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The economic growth and electricity consumption nexus: Evidence from Mauritius

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Abstract

This paper has tried to unfold the causal relationship between electricity consumption and real economic growth in Mauritius using co-integration models applied to time series data between 1961 and 2011. The results unambiguously show that there is a short-term unidirectional causality from electricity consumption towards economic growth. Therefore GDP growth depends on electricity consumption. The implications of this distinct causal relationship between the two variables on the formulation of policies for the power sector are discussed.

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1. Introduction

Over the last decade numerous studies have depicted the relationship between energy (Wolde-Rufael, 2009; Akinlo, 2008; Apergis and Payne, 2009a, 2009b; Galindo, 2005; Glasure and Lee, 1997) or electricity (Odhiambo, 2009; Yoo, 2005; Wolde-Rufael, 2006; Shiu and Lam, 2004; Narayan and Singh, 2007; Ghosh, 2002) consumption and economic growth for several countries. There are four possibilities regarding the causal relationship between electricity (or energy) consumption and economic output. Firstly, the growth hypothesis where there can be unidirectional causality running from electricity consumption to economic growth (Shiu and Lam, 2004; Chandran *et al*., 2010; Kouakou, 2011), wherein a shortfall in electricity consumption (through for instance the inability to generate electricity to meet consumption), could lead to a fall in economic growth. If the unidirectional causality is in the opposite direction (Ghosh, 2002), it may imply that decreasing electricity consumption would not have a bearing on economic growth. This is also termed the conservation hypothesis. Thirdly there is a feedback hypothesis that upholds bidirectional causality. A bi-directional causality could mean that both electricity consumption and economic growth affect each other in a feedback fashion (Ahamad *et al*., 2011; Shuyun and Donghua, 2010; Odhiambo, 2009; Tang, 2008; Yoo, 2005). Lastly, no causality in either direction implies that implementing policies that affect electricity consumption would not affect economic growth, and vice versa (Altinay and Karagol, 2004). This is the neutrality hypothesis. Odhiambo (2009) has provided an exhaustive review of the literature concerning the four possibilities.

Understanding these relationships and their direction is necessary from a practical policy perspective that goes beyond its academic merit, since it is essential to establish whether or not economic growth, and hence socio-economic development, is constrained by the consumption, and hence, the generation of energy or electricity. Electricity is the foundation of economic growth and constitutes one of the vital infrastructural inputs in socioeconomic development. For instance, if there is no causality between electricity and Gross Domestic Product (GDP), or that there is a unidirectional Granger causality running from GDP to electricity, it would imply that a reduction in the use of electricity (for e.g. by increasing electricity productivity through behavioural change and efficiency measures) would not reduce economic growth. In contrast, economic growth would be reduced if electricity use were reduced when a unidirectional Granger causality runs from electricity use to GDP. The situation becomes more complex in the event that a bidirectional relationship was established between electricity use and GDP. Understanding such relationship flows is important for developing countries that rely on economic growth as a way to reduce poverty and achieve the Millennium Development Goals.

However the empirical evidence from the literature, emanating from studying the electricity-economic development nexus is mixed and ambiguous, reflecting the divergent hypotheses with causality ranging from bi- to uni-directional or being inexistent. As such findings from the literature do not lend themselves as policy prescription for countries where the electricity and economic growth nexus has not been systematically studied. In Mauritius, research on establishing the drivers of electricity consumption, and their relationships with economic output remains scattered at best. This study is an attempt to remedy this situation by undertaking an econometric analysis to establish any causal relationship between electricity consumption and economic growth. This is important at a juncture where Mauritius is implementing its long-term energy policy. For instance, a recent report quotes that "the method adopted by the (Central Electricity Board) CEB to forecast the electricity sales (GWh) and capacity demand (MW) over the long-term does not use GDP as input. This approach is supported by the fact that energy demand has been growing faster than GDP over the past decade. While GDP has grown by 85% from 1992, electricity sales have grown by 166% over the same period. Hence, GDP and energy growth are decoupled in our economic context" (Government of Mauritius, 2007)[1]. Even though there has been a decoupling between electricity consumption and economic growth rates, we posit that electricity consumption impacts GDP and aim to characterise the direction of such causation. The presence if any of causation between the two variables should be considered in energy policy decision making. It is hoped that the justification provided for carrying out this study for Mauritius will take care of the viewpoint recently expressed by Karanfil (2009) on the use of conventional methodologies for investigating the energy-income nexus, towards informing policy making.

2. Methodology

Time series data for electricity consumption (GWh) and growth in real Gross Domestic Product (GDP) has been used covering four decades, spanning the period 1961 and 2011.

2.1. Granger-causality

The Granger-causality test is a simple and generic way for establishing any causal

[1] A similar reasoning can be found on page 35 of the Integrated Electricity Plan 2003-2012 produced by the Central Electricity Board in November 2003 (http://ceb.intnet.mu/CorporateInfo/IEP2003.pdf – accessed 10th July 2012).

relationship between two variables, say X_t and Y_t, specified as time series. In this case, X_t is said to Granger-cause Y_t if the prediction error of current Y_t declines by using past values of X_t, together with past values of Y_t (Granger, 1969). Concurrently the coefficients on the lagged X_ts and Y_ts should be statistically significant. Although the attractiveness of this general approach lies in its simplicity, its use in detecting causal relationships needs to be applied with caution. Foremost, a series of variables needs to be stationary or else erroneous conclusions could be reached. A Vector Autoregressive model (VAR) provides an ideal framework for testing for Granger causality between electricity consumption and GDP.

2.2. Stationarity

A stationary series has basic statistical properties which are invariant with respect to time. Thus, it has a constant mean, a constant finite variance and covariances between observations that depend only upon their distance apart in time. Practically most economic data are not stationary, but are rather integrated.

According to Stock and Watson (1989), using non-stationary data in causality tests can give spurious results. Therefore, the unit roots of the series are tested to check the stationarity of each variable. The Philips-Perron (Philips and Perron, 1988) test (thereafter called the 'PP' test) is used, as it is known to be robust to a variety of serial correlations and time-dependent heteroskedasticities (Yoo, 2005). If any of the series is found to be non-stationary and it becomes stationary after differencing once, it is said to be integrated of order one, I(1). Therefore, an I(1) can be first-differenced before the Granger causality test can be applied to it.

2.3. Cointegration

Cointegration between two variables requires the satisfaction of two conditions. Firstly, the two series must have similar basic statistical properties, that is they must be integrated of the same order. Secondly, some linear combination of the series should exist such that it is stationary even though the individual series X_t and Y_t are not. This linear combination is simply the residual from a static ordinary least squares regression of Y_t on X_t. Such a regression is known as the cointegrating regression. If two series are I(1) then their linear combination will typically be I(1). It is only when there is cointegration that there would be a linear combination which is I(0).

Cointegration says nothing about the direction of causation between X_t and Y_t, but only whether or not a long-run relationship exists between the variables. It implies Granger causality in at least one direction. If X_t and Y_t each are non-stationary and cointegrated, then any generic Granger-causal inferences will be invalid. In this situation, the error -correction model (ECM) provides a more comprehensive causality test (Engle and Granger, 1987).

2.4 Error-correction model

If two series are cointegrated then a vector error correction model (VECM) must be used instead of the standard Granger-causality to investigate both short- and long-run causality. ECMs are a particular form of dynamic econometric model. According to this specification, changes in the dependent variable in response to changes in the explanatory variables aim at restoring the long-run relationship between them. The long-run relationship reflects cointegration between the previously-mentioned variables. Cointegration and VECMs are formally related through the Granger representation theorem, which stipulates that validity of the latter is dependent on the existence of the former. Therefore,

$$\Delta Y_t = \beta_{10} + \sum_{i=1}^{n} \beta_{11i} \Delta Y_{t-i} + \sum_{j=1}^{m} \beta_{12j} \Delta X_{t-j} + \beta_{13} \varepsilon_{t-1} + \mu_{1t}, \quad (1)$$

$$\Delta X_t = \beta_{20} + \sum_{i=1}^{p} \beta_{21i} \Delta Y_{t-i} + \sum_{j=1}^{q} \beta_{22j} \Delta X_{t-j} + \beta_{23} \varepsilon_{t-1} + \mu_{2t}, \quad (2)$$

Where, X_t and Y_t represent the natural logarithms of electricity consumption and real GDP, respectively. Δ is the difference operator, *n*, *m*, *p*, *q* are the number of lags, βs are parameters to be estimated, μ_ts are the serially uncorrelated error terms, and ε_{t-1} is the error correction term (ECT) which is derived from the long-run cointegration relationship, $Y_t = \eta_0 + \eta_1 X_t + \varepsilon_t$ where ηs are parameters to be estimated and ε_t is the error term.

Sources of causation can be identified by testing for significance of the coefficient on the lagged variables in Eqs. (1) and (2). According to Masih and Masih (1996) weak Granger causality can be interpreted as 'short-run' causality in the sense that the dependent variable only responds to short-term shocks to the stochastic environment. We, therefore, test

$H_0 : \beta_{12j} = 0$ against $H_1 : \beta_{12j} \neq 0$ for Eq. (1), and $H_0 : \beta_{21i} = 0$ against $H_1 : \beta_{21i} \neq 0$ for Eq.(2).

Another source of causation is the ε_{t-1} term in Eqs. (1) and (2). Through ε_{t-1}, an ECM offers an alternative test of causality. The coefficient on the ε_{t-1} represents how fast deviations from the long-run equilibrium are eliminated following changes in each variable. If for example β_{13} in Eq. (1) is zero, then LGDP (i.e. natural logarithm of real GDP) does not respond to deviation from the long-run equilibrium in the previous period, that is there is Granger non-causality in the long-run.

We also check whether the two sources of causation are jointly significant, in order to check for Granger causality. This is done by testing the joint hypotheses $H_0 : \beta_{12j} = 0$ and $\beta_{13} = 0$ for all *j* in Eq. (1) or $H_0 : \beta_{21i} = 0$ and $\beta_{23} = 0$ for all *i* in Eq. (2). These tests are referred to as strong causality tests and according to Asafu-Adjaye (2000) the joint test indicates which variables bear the burden of short-run adjustment to establish long-run equilibrium following a shock to the system. If there is no causality in either direction, the 'neutrality hypothesis' holds.

One important point to ensure is that the data do not contain structural breaks. A structural break implies that there are multiple regression relationships between the dependent and the independent variables with different intercepts and/or slopes. If structural breaks are identified, there is need to control for them by using dummies.

In the event that the variables GDP and electricity consumption are not integrated, equations (1) and (2) become (3) and (4). A standard Granger causality test is then conducted, that is $H_0 : \beta_{12j} = 0$ against $H_0 : \beta_{12j} \neq 0$ for Eq. (3) and $H_0 : \beta_{21i} = 0$ against $H_0 : \beta_{21i} = 0$ for Eq (4).

$$\Delta Y_t = \beta_{10} + \sum_{i=1}^{n} \beta_{11i} \Delta Y_{t-i} + \sum_{j=1}^{m} \beta_{12j} \Delta X_{t-j} + \mu_{1t}, \qquad (3)$$

$$\Delta X_t = \beta_{20} + \sum_{i=1}^{p} \beta_{21i} \Delta Y_{t-i} + \sum_{j=1}^{q} \beta_{22j} \Delta X_{t-j} + \mu_{2t}, \qquad (4)$$

3. Data analysis and results

3.1. Data

To investigate whether there is a causal relationship between electricity consumption and economic growth in Mauritius, data covering the period 1961 to 2011 are used. Electricity consumption is expressed in gigawatt hours (GWh). The GDP series is transformed into real terms using GDP deflators, and is expressed in Mauritian rupees. GDP deflators were obtained from World Development Indicators (World Bank, 2012), and GDP and electricity consumption figures were obtained from the Statistics Mauritius (1961-2012). The two series are presented in Fig. 1. It can be seen that they have both generally been trending upwards, indicating a positive association between them. Electricity consumption has been growing faster than real GDP since around 1985, and it is because of this that official documents have assumed that there is a decoupling – i.e. there is no causal relationship between the two variables (Government of Mauritius, 2007).

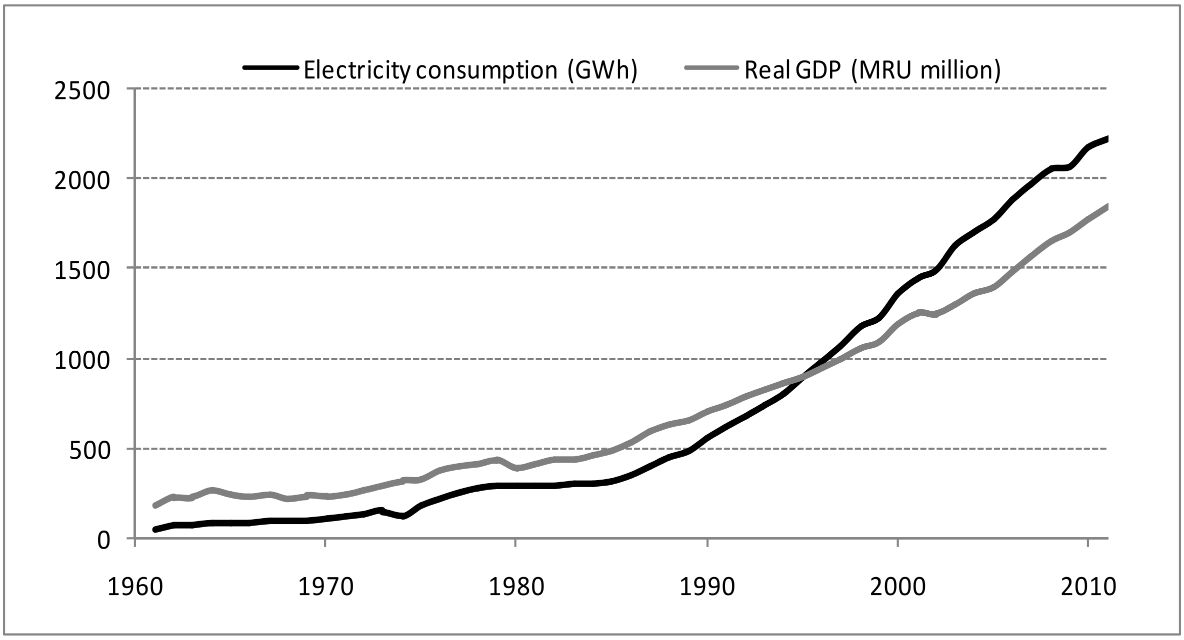

Fig. 1: Electricity consumption and real GDP in Mauritius between 1961 and 2011.

3.2 Unit roots tests

In order to establish any causal relationships between electricity consumption and real GDP, we first undertake the unit roots tests using both the Augmented Dickey-Fuller (ADF) and the Phillips-Perron tests. The variables used in the models are respectively LEC, natural logarithm of electricity consumption, and LGDP, natural logarithm of real GDP. The ADF values of -0.801 and 0.717 and the PP values of -1.17 and -0.13 for LEC and LGDP in levels are not significantly negative (Table 1). The test indicates the existence of unit roots, and that both series are non-stationary. Any causal inferences derived from them would be invalid as previously discussed. The series are therefore first-differenced and the ADF tests carried on them. We used the Schwarz Information Criterion to choose a lag length of 1 for both variables. Non-stationarity is rejected for both series at the 1% level of significance – i.e. they are both I(1).

Table 1: Results of the PP unit root tests

Variables	PP values in levels	PP values in first differences	ADF values in levels	ADF values in first differences
LEC	-1.17	-7.41[a]	-0.801	-3.95[a]
LGDP	-0.13	-7.99[a]	0.717	-4.92[a]

Note: [a] significant at the 1% level

3.3 Cointegration tests

One important consideration before investigating long-run causality was to check for the existence of a structural break. The Chow breakpoint test on the stability of the parameters was conducted with the breakpoint in at 1974[2]. The null hypothesis of no structural break was rejected. The model was subsequently amended to account for the structural break by adding a dummy variable for each year with the shift at the break to act as an intercept shifter. Given that both electricity consumption and GDP are integrated of order 1, we subsequently check whether they are cointegrated over the time period studied here. The results of the Johansen (1990) cointegration test for both series are reported in Table 2.

[2] A visual examination of the electricity series showed a break in 1974, which occurred as a result 1973-1974 oil crisis.

Table 2: Results of Johansen cointegration tests

Null hypothesis	Trace statistic	1% Critical value
The number of cointegrating equation is zero (R=0)	8.34	20.04
The number of cointegrating equation is at most one ($R \leq 1$)	0.21	6.65

The results of the Johansen cointegration test are presented in Table 2. The trace statistics show that the null hypothesis of absence of cointegration (R=0) between the electricity consumption and the GDP series cannot be rejected at the 1% level of significance. Therefore the absence of a cointegrating equation between GDP and electricity consumption implies that there is no long-run equilibrium relationship between the two series. Therefore the standard VAR is used to investigate causality instead of a VECM.

3.4. Granger causality

Regressions (3) and (4) were run to investigate short-run causality. The respective optimal lag length was chosen as 8, using both the Akaike's Information and the Hannan-Quinn information criteria. This method removed the ambiguity involved in the arbitrary choice of the different lag lengths. A similar approach with respect to the existence ofstructural break was adopted. The Chow breakpoint test on the stability of the parameters was again conducted with the breakpoint in at 1974. The null hypothesis of no structural break was rejected. This meant that the model was improved by adding a dummy variable for each year with the shift at the break to act as an intercept shifter. Granger causality tests were then based on the amended VAR to investigate short-run causality between the two variables under study. The F test is used to determine whether a SR relationship exists between the variables through testing the significance of the lagged levels of the variables. The results of the F tests on short-run causality are presented in Table 3.

Table 3: Results of Granger causality tests

Null hypothesis	F statistics	F critical (5%)
EC does not Granger cause GDP	4.48	1.968
GDP does not Granger cause EC	1.609	1.968

The coefficients on electricity consumption are jointly significant in the GDP equation, indicating that short-run causality runs from electricity consumption to GDP. However the reverse short-run causality does not exist in the electricity consumption equation. It is concluded that there is a uni-directional short-run Granger causality from electricity consumption to economic growth in Mauritius over the period 1961 to 2011.

4. Discussions and conclusions

This paper has investigated the relationship between electricity consumption and economic growth in Mauritius using data from 1961 to 2011. The empirical evidence suggests that electricity consumption and economic growth are not cointegrated, however standard granger causality tests indicate that there is unidirectional short-run causality from electricity consumption to GDP, that is an increase in electricity consumption promotes economic growth through the Keynesian multiplier. Even though the Mauritian economy is services-driven, our results point to the fact that production of such services are electricity intensive. We believe that the results provide vital information between the linkages between economic growth and electricity consumption at a time when Mauritius is articulating its first ever long term energy strategy. Such a finding has a number of implications for policy formulation in the power sector of Mauritius. It assists in reducing the ambiguity surrounding the role of electricity consumption in economic growth and in providing policy makers with a better understanding of the roles of the two variables.

An increase in electricity consumption therefore leads to an increase in real GDP. Conversely, a depression in electricity consumption can slow economic growth in Mauritius in the short-run. Approximately 97% of the electricity of Mauritius is generated through thermal (secondary) sources, of which about 80% is from the combustion of fossil fuels like heavy fuel oil, coal and kerosene (Statistics Mauritius, 2012). In order to reduce the vulnerability of Mauritius from external shocks arising from the price volatility of fossil fuels, and also as a means to reduce its national greenhouse gas emissions, it has been proposed to close to halve the growth in consumption of electricity in the next few years (National Economic and Social Council, 2009). Since Mauritius also wishes to pursue social development by increasing economic growth, these two objectives would appear to be in contradiction based on the results reported here, as energy conservation without improvement in productivity and efficiency of energy use may adversely affect economic growth in the short-run. But such energy conservation measures would not necessarily negatively impact economic growth in the long-run.

The results of this study have unambiguously shown that there is a causal relationship between electricity consumption and real GDP in the short-run. This causality needs to be taken into account in formulating meaningful policies and strategies for energy conservation in the power sector. While electricity consumption is a contributing factor to economic growth, the authors acknowledge that there are other factors which impact on economic growth. Hence, this study provides a basis and makes room for further research to be carried out on the electricity consumption and economic growth linkage in Mauritius.

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