Electricity Consumption and Economic Growth: The Case of Mexico

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***Abstract*—**The causality between energy consumption and economic growth has been an important issue in the economic literature. This paper studies the causal relationship between electricity consumption and economic growth in Mexico for the period of 1971-2011. In so doing, unit root and causality tests are applied. The results show that energy consumption and economic growth series are stationary and there is also a causality relationship running from economic growth to electricity consumption. Therefore, any energy conservation policy would have little or no impact at all on economic growth in México.

***Keywords*—**Causality, economic growth, electricity consumption, Mexico.

I. Introduction

THIS paper analyzes the relationship between energy consumption and economic growth. The hypotheses derived from these analyses are as follows [1]-[6]. The growth hypothesis suggests that if energy consumption causes economic growth, then decreasing energy consumption could lead to a lower level of income, it means that economic growth is dependent on energy consumption, and thus energy consumption would be an important factor for economic activity. On the other hand, the conservation hypothesis suggests that if economic growth causes energy consumption, any energy conservation policy have little or no impact at all on economic growth. In the same way, the neutrality hypothesis suggests that if there is not a causality relationship between these variables, policies to conserve electricity will not affect economic growth because it might represent only a small proportion of GDP. Finally, the feedback hypothesis suggests that there is a two-way causality, and therefore there is interdependence and complementarity between these two variables. This is true when there is a positive causality between these variables. However, when there is a negative causality relationship between energy consumption and economic growth, the interpretation of energy dependence opens up the possibility of many other interpretations, as it happens when energy is negatively related to income, implying that an increase in the energy consumption will negatively affect economic growth. When the causation negatively runs from income to energy, then an increase in income levels leads to a reduction in energy consumption that can be explained by some kind of infrastructure constraints, inadequate policies (income distribution, poverty and reduced demand for goods and services that includes energy, and so forth), as well as other obstacles leading to a reduction in energy consumption [6].

Accordingly, some authors have pointed out that if electricity consumption causes economic growth, energy policies that promote a reduction in electricity consumption may negatively affect economic growth [7]. However, if there is no relationship, or the causation runs from economic growth to energy consumption, electricity conservation policies would not have any effect on economic growth. In case of a two-way causality, energy conservation policies would not affect economic growth [7].

For econometric modelling, it is highly important to test for stability of the parameters in a regression model. Structural change or structural instability has been commonly interpreted as changes in the regression parameters [8]. The stability of the parameters of the regression model is one of the basic assumptions in econometric models, which is necessary for econometric inference and forecasting.

In the case of Mexico, as in many other countries in Latin America, after four decades of applying the import substitution model and its obvious exhaustion, in the mid-80s, this country began implementing some important structural reforms in order to increase economic efficiency, including opening markets to competition and foreign investment, privatization of public enterprises, deregulating domestic markets, and finally adhering to the North American Free Trade Agreement (NAFTA) in 1994. However, these reforms have also been given strong devaluation and economic crisis like those in 1976, 1982, 1987 and 1994-95. These events in the Mexican economy may give the impression that there were structural changes that should be incorporated for economic modelling. Therefore, this study should incorporate structural changes in the econometric modelling.

The analysis of the causal relationship between these variables would be useful to design more accurate economic policies for economic growth and job creation. In this regard, this research aims to analyse the causal relationships between GDP per capita and electricity consumption in Mexico during the period 1971-2011, incorporating structural changes. The paper is organized into five sections. In addition to this introduction, Section II presents the literature review. Section III discusses the econometric methods used is this research. Section IV discusses the main results achieved in this paper. Finally, Section V presents some concluding remarks.

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II. Literature Review

The relationship between energy or electricity consumption and economic growth has been analysed in many studies. Some studies did not incorporate structural breaks in the model specification. For example, the causal link between energy consumption and economic growth in Nigeria during 1960-1984, and Tanzania during 1960-1981 [9]. The results achieved in these studies suggest a bidirectional causality relationship between energy consumption and economic growth in both countries [9]. Other scholars have analysed the relationship between energy consumption and income in 10 emerging markets (excluding China) and G7 countries [10]. The results in this analysis suggested that the relationship between energy consumption and economic growth is bidirectional for Argentina, from GDP to energy consumption for Italy and Korea, and from energy consumption to GDP for Turkey, France, Germany and Japan [10].

In other paper, some authors analysed the relationship between energy consumption and economic growth in South Korea using a multivariate model of capital, labour, energy and GDP for the period 1970-1999 [11]. The results suggest that there is a bidirectional causality relationship between energy and GDP in the long term, while in the short term, there is a relationship running from energy consumption to GDP [11]. In this regard, some scholars investigate the long term relationship between energy consumption and GDP per capita for 19 African countries during the period 1971-2001 [12]. The results in this study indicate that there is a long-term equilibrium relationship for 8 countries, and causality relationship for 12 countries of which causality goes from energy consumption to GDP per capita for 5 countries, and from GDP per capita to energy consumption for 7 countries [12].

Other authors explore the relationship between energy consumption and economic growth for the members of the Organization of the Petroleum Exporting Countries (OPEC) using annual data from 1980 to 2003 [6]. The results show no evidence of a long-term relationship between these variables [6]. However, causality tests indicate that economic growth is dependent on energy consumption in five countries and less dependent in three countries, while independent in three other countries [6]. The difference of causality in these countries might be explained by some specific characteristics in each case. In this sense, other scholars study the co-movement and causality between energy consumption and economic growth in a multivariate model, incorporating capital and labor in the case of 16 Asian countries during the period 1971-2002 [13]. Using a panel data model, the results show that there is a cointegration relationship between energy consumption and real income [13]. In the short term, however, there is no causal relationship between these variables, while in the long term this relationship runs from energy consumption to economic growth [13].

Particularly, for the case of Malaysia, the relationship between economic growth, energy generation, exports and prices using a multivariate model using annual data from 1970 to 2008 is analysed [14]. These authors find that there is a relationship running from economic growth to the generation of electricity [14]. In the same way, the relationship between consumption of electricity and real GDP is analysed in the case of 12 European countries, using a panel data model with information for the period of 1970-2007 [7]. To avoid the problem of omitted variables, these authors include prices as a third variable in the model. The results show that there is a long-term relationship of equilibrium between the three variables and a short-term negative causality from electricity consumption to GDP [7]. In the same manner, there is bidirectional causality between energy consumption and energy prices. For example, in the case of Greece, some scholars have examined the causal relationship between aggregate and disaggregated energy consumption, on the one hand, and economic growth, on the other, for the period of 1960-2006 [15]. At an aggregate level, the results suggest that causality goes from total energy consumption to real GDP, while at a disaggregated level, causality is bidirectional and thus the relationship goes from industry and residential energy consumption to real GDP [15].

Other study explores the causality relationship between economic growth and energy consumption for the period 1980-2009 in the case of Lebanon [2]. The results in this study indicate that there is bidirectional causality in the short and long term, indicating that energy is a factor restricting economic growth [2]. In the case of G-6 countries (Canada, France, Germany, Japan, UK and USA), the Granger test of causality with panel data was applied to testing energy consumption driving economic growth for the period of 1972-2010 [16]. The results show evidence that form nuclear energy consumption to economic growth in Japan and United Kingdom, in the United States goes in both directions, and there is no causal link in the cases of Canada, France and Germany [16]. While there is only causality from economic growth to oil consumption in the case of the United Sates, and oil consumption does not cause economic growth in the G-6 countries, except for Germany and Japan [16].

Recently, in other paper, some scholars examine the causal relationship between financial development, trade, economic growth, energy consumption and carbon emissions in Turkey for the period 1960-2007 [17]. The results suggest that there is a long-term relationship between these variables [17]. However, there is evidence of a long-term causality from energy consumption per capita, real income per capita, openness and financial development to carbon emissions per capita [17]. In the short term, there is a relationship of causality from financial development to energy consumption per capita, real income per capita and the square of real income per capita [17]. Finally other authors examine the causal relationship between energy consumption, economic growth and CO2 emissions in the BRIC countries (Brazil, Russia, India, China and South Africa) for the period of 1990-2010 [18]. The results indicate that there is no causality at all in the case of Brazil, India and China [18]. In the case of Russia, causality goes in both directions, and in the case of South Africa, causality runs from energy consumption to economic growth [18]. The relationship between energy consumption and CO2 emissions, on the one hand, and economic growth and CO2 emissions results are not conclusive in all cases [18].

Some other studies include in the models structural changes for a better econometric specification. For example, some scholars analyse the causal relationship between GDP and energy consumption for Turkey during 1950-2000 [19]. Testing for unit root, this study also allows testing structural change [19]. However, the authors in this paper show evidence that there is not a causal link between energy consumption and GDP in this country [19]. In the same way, using a different methodology of causality, these authors have analysed causality relationship between energy consumption and real GDP in Turkey during 1950-2000 [20]. In this study, using unit root tests that allow testing for structural change, the series are stationary and there is evidence of unidirectional causality running from electricity consumption to income [20].

In other paper, causality between energy consumption and GDP for 18 developing countries is analysed using annual data from 1971 to 2002, and 22 developed countries using annual data from 1965 to 2002 [21]. This analysis takes into account the presence of structural changes applying unit root test with panel data [21]. The evidence indicates that the series are stationary and the causality goes in both directions in the case of developed countries, while in the case of developing countries, the causality goes from GDP to energy consumption [21]. In this sense, using a VAR panel, some scholars analyses the relationship between capital formation, energy consumption and real GDP in a panel of the G7 countries for the period 1972-2002 [22]. In this case, using unit root and cointegration tests in panel data that allows structural changes, the results indicate that there is a long-term equilibrium relationship between the three variables and the capital formation and energy consumption positively causes real GDP in the long term [22]. More recently, scholars provide evidence of a causality relationship between energy consumption and economic growth for 21 African countries for the period of 1970 to 2006 [5]. These authors use cointegration and causality tests with panel data through dividing importer and exporter countries [5]. They find a long-term relationship between energy consumption, real GDP, prices, labour and capital for each group of countries, as well as for all countries as a whole [5]. In regard to causality, in both groups of countries, there is a causality relationship in both ways [5]. Using annual data for the period of 1974-2009 and including structural change, other study analyses the causal relationship between electricity consumption and economic growth for the case of the Portuguese economy [23]. The results show a cointegration relationship between these variables, and there is bidirectional causality between electricity consumption and economic growth in the short and long term [23]. In the same way, other study analyses the relationship between energy consumption and economic growth in the case of China during the period of 1971-2011, including a production function, financial development, international trade and capital [24]. These authors use unit root tests that allow structural change [24]. The results indicate evidence of a long-term relationship between these variables, and they also demonstrate a causality relationship from energy use to economic growth [24].

Accordingly to the literature review, the causality can go from energy consumption to economic growth, from economic growth to energy consumption, bidirectional, or no causality at all [24]. In the case of Mexico, it was found that there is a two-way causality between energy consumption and output [25], while there is no statistically significant causal relationship [26]. In this case, there are not conclusive results and they are not incorporating structural changes in the models. It would be interesting to know the direction of causality between energy consumption and economic growth in Mexico for the period of 1971-2011 incorporating structural changes in the model.

III. Econometric Model

To perform causality tests, it is necessary that all variables are stationary in order to avoid spurious results in time series regressions. In so doing, the Lee-Strazicich test (LS) [27] is applied allowing for testing two structural changes and not differentiating the series when it is not necessary [28], [29]. In fact, series might be stationary while taking into account the deterministic trend and/or existing structural changes. In econometric terms, the stability of the parameters of a regression model is one of its basic assumptions, which is necessary to forecast and make econometric inference. Structural change or structural instability has been commonly interpreted as changes in the parameters of a regression model [8]. Accordingly, in this search, it is considering the following a data generating process (pgd) [27]:

$$y_t = \delta' Z_t + X_t,\ \mathrm{X}_t = \beta \mathrm{X}_{t-1} + \varepsilon_t \qquad (1)$$

where Z_t contains exogenous variables and ε_t is *iid* $N(0,\sigma^2)$. For this test, in Crash Model allowed two structural changes in the level and in Mixed Model allowed two structural changes in the level and slope. In the case of the first Model, $Z_t = [1, t, D_{1t} D_{2t}]'$ where $D_{jt} = 1$ for any $t \geq T_{Bj} + 1,\ j = 1,2$ and 0 otherwise, T_{Bj} is the time period of structural change. For Mixed Model, $Z_t = [1, t, D_{1t}, D_{2t}, DT_{1t,} DT_{2t}]'$, where $DT_{jt} = t$ for $t \geq T_{Bj} + 1,\ j = 1,2$ and 0 otherwise. The pgd incorporates structural changes under the null hypothesis (unit root) and the alternative (trend stationary), and are determined endogenously based on the data, where the t-statistic of the unit root null hypothesis is minimized (the most negative).

In this sense, in relation to the unit root tests with structural change [30]-[32], this authors have been criticized because they often incorrectly determine the period of structural change, and make spurious rejections null hypothesis of unit root, since they only incorporate structural changes in the alternative hypothesis, and not in both the null and alternative hypothesis. Erroneously, they reject the null hypothesis of unit root in a series that is stationary, and accept it when series have a unit root with structural change. This deviation and spurious rejection increase with the size of structural change [27], [33].

According to the principle LM, the unit root test statistic is obtained from:

$$\Delta y_t = \delta' \Delta Z_t + \phi \tilde{S}_{t-1} + u_t \qquad (2)$$

where $\tilde{S}_t = y_t - \tilde{\varphi}_x - Z_t\tilde{\delta}, t = 2,..,T$; $\tilde{\delta}$ are the regression coefficients Δy_t on ΔZ_t, and φ_x is given by $y_1 - Z_1\tilde{\delta}$. y_1 and Z_1 represent the first observation of y_t and Z_t, respectively. The unit root null hypothesis is described by $\phi = 0$. To correct the errors autocorrelation include terms $\Delta\tilde{S}_{t-j}$, $j = 1,...,k$ in (2) as in the standard DFA test.

Several tests of causality have been proposed [34]-[37]. According to [34], a time series X causes another time series if the prediction error decreases using past values of X, in addition to past values of Y. Similarly, Y causes another time series X if the prediction error decreases X using past values of Y, in addition to past values of X. In the first three tests is required that the variables are stationary; to avoid spurious results obtained in regressions of no stationary time series and know the order of integration of the series for the last test. This research applies Granger [34] and Toda and Yamamoto [37] tests. The former is well known and will not be describe in this paper, but only the Toda and Yamamoto [37] test will be discussed.

In this regard, it has been proposed an approach for assessing causality regardless of the order of integration and/or cointegration rank in the VAR system (vector autoregressive) estimated through the SUR system (seemingly unrelated regressions) [37]. This test is robust regarding the properties of integration and cointegration. The procedure uses the modified Wald test statistic (MWald) for the restriction of the parameters in the VAR (k), where k is the order of the lags in the system. The MWald statistic has an asymptotic chi-square distribution when the VAR (k + dmax) is estimated (where dmax is the maximum order of integration is expected to occur in the system) [37].

IV. Results

Data on per capita electricity consumption were taken from the World Bank [38] and the per capita GDP was taken from the International Financial Statistics of the International Monetary Fund [39]. Fig. 1 shows the behaviour of electricity consumption in the case of Mexico, where a relatively stable positive trend is observed in the period analysed in this paper.

In the case of GDP, a positive trend with strong sharp movements in the early 80s (1982-1983), mid-90s (1994-1995), and around 2009 are observed, which indicate the possibility of finding structural changes in the series (Fig. 2).

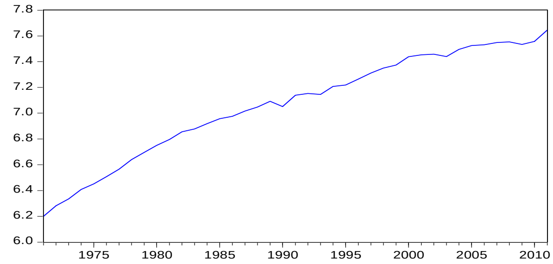

Fig. 1 Electricity consumption per capita (EC) in Mexico

To distinguish whether it is a deterministic or stochastic trend, unit root tests are applied. To account for the possible of the presence of structural changes, we proceeded to apply the LS test. Results are presented in Table I.

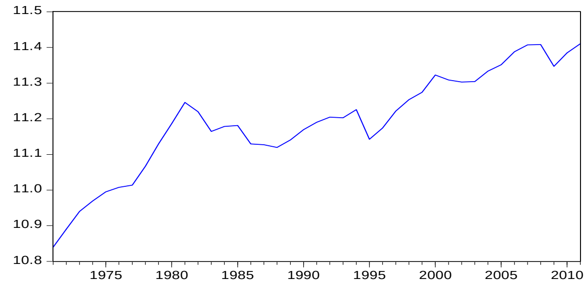

Fig. 2 GDP per capita in Mexico

The results show that both series are stationary taking into account both structural changes and a deterministic trend, given that it can be rejected the unit root hypothesis at a level of 5 and 10% level for EC and GDP, respectively.

TABLE I
LS Unit Root Test for Mexico

Variable	Model	Break	LM Test	Lags (k)	Significance Level
EC	Mixed	1981/1999	-4.990	0	10%
GDP	Mixed	1984/1998	-5.794	2	5%

The critical values for 1%, 5% and 10% significance levels of statistical LM are -5.82, -5.28 and -4.98, respectively, for Mixed Model [27].

To remove the deterministic trend and incorporate structural changes in the series, it was estimated the following equation [28], [29]. Once we know the order of integration of the series, causality tests are applied and the results are presented in Table II. It is worth saying that the number of lags chosen are based on the AIC (Akaike information criterion), SC (Schwarz information criterion), and HQ (Hannam-Quinn information criterion).

From the results shown in Table II we can reject the null hypothesis of no causality from economic growth to electricity consumption at a level of significance of 5% based on Granger test [34], and 1% based on Toda and Yamamoto test [37]. Causality runs unidirectional from economic growth to electricity consumption, meaning that economic growth contains useful information to predict electricity consumption. This implies that electricity conservation policies have little or no impact at all on growth.

TABLE II
CAUSALITY TEST FOR MEXICO

Null Hyphotesis	Granger test	Toda and Yamamoto test
EC does not cause GDP	1.612	3.70
GDP does not cause EC	4.410b	10.24a

a rejection of the null hypothesis at significance level 1%., b rejection of the null hypothesis at significance level 1%

V. CONCLUSION

The causality between energy consumption and economic growth has been an important issue in the economic literature. The hypotheses derived from these analyses suggest several explanations on this issue. The growth hypothesis suggests that energy consumption causes economic growth. The conservation hypothesis proposes that economic growth causes energy consumption, and energy conservation policies have little or no impact at all on growth. The neutrality hypothesis suggests that there is no causality relationship between energy consumption and economic growth. Finally, the feedback hypothesis proposes a two-way causality (there is interdependence and complementarity between the two variables).

In this research the causality between electricity consumption and economic growth in the case of Mexico during the period 1971-2011 was analyzed. The results show that the series are stationary in levels with two structural changes and a deterministic trend. In the same way, the results show that there is a causality relationship running from economic growth to electricity consumption in the case of Mexico. The energy conservation policies have little or no impact at all on economic growth in the case of Mexico.

ACKNOWLEDGMENT

M. G. Author shows gratitude to Professor Aitor Ciarreta for hosting him as a Visiting Researcher at Universidad del País Vasco in Spain. Financial support from the National Council for Science and Technology (Consejo Nacional de Ciencia y Tecnología, CONACYT) in Mexico is gratefully acknowledged.

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