demand in Tunisia and the quantifications of their impact on this consumption have a crucial importance in the contemplation of energy policy. In this context, debate among economists and policymakers is stimulated in order to determine the most effective policy instrument to reduce electricity demand.

Certainly, many economists stand by the effectiveness of the price policy to decrease electricity demand however; others defend the important role of non-price instruments to control this consumption. The object of this paper rests then in the confirmation of this idea and in proving the efficiency of non price instrument (equipment policy) in reducing electricity demand. In other words, non-price instruments can constitute another viable way to rationalize and moderate electricity demand in Tunisia. Moreover, we sought to demonstrate that a price policy can be also effective by the calculation of elasticity price and cross elasticity price.

There have been numerous empirical studies of total energy demands and electrical demands that take care of the variable "equipment" but the most of those studies are suitable for industrialized countries. However the studies that examine the demands of electricity in Tunisia are rare.

In the present study, we estimate a Translog production function "KLEM" to determine the real role of "Equipment" on electricity demand in Tunisia.

This paper is organised into three sections. The first section studies some electricity demand models interested by "equipment variable" and used in the literature. The second section is conserved to present and develop the KLEM production function. Finally, we will present the econometric issues and the empirical results. We will achieve our study by a conclusion summarizing the findings of the paper and discussing the policy implications.

2. Electricity Demand Models

Further to the increasing needs in energy and given the importance of this sector in our life, several formalizations and modelling appeared to decrypt this field. The importance of energy models is that they mainly aim to clarify the complex relationship between electricity consumption and factors that influence this consumption and subsequently to elaborate policies and strategies.

Those models are very numerous but most of them are interested by analysing the consumers respond to higher price, In other words, the effectiveness of a price policy. Other economists emphasize that energy consumption is possible only through energy equipment. That's why they insist to use the "Equipment variable" in the energy model.

In this section, we are interested only by models analysing the role of equipment on decreasing energy demand. Using annual data covering the period 1960–1970, Erickson et al., (1973) analyse the industrial demand of Gas-oil, Fuel-oil, natural gas and electricity in United-States.

With their paper Erickson et al., (1973) sought to determine the impact on the energy demand both in the short and in the long term of the price of different type of energy, economic activity index and urbanisation index. This variable is used to approximate the variable "Equipment" which is quantified with difficulty. The introduction of this variable makes the model easily estimated due to the availability of statistics. The interest of this model is that it permits to determine the possibility of substitution between Electricity and other energy.

From his hand, Baughman and Joskow (1975) divided the annual energy demand of a sector into three parts: a basic demand (represents the quantity of energy that consumers continue to use from a period to the next), the replacement demand (the fraction of energy demand due to renew energetic equipments and the possibility of substitution with others form of energy), the additional demand (further to the introduction of new consumers or the economic growth of the sector). Referring to Baughman and Joskow formalization the price of energy and the equipment cost may constitute substitution factors. Khazzoom (1980) from his part divided the energy demand into two groups: specific energy demand and substitutable demand. This decomposition was based on the equipment's quantity (equipment in stock and equipment purchased every year) owned by the users. In this paper, Khazzoom (1980) sought to estimate the total demand of energy as a function of the use rate of equipment and quantity of equipment in service. Despite its advantages, this model suffers from a major drawback. It is very hard to determine exactly the parts between specific demand and substitutable demand for lack of information about equipment and their way of using. To overcome this problem, Holtedahl and Joutz (2004) from their part introduced the variable "Urbanisation" to capture the electricity-using capital stocks. The introduction of this variable has made the model easily estimated thanks to the availability of statistics. By their model Holtedahl and Joutz sought to quantify the impact of the real income, the real price of electricity, the world price of oil, the temperature and the urbanisation rate on the residential electricity consumption on the short and long term using Taiwan annual data covering the period 1955 – 1995.

Following the same principle of approximation, Halicioglu (2007) estimated the residential electrical demand in Turkey. With his paper Halicioglu sought to determine the impact of real income, electricity price and urbanisation rate on the residential electricity demand using annual data covering the period 1968 – 2005.

Many other papers analyse the energy demands and electrical demands both for developed and developing countries such as Hondroyiannis (2004), Silk and Joutz (1997), Amusa t al., (2009), Kraft and Kraft (1980).

Other models are distinguished by the fact that they retain the variable "Equipment" implicitly like the KLEM model. In fact, in this context fits our paper. We want to apply the KLEM model to analyse the electricity demand in Tunisia.

3. KLEM Model

3.1. Specification of the model

For lack of statistics data, some authors confuse the equipment with other capital goods (K). The same principle of incorporation is done with all forms of energy (E), quantities of labor (L) and the raw materials (M) hence the appearance of a new economic model noted “KLEM” model. The objective of this model is to analyse the relationship among the overall energy demand of a branch or a sector and the other three factors of production.

The prototype of this type of models was presented by Berndt and Wood (1975). It was written as follow:

$$\text{Log } G = \text{Log } A_0 + \text{Log } Q + \sum_i A_i \text{ Log } P_i + \tfrac{1}{2} \sum_i \sum_j C_{ij} \text{ Log } P_i \text{ Log } P_j$$

With:

i , j = K, L, E, M (factors of production).

G: the production cost.

Q: the production.

P_i: the price of the four factors of production.

In order to estimate the coefficients, we will impose to our model the degree-one homogeneity constraint with regards to price.

$$\text{Log}[G(\lambda P_K,\lambda P_E, \lambda P_L,\lambda P_M)] = \log[\lambda G(P_K,P_E,P_L,P_M)] = \log \lambda + \log G$$

We Know that:

$$\text{Log}[G(\lambda P_K,\lambda P_E, \lambda P_L,\lambda P_M)] = \text{Log } A_0 + \text{Log } Q + \sum_i A_i \text{ Log } P_i + \text{Log } \lambda \sum_i A_i$$
$$+ 0.5 \sum_i \sum_j C_{ij} \text{ Log } P_i \text{ Ln } P_j + 0.5 (\text{Log } \lambda)^2 \sum_i \sum_j C_{ij}$$
$$+ 0.5 \text{ Log } \lambda \sum_i \text{Log } P_i \sum_j C_{ij} + 0.5 \text{ Log } \lambda \sum_i C_{ij} \sum_j \text{Log } P_j$$

Hence, $\text{Log } \lambda = \text{Log } \lambda \sum_i A_i + 0.5 (\text{Log } \lambda)^2 \sum_i \sum_j C_{ij} + 0.5 \text{ Log } \lambda \sum_i \text{Log } P_i \sum_j C_{ij}$ $+ 0.5 \text{ Log } \lambda \sum_i C_{ij} \sum_j \text{Log } P_j$

This equality is valid only for all values of $\lambda \in R_+ \{-1\}$. The application of this Hypothesis conduct to verify those five constraints:

$$\sum_i A_i = 1$$

$$\sum_i C_{ij} = 0 \text{ pour } j = K, L, E, M$$

In addition, the different factors demand functions are deducted from Shephard’s (1953) lemma

$$F_i^* (Q, P_i) = \frac{\partial G}{\partial P(i)}$$

Thus, the theoretical part of factor I in the total cost is given by this formalization:

$$R_i^* = \frac{F^*(i)P(i)}{G} = \frac{\partial G}{\partial P(i)} \cdot \frac{P(i)}{G} = \frac{\partial LogG}{\partial LogP(i)}$$
$$= A_i + C_{iK} \text{ Log } P_K + C_{iL} \text{ Log } P_L + C_{iE} \text{ Log } P_E + C_{iM} \text{ Log } P_M$$
$$= A_i + \sum_j C_{ij} \text{ Log } P_j$$

Whereas the observed part is

$$R_i = \frac{F(i)P(i)}{G} = R_i^* + \varepsilon(i)$$

With $\sum_i R_i = 1$

From this formalization, we deduce that the optimal part of each factor in the total production cost depends from the price logarithm. We obtain then four linear relations.

Following the approach of "Pindyck (1979)" and "Griffen and Gregory (1976)", we estimate only the three equations that consider the Capital, Labor and Energy factors of production and we suppose that there are separable from the fourth production factor "Raw Materials".

The model to estimate is written then as follow:

$R_{Et} = A_E + C_{KE}$ Log $(P_{Kt} / P_{Et}) + C_{LE}$ Log$(P_{Lt} / P_{Et}) + \varepsilon_{Et}$

$R_{Kt} = A_K + C_{KL}$ Log $(P_{Lt} / P_{Kt}) + C_{KE}$ Log $(P_{Et} / P_{Kt}) + \varepsilon_{Kt}$

$R_{Lt} = A_L + C_{KL}$ Log $(P_{Kt} / P_{Lt}) + C_{LE}$ Log $(P_{Et} / P_{Lt}) + \varepsilon_{Lt}$

With R_{it} are the endogenous variables representing the parts of the different factors of production in the total cost whereas the exogenous variables are represented by the different prices (P_i). A_i and Cij represent the estimated coefficients.

3.2. The Demand Function Elasticities

Elasticity is an economic measurement. It is the most important indicator that measures the consumer's response via changes affecting any variable. Two types of elasticities are used in this paper: partial elasticity of substitution and cross-elasticity.

The importance of Allen's (1938) partial elasticity of substitution between two factors i and j is that it can assess the liaison nature between the different factors of production. It has the following general form:

$\sigma_{ij} = (G \,.\, G''_{ij}) / (G'_i \,.\, G'_j)$

With : $G'_i = \dfrac{\partial G}{\partial P(i)}$ et $G''_{ij} = \partial^2 G / (\partial P_i \, \partial P_j)$

First of all, we must determine

$$\frac{\partial G}{\partial P_i},\ \frac{\partial^2 G}{\partial P_i^2} \text{ et } \frac{\partial^2 G}{\partial P_i \partial P_j}$$

We Know that :

$$R^*_i = \frac{F^*(i)P(i)}{G} = \frac{\partial G}{\partial P(i)} \cdot \frac{P(i)}{G} \Rightarrow \frac{\partial G}{\partial P_i} = \frac{R_i G}{P_i}$$

$$\frac{\partial^2 G}{\partial P_i^2} = \frac{\left(\dfrac{\partial R_i}{\partial P_i} G + \dfrac{\partial G}{\partial P_i} R_i\right) P_i - R_i G}{p_i^2} = \frac{\left(\dfrac{C_{ii}}{P_i} G + R^2{}_i \dfrac{G}{P_i}\right) P_i - R_i G}{P_i^2} = \frac{(C_{ii} + R_i^2 - R_i) G}{P_i^2}$$

$$\frac{\partial^2 G}{\partial P_i \partial P_j} = \frac{(C_{ij} + R_i R_j) G}{P_i P_j}$$

As a result:

$\sigma_{ij} = (C_{ij} + R_i \,.\, R_j) / (R_i \,.\, R_j)$ pour $i \neq j$

$\sigma_{ii} = (C_{ii} + R_i^2 - R_i) / R_i^2$ pour i = K, L, E, M

For the cross-elasticity of the demand F_i with regards to price P_j, it can be written as follow:

$$E_{ij} = \frac{\partial Log F(i)}{\partial Log P(j)} = \frac{\partial F_i}{\partial P_j} \frac{P_j}{F_i}$$

Replacing F_i by its expression ($F_i^*(Q, P_i) = \dfrac{\partial G}{\partial P(i)}$)

$$E_{ij} = \frac{\partial^2 G}{\partial P_j \partial P_i} \frac{P_j}{\frac{\partial G}{\partial P_i}} = \frac{\frac{\partial^2 G . P_j}{\partial P_i \partial P_j}}{\frac{\partial G}{\partial P_i}}$$

Knowing that $R_j = \frac{\partial G}{\partial P_j} . \frac{P_j}{G} \Rightarrow P_j = \frac{G.R_j}{(\partial G / \partial P_j)}$

Replacing P_j By its value in the expression of E_{ij}, we find:

$$E_{ij} = \frac{\lfloor (\partial^2 G / \partial P_i \partial P_j).G.R_j \rfloor}{\lceil (\partial G / \partial P_i).(\partial G / \partial P_j) \rceil} = \sigma_{ij} . R_j$$

After effecting the necessarily changing, we found those two expressions:

- Direct price elasticity: $E_{ii} = (C_{ii} + R_i^2 - R_i) / R_i = \sigma_{ii} . R_i$
- Cross price elasticity: $E_{ij} = (C_{ij} + R_i R_j) / R_i = \sigma_{ij} . R_j$

We can judge the complementary or the substitutability of the factors by examining the sign of σ_{ij}. Two factors i and j are complementary only if σ_{ij} is negative indeed they are substitutable if σ_{ij} is positive.

4. Empirical Results and Discussion

The KLEM model to estimate is written as follow:

$$R_{it} = A_i + \sum_j C_{ij} Ln \frac{P_{jt}}{P_{it}} + \varepsilon_{it}$$

It follows from this specification a system with three equations:

$R_{Et} = A_E + C_{KE} \text{ Ln } (P_{Kt} / P_{Et}) + C_{LE} \text{ Ln}(P_{Lt} / P_{Et}) + \varepsilon_{Et}$
$R_{Kt} = A_K + C_{KL} \text{ Ln } (P_{Lt} / P_{Kt}) + C_{KE} \text{ Ln } (P_{Et} / P_{Kt}) + \varepsilon_{Kt}$
$R_{Lt} = A_L + C_{KL} \text{ Ln } (P_{Kt} / P_{Lt}) + C_{LE} \text{ Ln } (P_{Et} / P_{Lt}) + \varepsilon_{Lt}$

With:

R_{it} : represent the share of the expense on factor i (electricity, capital, Labor) in the total expenditure in the year t.

A_i : Constant

C_{ij} : Coefficients determining the effect of price on the factor i demand.

P_i : the factor i price.

To estimate our model, we suppose those two hypotheses on the error term ε_{it} :

$$\begin{cases} E(\varepsilon_{it}) = 0 \forall i = E, K, L \\ E(\varepsilon_{it} \varepsilon_{jt'}) = \begin{cases} \sigma_{ij} sit = t' \\ 0 sit \neq t' \end{cases} \end{cases}$$

In other words, those two hypotheses argue that:

- The errors of each equation are homoscedastics and independents.
- Among two equations, we register the absence of cross-autocorrelation and contemporaneous co variances are not equal to zero.

To estimate this model, we apply the Zellner's iterative procedure on 18 observations covering the period 1990 to 2007. We limit our work to estimate only the electricity and capital equations since this estimation will lead directly to determine all the coefficients of the model. The estimated equations of electricity and capital are presented in the tables follow:

Table 1. Electricity equation estimation

	A_E	C_{KE}	C_{LE}
RE_t	-2.256494 (-10.32)*	-0.124191 (-1.39)	0.103911 (2.98)*
R – squared	0.469184		
Adj. R – squared	0.398409		
Durbin Watson stat	0.735748		

*Significant at 0.05.

Table 2. Capital equation estimation

	A_K	C_{EK}	C_{LK}
RK_t	-1.581446 (-15.7)*	-0.125240 (-2.5)*	0.060466 (-3.71)*
R – squared	0.744069		
Adj. R – squared	0.709945		
Durbin Watson stat	2.410772		

* Significant at 0.05.

As we can see, the empirical results show that only the coefficient of Ln (P_{Kt} /P_{Et}) in the electricity equation is not significant. Furthermore, the capital equation has a high explanatory power (0.74) while the electricity equation has an average one (0.46). Moreover, the Durbin Statistics shows the existence of a positive error autocorrelation for the electricity equation and the absence of this problem in the capital equation.

To conclude, the estimation results of the KLEM model show the model's robust performance. Most of coefficients respect the right signs and statistical significance.

Using the results of our estimation and basing on those formalizations:

- Direct price elasticity: $E_{ii} = (C_{ii} + R_i^2 - R_i) / R_i = \sigma_{ii} . R_i$
- Cross price elasticity: $E_{ij} = (C_{ij} + R_i R_j)/ R_i = \sigma_{ij} . R_j$
- $C_{KK} + C_{KE} + C_{KL} = 0$
- $C_{EK} + C_{EE} + C_{EL} = 0$
- $C_{LK} + C_{LE} + C_{LL} = 0$

We can determinate the direct and cross-elasticity in the mean point of our sample (R_E, R_K, R_L) = (0.23071144, 0.11953709, 0.64975147). The tables below trace the results:

Table 3. Direct and Cross Price Elasticity

Eij	Electricity	Capital	Labor
Electricity	-0.681	-0.4233	1.10
Capital	-0.8169	0.673	0.1439
Labor	0.39	0.02647	-0.4171

Table 4. Partial Substitution Elasticity

σ_{ij}	Electricity	Capital	Labor
Electricity	-2.9534	-3.541	1.693
Capital	-3.541	5.63	0.221
Labor	1.693	0.221	-0.642

As shown on table 3 the coefficient of electricity price is, as expected, negative. The estimated elasticity is equal to -0.681. The magnitude of the electricity price variable implies that a 10 percent increase in price will lead to an electricity demand decrease by 6.81 percent. In other words, consumers respond to higher prices by decreasing their consumption. The price elasticity estimated is comparable with other previous Electricity demand studies (Berndt and Wood, 1975). So, this result highlights the importance and the effectiveness of a price policy on decreasing electricity demand but it doesn't clarify the different price responsiveness and the consequence of higher prices by different type of consumers (industrial, domestic). Even if this result corroborates the argument of the effectiveness of a price policy on decreasing the electricity demand it highlights also the importance of studying the different price responsiveness before using this policy.

Moreover, similarly with Berndt and Wood (1975) study, our empirical results emphasize the existence of positive cross price elasticity among Electricity and Labor. The magnitude of Labor variable implies that a 10 percent increase in labor will increase electricity demand by 11 percent. Since the Gross Domestic Product is aggregated in the Labor variable, we can conclude that there is a positive relation between GDP and electricity demand. In other words, an increasing in GDP affects positively the electricity consumption in Tunisia.

More importantly, the cross price elasticity between Electricity and capital has as expected a negative sign. The importance of this measure is that it provides policymakers with additional information about the consumers respond via increasing in equipment price. The estimated cross-price elasticity is equal to -0.4233, implying that the electricity demand fell 4.233 percent due to an increase of 10 percent in the capital price. This result draw that a policy price is effective to drop the electricity consumption. This instrument can be applied using two different ways: increasing equipment price or increasing the electricity price. In other words, a rising in the equipment price has the nearly same effect on electricity demand as a rising in electricity price. In this stage, we are faced with a crucial question “What is the real relation among equipment and electricity that make a chock on equipment price affect negatively the electricity consumption?”

The relationship between capital and Energy stimulated a debate the end of 70 among Berndt and Wood (1975) from the first hand and Griffin and Gregory (1976) from the second hand. According to Berndt and Wood a complementary relation exist between energy and capital since the energy is always consumed through energetic equipments. This theory is untenable for Griffin and Gregory; in contrast, they support the idea of the substitutability relation between energy and capital. This result is justified by the fact of the possibility of economizing energy using additional investments. In order to make a reconciliation attempt, Berndt and Wood putted forward in 1979 a simple justification: Energy and capital are complementary in the “Economic” sense but substitutable in the “Technical” sense.

The examination of table four confirms the results of Berndt and Wood (1975). The partial elasticity of substitution between electricity and capital is negative (-3.541) showing the existence of a complementary relation among those two variables in Tunisia.

4. Conclusions and Policy Recommendations

The main objective of this research is to evaluate the performance and the effectiveness of some policy instruments in order to diminish and streamline the electricity consumption in Tunisia. Results indicate that price policy is effective in reducing electricity demand in Tunisia. In other words, consumers respond to any chock on electricity price. The magnitude of the electricity price variation implies that a 10 percent increase in electricity price will decrease electricity demand by 6.81 percent. More importantly, results show that achieving decreasing in electricity demand in Tunisia as efficiently as possible can be done also through an increase of the equipments price. By the way, a 10 percent increasing on capital price cause a 4.233 percent decrease in electricity demand. Overall, electricity demand was responsive to both electricity and equipment price changes.

Moreover, the Gross Domestic Product (aggregate on Labor variable) elasticity of electricity demand is positive proving that an increase on GDP will lead to an increase on electricity demand. This result may be justified by the fact that the constructions of new investments participate by an important part in increasing the GDP but at the same time new investments mean additional electricity consumption so there is a positive relation between increasing electricity consumption and increasing the GDP.

The carefully examination of the partial substitution lead us to conclude the existence of a complementary relation between electricity demand and Equipment (aggregate on the variable capital). In other words, that’s mean that we can’t consume electricity without equipment. This result is really important, it emphasize the crucial role of non-price policy. The fact that electricity consumption can be done only through electrical equipments give us a great deal of thought about the role that play the quality of equipment on reduction electricity demand. Obviously, the best quality of equipment consumes less electricity than others.

Overall, these results highlight the effectiveness of a price policy to streamline the electricity consumption in Tunisia. However the pricing instruments must be combined by non pricing instruments such as the commercialization of only equipments that consume less electricity in the Tunisian market to achieve required reductions. This study can be ameliorated by the examination of the different policy responsiveness based on sectoral electricity demand.

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