# THE DYNAMIC RELATION OF ELECTRICITY CONSUMPTION IN TUNISIA

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**Abstract**

In this article, we will study the electricity consumption function in Tunisia from a sample of twenty regions during a period from 2000 to 2017 on annual frequencies. We will synthesize the main empirical work of the function of electricity consumption in a review of the literature. We will validate this function by the static Panel technique and we will use the within and GLS methods to estimate this function. We will identify the nature of the individual effects by the Hausman test (1978). We will refer to the Dynamic Panel procedure to estimate the electricity consumption of the twenty Tunisian regions.

**Keywords:** Consumption of electricity, Static Panel, Dynamic Panel

**Jel classification :** Q43, C52, L52, P1

## 1. INTRODUCTION

Energy sources available in Tunisia are very narrow. Electricity is the most form of energy used among all energy sources in the commercial and industrial sectors. In the residential sector, the electricity represents even two-thirds of the energy consumption of this sector. Moreover, the most important part of the household energy consumption constitutes the space heating; electricity dominates widely in this regard.

The Tunisian Company of Gas and Electricity (STEG) is the main supplier of electricity in Tunisia. Having the most accurate estimates of future electricity consumption is most important for the government-owned corporation. The construction of power plants requires several years of works and substantial investments. Therefore, to know and to be able to answer the energy needs are essential and constitutes long-term exercises. Consequences, if there is gap in prediction, are important: major electricity failures and offloading can arise. In addition, short-term solutions on electricity supply can turn out more polluting and more expensive; it is therefore crucial to be able to predict the demand for future electricity and to know the influencing variables of it, increases the predictions capacities.

The demand of electricity is divided in mainly three sectors: commercial, industrial as well as residential. Our study concerns exclusively the latter. The purpose of the present study is to estimate the electricity demand by use for the residential sector in Tunisia. We use as basic methodological framework STATZU, Vania and Elisabetta Strazzera (2008). the conditional analysis of the demand (CAD) developed by The approach of CAD consists in disintegrating the total electricity consumption of the sampled households in an exhaustive list as possible of electricity uses, while connecting to these uses the households' characteristics and their housing characteristics that can influence the electricity demand.

This article is organized around the three parts. In the first part, we will summarize the different theoretical approaches to electricity consumption. In the second part, we will refer to the main previous works of this consumption of electricity. In the third part, we shall validate empirically the total electricity consumption for twenty Tunisian regions during a period of study going from 2000 to 2017 using the technique of static and dynamic Panel.

## 2. THEORETICAL REVIEWS

To disintegrate the total electricity demand in various uses consuming some electricity is a prolific source of information; the purpose of these estimated unit consumptions is to develop forecast tools. These estimated of consumptions by use allow observing the behaviour of the households towards the energy consumption; this establishes an essential input for any simulation of setting-up energy efficiency politics or to make future forecasts of electricity sales.

Different approaches have been used to predict electricity demand. Macroeconomic approaches have been attempted: regressing the population electricity demand of a territory on various aggregated variables such as real income, number of appliances using electricity, energy market price. To obtain precise unit consumptions by use, estimations based on engineering techniques or direct measurement were used. However, engineering techniques although specified do not allow linking between the analysed electricity consumption of use and households characteristics and their housing characteristics. For the direct measurement techniques, although the association of measured consumptions with the characteristics defining the sampled households is possible, their major disadvantages are their exaggerated cost. Microeconomic approaches, inexpensive and allowing to associate the energy consumption with its influencing characteristics were thus developed such the CAD of THOMSON Henry (2005).

The approach developed by **RENOU-MOISSANT Patricia (2002)** to estimate unit consumptions was to explain the total electricity consumption of a household as a linear function of electric equipment, in interaction with certain exogenous characteristics of the households. This CAD function can be expressed in a general manner as follows:

$$E = \sum_{i=0}^{N} \sum_{j=0}^{M} bij(VjAi) + \varepsilon$$

N: The number of considered electric uses

M: is the number of exogenous variables characterizing the households and their housing having an impact on the electricity consumption.

$A_{i:}$ is an indicator variable that equals 1 if the household owns the device $i$ and $A_i$ equals 0 if not.

$V_j$ is the j$^{th}$ exogenous variable characterizing the household or their dwelling, and $b_{ij}$: is the parameter associated with the interaction between $A_i$ and $V_j$. Finally, E represents the total households' electricity consumption and $\varepsilon$ : is the error term of the equation.

In the study of **GRIFFIN and al. (2005)** the estimated uses i are: central air conditioner, electric water heater, electric dryer, freezer, refrigerator with or without frost, black and white television set and colour television, dishwasher, electric stove, as well as a constant for the not defined uses, $A_0$. For characteristics influencing electricity consumption, $V_j$, we find variables such as: the number of people, the income and the surface of the housing.

The regression model of **GILBERT and David (2008)** supposed the independence between the error term of the equation, $\varepsilon$, and the explanatory variables, especially the uses, $A_i$, An essential hypothesis to obtain estimated coefficients unbiased. We keep this hypothesis also throughout our study in the effect that the uses, $A_i$, are exogenous. The conditional analysis of the demand thus fills the gaps of the estimation types previously approached and, furthermore, the CAD is applicable to a very low cost.

Our main reference in terms of results comparison constitutes the work undertaken by researchers of National Institute of Scientific Research (INRS), although they used a statistical approach in certain different points from ours. The study, produced by **Arcavci and Orzturck (2009)** of the INRS, uses the conditional analysis of the demand as methodology. In addition, their estimations are also made from the annual data of consumptions supplied by Hydro-Québec.

**Ouedraogo (2010)** used the following linear function for the purposes of their regression which is a simple mathematical transformation of the equation above developed by **Squalli (2007)**. There is only an interpretation of the estimated parameters which diverges slightly:

$$E = \sum_{i=0}^{N} \overline{E}_i \left[A_i\right] + \sum_{i=0}^{N} \sum_{j=1}^{M} b_{ij} \left[(V_j - \overline{V}_{ij}) * A_i\right]$$

The dependent variable *E*, the annual electricity consumption of the households, is regressed according to variables in brackets [·]. The coefficient $\overline{E}_i$ expresses thus the average electricity consumption of the device *i* and $b_{ij}$ constitutes the average impact of the socioeconomic or technical variable *j* on the electricity consumption of the device *i*. Furthermore, it is necessary to underline that **Akinlo A. E (2009)** produce their estimations of consumption by type of housing, single-family dwelling and multi-lodging, as well as by age category of residences.

The differences between their study and ours are a further statistical analysis from us as well as an interval of time which the study concerns. **Shiu and Lam (2004)** use the data of 1994 and 1999 produced by Hydro-Quebec; for our part, we include in addition the poll of 1989. Their estimations of unit consumptions establish all the same an excellent base of comparison. We use similarly the data of Hydro-Quebec for the residential sector from Quebec; thus there are no major differences on the composition of the data. Moreover, none of the temperature difference and behaviour can appear; this can sometimes make the estimations hardly comparable when studies are undertaken in another region.

**Yoo and Kwak (2010)** used the stepwise regression procedure to estimate the parameters of the equation above. This approach can pull an overvaluation of the significance of the estimated parameters because the choice of the relevant explanatory variables is made on the basis when the most strongly correlated exogenous variables with the dependent variable are kept. Furthermore, the stepwise method without correction is invalidated by the heteroscedasticity. This estimation method is not used in the economic studies where a structural approach is favoured.

**Wolde (2005)** suggested making an analysis which calls more on natural economic variables as explanatory factors of the electricity consumption; furthermore, the choice of the explanatory variables of the electricity demand will be made partially on the basis of considerations a priori and their relevance will be confirmed by statistical tests of significance.

At present, Hydro-Québec uses the results produced by the INRS-ENERGY and MATERIALS. Although their results of unit consumptions are for us an excellent comparison basis, we suggest undertaking a further statistical analysis which calls more on the economic considerations. The following section presented the statistical model which we developed by being inspired by the CAD model of **Narayan and Singh (2005)**.

The conditional analysis of the demand is a regression method which aims at disintegrating the total electricity consumption of the sampled households in all the consumptions linked with the electric equipment which they possess. The households have a derived demand for electricity; their demand is linked to the supplied services by the various electric devices, whether it is the heating, the lighting or any other service of comfort. The derived character of the electricity demand allows, in fact, associating the households demand for the electric devices which they possess while considering the characteristics defining the households and their housing which can influence their consumption.

In fact, if the energy consumption of uses was known, we could be regressed these unit consumptions on various explanatory variables. Thus, the demand parameters for each of the uses would be estimated. In this vein, the CAD would look as follows in its mathematical form:

$$Ei = fi\,(V) + e\,; \qquad i = 1, \ldots, N$$

Where $E_i$, the dependent variable is the electricity consumption of the use i, $f_i$ : is the function of electricity demand for the use i , $V$: is the vector of explanatory variables and e: is the error term of the equation. If $f_i$ : is linear, the equation below can be rewrite:

$$E_i = \sum_{j=0}^{M} bij \; * V_j + e \; = b_{i0} + \sum_{j=1}^{M} bij \; * V_j + e\,, \qquad i = 1, \ldots, N.$$

It is assumed that the vector $V$ has M + 1 components with $V_0 = 1$, and the $b_{ij}$ are the M + 1 parameters of the $i^e$ function of the demand. While we do not know the consumptions, $E_i$ ($i = 1, \ldots, N$), the CAD methodology allows to estimate the parameters of the equation above.

The unit consumption $E_i$ : is unknown and the total electricity consumption of the households is the only known variable. Simply, we can design that the total electricity consumption is equal to the sum of the unit consumptions:

$$E = E_0 + \sum_{i=1}^{N} Ei \; + e$$

Where $E$ represent the total electricity consumption of the households and $E_i$ ($i = 1, \ldots, N$) represents the unit consumptions of the uses. $E_0$ : is the electricity consumption of undefined uses, such as devices with too high penetration rates, such as a refrigerator, a stove, lighting, or having relatively low consumption, such as a radio, a dryer, a video recorder.

The total energy consumption of the uses is represented by a conditional demand function on whether or not the device is owned. We define therefore dummy variables, $A_i$, representing each of the defined uses and taking the value 1 for households with device $i$ and 0 otherwise. So:

$$E_i = f_i\,(V) * A_i + e\,; \qquad i = 1, \ldots, N$$

$$E = \sum_{i=0}^{N} \sum_{j=0}^{M} bij(VjAi) + e.$$

The above equation can be estimated by the least squares method. The regressors being the variables characterizing the households and their dwelling, $V_j$ and the dummies variables of uses, $A_i$. $b_{ij}$ is the estimated parameter associated with the interaction between $A_i$ and $V_j$. However, the relevance of the obtained results, the estimated parameters $b_{ij}$, depends to a large extent on the methodological framework used, but also for the better reason of the data quality with which we work, hence the importance of starting the statistical analysis by processing in-depth of the data used.

## 3. EMPIRICAL ELEMENTS

Kraft and Kraft (1978) were the first to point to the existence of unidirectional causality in an analysis of the US economy between 1947 and 1974. These authors showed that in the United States, the gross national product is determined energy consumption. Kraft and Kraft (1978) indicated that energy saving policies could be implemented without affecting the growth of the gross national product. So, these policies can be carried out without damaging the economic dynamics. However, Akarca and Long (1980) were unable to obtain similar results when they reduced the sample data from Kraft and Kraft (1978), which proves that the chosen period can strongly influence the results (temporal instability).

Yu and Hwang (1984) updated the data for the United States for the period 1947-1979 to confirm the lack of a causal relationship between gross national product and energy use using a series of tests developed by Sims (1972). Yu and Choi (1985) used data from five countries and confirmed the absence of causality between GNP and total energy consumption for the USA, the UK and Poland, but a causal sense between this GNP and energy consumption was detected for South Korea and the opposite for the Philippines.

Ferguson et al. (2000) analysed the correlation between the amount of electricity used and economic development for a sample of 100 countries and found that there is a strong correlation between electricity consumption and economic growth. But since the correlation analysis does not necessarily imply a causal relationship, other studies have focused on studying the causal meaning of electricity consumption and growth (Ghosh (2002), Moritomo-Hope (2004) and Jumbe-al. (2004).

Asafu and Adjaye (2000) included in the production function, GDP, energy, labour, capital and technology. Shiu and Lam (2004) used the energy demand function with three variables: energy, GDP, and energy price, as measured by the consumer price index. Alves and Bueno (2003) studied energy demand in

Jordan. This author used the Stock-Watson (1993) Dynamic Ordinary Least Squares (DOLS) method. These authors have shown that the income elasticity of total energy demand is very close to unity, implying that economic growth is likely accompanied by a proportional growth in energy demand. Their approaches are very original because they avoid problems that arise from a simple error-correction model.

Stoytas and al. (2003) used a generalized technique of error variance decomposition by Pesaran and Shin (1997) to determine the information content of the variance of growth in energy consumption in Turkey over the period 1960-1995.The result indicates a unidirectional causality of energy consumption towards GDP. Thus, energy consumption positively affects GDP and this suggests that it is possible that, in the long run, the energy saving agenda may influence economic growth.

Samuel A. and Christophe M. (2005) studied the causality between economic growth and energy consumption in Congo, the Granger causality test revealed the existence of a unidirectional causality of GDP towards the consumption of energy. In addition, Patrice O. (2009) analysed the causality between electricity consumption and GDP in Cameroon. The results show that at the global level and in the primary sector, there is no causality between GDP and energy consumption. In the secondary sector, causality ranges from performance to energy consumption. In the tertiary sector, it is rather the consumption of energy that causes the growth of production in services.

Gbaguidi (2005) specified the evolution of electricity consumption for a sample of CEDEAO countries from an error-correction model during the period 1975 to 2005.The author used panel data econometrics to estimate the energy demand function at the regional scale. He showed that income negatively affects the demand for electricity. According to this author, a variation in the share of agriculture or industry leads to a variation in the same direction of energy demand but of a lesser magnitude. Gbaguidi (2005) first limited himself to Benin to do the same work. A 1% increase in GDP led to an increase in electricity consumption of just over 1%. Kraft-Kraft (1978), Yu-Choi (1985), Yu-Wang (1984), Masih (1996-1998), Asafu-Adjaye (2000), Fatai-al. (2002), Lee (2005) and Al-Iriani (2006) have highlighted the existence of the relationship between economic growth and energy consumption. This relationship is perceived by some authors as a waste caused by the rising standard of living of the inhabitants. Among these authors, it is worth mentioning Yoo (2005) and Shiu-al. (2004).

The economic literature on energy demand distinguishes CGEM (Computable General Equilibrium Model) models, trend forecasting models, and traditional econometric models. Models of the CGEM type in this area have been developed by Beaver and Huntington (1992), Beaver (1993) and Bhattacharyya (1996). The second group of the model includes logistic function estimation models, so-called learning models and trans-log models. Finally, the last group postulates that the energy demand depends on total expenditure, relative prices and a state variable which is generally the stock of the previous period. According to

Apergis (2009a) the model is also under-determined because "it would be necessary to find long-term arguments to the stock variable, for example population, total wealth, housing stock (heating) or fleet (fuel)". The interest rate for energy has been added to the determinants of energy demand.

Zamani (2016) used the econometrics of non-stationary heterogeneous panel data to determine the explanatory variables of the energy intensity of the gross domestic product in UEMOA. This author applied the Granger causality test in a heterogeneous panel model based on the work of Hurlin (2008).The interest of transposing causality on panels lies in the determination of deadlines. For one and two year delays, there is no causality between wealth and electricity consumption per capita. On the other hand, this author considered a delay of three years, the hypothesis of non-causality is rejected, which means that there is at least one UEMOA country in which the per capita income causes the consumption of electricity.

## 4. EMPIRICAL VALIDATIONS

Our database is extracted from the World Bank, the International Monetary Fund and the Central Bank of Tunisia. This database is the subject of a thorough study of the residential electricity demand in Tunisia. This demand is evaluated over time and through economic and climatic factors. We will treat the electricity demand approximated by the amount of electricity consumed by residential customers for each region. We will study this electricity consumption in Tunisia during a period of study from **2000 to 2017** for a sample of **20 Tunisian regions** namely: Tunis city, Zaghouan, Bizerte, Nabeul, Siliana, Beja, Jendouba, Monastir, Mahdia, Kef, Kairouan, Sfax, Kebili, Tataouine, Mednine, Gabes, Kasserine, Sidi Bouzid, Gafsa, Touzeur, to study the effect of electricity demand on the profitability of STEG in Tunisia, we will refer to a non-linear model that links the endogenous variable total electricity consumption (CTE) according to the number of subscribers (NB); income by region (RR); the average price (PM); the degree of heating day (DCH) and the degree of cooling (DR). This nonlinear model is written as follows:

$$CTE_{it} = \mathrm{A_i}\left(NB_{it}^{\alpha}\right)\left(PM_{it}^{\beta}\right)\left(RR_{it}^{\delta}\right)\left(DR_{it}^{\theta}\right)\left(DCH_{it}^{\gamma}\right)\mathrm{Exp}(\varepsilon_{it})$$

With Exp: matches the exponential

The estimation of this model above requires in the first integrated step the Log-Log specification in order to linearize this model.

$$Log(CTE_{it}) = Log(A_i) + \alpha Log(NB_{it}) + \beta Log(PM_{it}) + \delta Log(RR_{it}) + \theta Log(DR_{it}) + \gamma Log(DCH_{it}) + \varepsilon_{it}$$

We will use position, dispersion and shapes indicators to analyse the quality of fit, symmetry, flattening and normality of the different components of the electricity consumption function over the 15 years for the twenty Tunisian regions. The table below corresponds to the descriptive statistics for these different components.

***Table 1:*** *Descriptive statistics*

| | CTE | NB | PM | RR | DR | DCH |
|---|---|---|---|---|---|---|
| Mean | 18.23222 | 11.24956 | 4.815295 | 10.07791 | 5.222079 | 4.870257 |
| Median | 18.14674 | 11.28284 | 4.808927 | 10.10628 | 5.215162 | 4.751713 |
| Maximum | 19.80401 | 12.67723 | 5.324959 | 11.54876 | 5.808393 | 5.805386 |
| Minimum | 17.10857 | 10.22427 | 4.552824 | 8.442065 | 4.836282 | 4.137830 |
| Standard deviation | 0.651823 | 0.529327 | 0.127712 | 0.700525 | 0.265232 | 0.388713 |
| Skewness | 0.435178 | 0.416341 | 0.607417 | -0.136294 | 0.656554 | 0.586269 |
| Kurtosis | 2.652278 | 3.350332 | 4.962423 | 2.682708 | 2.555280 | 2.560141 |
| Jarque and Bera | 3.660131 | 3.400387 | 22.19553 | 0.729077 | 8.008459 | 6.534671 |
| Significance | **0.160403** | **0.182648** | 0.000015 | **0.694517** | 0.018238 | 0.038108 |

The first table of the standards deviations is very low; these mean that there is a good linear adjustment for these various components of the electricity model in Tunisia. The averages are very high for these different components, these mean that the consumption of electricity very increases for the twenty Tunisian regions during the reference period. The median divides the population into two equal groups and we noticed that the medians for the variables of this model are very high. The total electricity consumption, the number of the subscribers and the income by region follow a normal distribution because the statistics values of Jarque and Bera are lower than the critical value of Chi-Squared in two degrees of freedom. On the other hand, the other components do not follow a normal distribution because there are problems of asymmetry and flattening for these components. We shall analyse the relations of the dependences of these various components from the Variance-Covariance Matrix. The Matrix below represents the dependences of these various variables.

***Table 2****: Variance-Covariance Matrix*

| | CTE | NB | PM | RR | DR | DCH |
|---|---|---|---|---|---|---|
| CTE | 0.420625 | 0.318359 | 0.014158 | 0.204517 | 0.007846 | -0.066613 |
| NB | 0.318359 | 0.277386 | 0.007463 | 0.169044 | -0.003365 | -0.042499 |
| PM | 0.014158 | 0.007463 | 0.016147 | 0.033438 | -0.003322 | 0.001081 |
| RR | 0.204517 | 0.169044 | 0.033438 | 0.485827 | -0.056192 | -0.030799 |
| DR | 0.007846 | -0.003365 | -0.003322 | -0.056192 | 0.069645 | -0.070507 |
| DCH | -0.066613 | -0.042499 | 0.001081 | -0.030799 | -0.070507 | 0.149587 |

The second table of relations dependences are positive for the endogenous variable of the total consumption of electricity and the various explanatory variables, that is the increase of the electricity consumption is explained by the increase of the numbers of the subscribers, the average price, the income by region and the degrees of day of heating-cooling. On the other hand, the numbers of the subscribers exercise a negative influence on the degrees of day heating-cooling. Also, the average price has a negative effect on the degree of the cooling day and a positive impact on the degree of the heating day. We will identify the presence or absence of multi-collinearity problems from the total correlation matrix. The matrix below presents the coefficients of the total correlations for these different components of the total electricity consumption function in Tunisia.

***Table 3**: Total Correlation Matrix*

| | NB | PM | RR | DR | DCH |
|---|---|---|---|---|---|
| NB | 1.000000 | 0.111518 | 0.460487 | -0.024208 | -0.208635 |
| PM | 0.111518 | 1.000000 | 0.377527 | -0.099061 | 0.021991 |
| RR | 0.460487 | 0.377527 | 1.000000 | -0.305488 | -0.114249 |
| DR | -0.024208 | -0.099061 | -0.305488 | 1.000000 | -0.690780 |
| DCH | -0.208635 | 0.021991 | -0.114249 | -0.690780 | 1.000000 |

The third table by referring to this matrix, we can conclude that there is no problem of multi-collinearity for the various explanatory variables of the model of the total electricity consumption in Tunisia. We would try to specify this model from the Homogeneity-Heterogeneity Tests, the table below corresponds to this test.

***Table 4 :** Homogeneity-Heterogeneity Tests*

| | Constants Homogeneity | Coefficients Homogeneity |
|---|---|---|
| $\text{Log}(CTE_{it})$ | 163.25(0.000) | 0.75 (0.9124) |

In the fourth table, we use the operator neperian logarithm to linearize this model which relates the total electricity consumption according to the explanatory variables during 15 years for a sample of twenty Tunisian regions. We notice that from this table above that, all the coefficients of reactions of this model are identical for twenty Tunisian regions and during 15 years. On the other hand, constants are heterogeneous for this sample. For that purpose, we model the Tunisian electricity consumption function by a statistical panel with individual effects and we shall use the **within method** and **Generalized Least Squares (GLS) method** to estimate this function. The table below redraws these methods of estimation for this function.

*Table 5 : Techniques for estimating the function of Tunisian electricity*

| | Within Estimation | | GLS Estimation | |
|---|---|---|---|---|
| | Coefficients | Significance | Coefficients | Significance |
| $\text{Log}(NB_{it})$ | 0.7026442 | 0.000 | 0.8115817 | 0.000 |
| $\text{Log}(PM_{it})$ | 0.1022077 | 0.028 | 0.1026157 | 0.000 |

| | | | | |
|---|---|---|---|---|
| $Log(RR_{it})$ | 0.1069091 | 0.000 | 0.0934916 | 0.000 |
| $Log(DR_{it})$ | 0.0608712 | 0.225 | 0.0664617 | 0.190 |
| $Log(DCH_{it})$ | 0.0417175 | 0.102 | 0.0381608 | 0.142 |

The fifth table, the appropriate estimation techniques of the electricity consumption function gives the expected and significant results. But, the interpretation of these results is above all based on a **Hausman arbitrage test (1978)**. The table below corresponds to the **Hausman test (1978).**

***Table 6 :*** *Hausman Test (1978)*

| | $Log(CTE_{it})$ |
|---|---|
| Stat-Hausman | $\chi^2(5)$ = 9.42 (0.0935) |

The value in parenthesis corresponds to the statistical significance of Hausman (1978)

The **Hausman test (1978)** indicates that the individual effects are fixed; because the statistics of **Hausman (1978)** is superior to the tabulated value of Chi-Squared in five degrees of freedom. Hence, the constants of twenty Tunisian regions do not vary for the individuals and during the time. We use the estimation results by the **within** procedure as a good interpretation of the static relation which describes the total electricity consumption according to the explanatory variables. All the explanatory variables have positive effects on total electricity consumption for the twenty Tunisian regions during the period 2000-2014. The elasticity of total electricity consumption in relation to the number of subscribers (NB) is less than unity, despite the fact that this elasticity is significant at the risk of 1%. Hence, this number of subscribers is inelastic with respect to this consumption. Also, income by region (RR) is insensitive to total electricity consumption. This income is significant at the risk level of 1%, although the contribution of this income to total electricity consumption is very low. The elasticity of total electricity consumption relative to the average price tends to zero, which is an indicator of the poor contribution of this price on the Tunisian electricity bill. This bad contribution is significant at the risk level of 5%. The shares of the degree days of heating and cooling are very low compared to the total consumption of electricity and the repercussions of these degrees are not significant on the electricity bill for a Tunisian citizen.

We shall call on the dynamic panel technique to estimate the cumulative quantity of the Tunisian electricity according to the explanatory variables. The dynamic model of the electricity consumption in Tunisia takes the following linear shape:

$$Log(CTE_{it}) = Log(A_i) + \rho Log(CTE_{it-1}) + \alpha Log(NB_{it}) + \beta Log(PM_{it}) + \delta Log(RR_{it}) + \theta Log(DR_{it}) + \gamma Log(DCH_{it}) + \varepsilon_{it}$$

The literature of the estimation of **dynamic models on Panel data** provides a series of techniques which the most used are in particular the **Anderson and Hsiao method (1982) and Arellano and Bond method (1991)**. Although with the first method we arrive at a convergent estimator, this technique does not exploit all the conditions on the moments and does not take into account the structure of the error terms. That's why in this study we will use the **Arellano and Bond method (1991)** which is more efficient. The **Arellano and Bond (1991)** technique is based on the use of instrumentation to exploit the information contained in the first differences that are introduced into our theoretical model to estimate. If, we add the consumed amount of the delayed electricity, the theoretical model can be written as follows:

$$Log(CTE_{it}) = \alpha_i + \rho Log(CTE_{it-1}) + \alpha Log(NB_{it}) + \beta Log(PM_{it}) + \delta Log(RR_{it}) + \theta Log(DR_{it}) + \gamma Log(DCH_{it}) + \Delta e_t + \varepsilon_{it}$$

In this model, $\alpha_i$ and $e_t$ are specific and temporal effects. The presence of delayed dependent variable does not allow using the standard econometric technique. Indeed, the estimation of this model by the classic methods (**OLS and within**) give biased and inconsistent estimators because of the correlation between the delayed residential electricity demand and the individual effect $\alpha_i$. To obviate this problem, we use the method of moments generalized in dynamic panel which allows to check the individual and temporal specific effects, and to mitigate the endogeneity biases of the variables.

Under the hypothesis of weak exogeneity of the explanatory variables and non-autocorrelation of the error terms, the estimator is done in two stages; it is assumed initially that the error terms are independent and homoscedastic between the individual and temporal dimension. In a second step, the **Arellano and Bond (1991)** estimation takes residues from the **first-step** to estimate the variance-covariance matrix and to relax, infinitely, the previous hypotheses. This **two-step** method allows therefore the consideration of heteroscedasticity between regions, autocorrelation of error terms, and simultaneity biases and measurement errors (**Kremp and al. 1999)**.

The consistency of the GMM estimator of Arellano and Bond (1991) is based on the hypothesis that there is no second order autocorrelation in the errors of the equation on the first differences and that the instruments are valid. They suggested the two tests whose rejection of the null hypothesis confirms the specification of our model: a direct test of the autocorrelation of second-order residues and a **Sargan Hansen test** on the over-identification of the equations.

The table below corresponds to the estimation of electricity consumption function during 15 years for the twenty Tunisian regions by the GMM technique of Arrellano and Bond (1991).

***Table 7****: Estimation of Electricity Consumption by the GMM method of Arrellano et Bond (1991)*

| Two-Stages | | One-Stage | |
|---|---|---|---|
| Variables | Coefficients | Variables | Coefficients |
| Constant | -0.291309748 | Constant | -0.848845860 |
| Log($CTE_{it-1}$) | 1.637235845** | Log($CTE_{it-1}$) | 2.297691877 |

| | | | |
|---|---|---|---|
| $Log(NB_{it})$ | 0.668408117* | $Log(NB_{it})$ | 1.351695817 |
| $Log(PM_{it})$ | 0.204210326** | $Log(PM_{it})$ | 0.226749083 |
| $Log(RR_{it})$ | 0.049418178** | $Log(RR_{it})$ | 0.110422603 |
| $Log(DR_{it})$ | 0.059351701*** | $Log(DR_{it})$ | 0.121233775 |
| $Log(DCH_{it})$ | 0.029674907* | $Log(DCH_{it})$ | 0.210336812 |
| Over-identification Test | | | |
| Sargan | $\chi^2(9)$= 16,346 (0,005) | Sagan | $\chi^2(9)$= 18,761(0,041) |
| Test of autocorrelation absence of errors in the equation on difference | | | |
| m2 | 0.498359 | m2 | 0.550739 |
| LB = Q | $\chi^2(2)$= 5.650 (0,123) | LB = Q | $\chi^2(2)$= 9.33(0,153) |

* ; ** and *** correspond respectively to the risk significance of 1%; 5% and 10%. LB represents the Ljung-Box statistic of autocorrelation of level errors. Values in parentheses refer to the significance of the variables.

The first remark concerning the estimation of the **dynamic panel model** of electricity consumption in Tunisia is that the coefficient of the delayed endogenous variable of this consumption takes a positive and significant sign from the generalized method of moments of **One-Stage and Two-Stages of Arrelano-Bond (1991)**. Also, the explanatory variables have positive and significant signs. But, the **two-Stage** estimation yields to consistent results then the **one-stage** estimation. These results are consistent with the work of **Arrelano-Bond (1991)**. The **Sargan statistic** is statistically significant at the risk threshold of 5%. Hence, the instruments are efficient because we accept the over-identification hypothesis of **Sargan and Hansen** where the instruments are over-identified. The **Ljung-Box** test and the m2 statistic validate the absence of a second order autocorrelation problem in terms of the electricity consumption function in Tunisia as the first difference.

## 4. CONCLUSION

In this article, we empirically studied the total electricity consumption during a study period from **2000 to 2017** on annual frequencies for a sample of twenty Tunisian regions which are: Tunis City, Zaghouan, Bizerte, Nabeul, Siliana, Beja, Jendouba, Monastir, Mahdia, Kef, Kairouan, Sfax, Kebili, Tataouine, Mednine, Gabes, Kasserine, Sidi Bouzid, Gafsa, and Touzeur. We have referred to the main previous works that have dealt with the electricity consumption function and we have identified the different approaches to this function.

We extracted a database from the Central Bank of Tunisia, the World Bank and the International Monetary Fund. We have studied the asymmetry, the adjustment and the normality of the different components of the electricity demand from the statistical indicators: Position, Dispersion and Shape.

We have attributed the different dependency relationships between these different components from the Variance-Covariance matrix and validated the absence of a multi-collinearity problem from the coefficients matrix of the total correlations.

We have specified the basic model by a panel with individual effects from the Homogeneity-Heterogeneity statistics. We used the **within and GLS** procedures to estimate the endogenous variable total electricity consumption according to the explanatory variables. We verified the nature of the individual fixed effects by **the Hausman arbitrage test (1978)** and we used the GMM method Arrelano-Bond (1991) in **one-stage and in two-stage**s in order to estimate the dynamic relation of electricity consumption in Tunisia.

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