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An Econometric Study of Economic Growth, Energy and Exports in Mauritius: Implications for Trade and Climate Policy

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ABSTRACT: While electricity from fossil fuels is among a major source of greenhouse gases and global warming, it is also a key resource in the industrial sector geared towards exports and economic growth. This study attempts to examine the export-GDP nexus and electricity-GDP nexus in addition to a supplementary hypothesis between exports and electricity in Mauritius for the period of 1970-2009. An augmented neo-classical aggregate production model is used. The ARDL bounds test and the Johansen cointegration test confirm the existence of a long-run relationship between these variables. The multivariate Granger-causality analysis indicates that electricity and exports Granger-cause economic growth in the long-run. Electricity remains a significant causal variable in the short-run and is also found to lead exports. The empirical findings suggest that conserving electricity as a climate policy may not be conducive for exports and economic growth. The use of renewable sources for electricity may be the right option.

Keywords: Growth; Exports; Electricity; Granger causality; Climate policy
JEL Classifications: Q37; Q43; Q48

1. Introduction

Since the 1970s, trade liberalisation and globalisation are increasingly recognised as one of the development policies to boost economic growth (Moon, 1998; Dodzin and Vamvakidis, 2004). In many countries, including small island states such as Mauritius, various initiatives were implemented to boost exports in order to reap the benefits of trade (Wellisz and Saw, 1994). However, exports and economic growth are linked within an economic, social and physical structure where fossil fuel consumption is essential. In theory, an adequate supply of infrastructure goods, such as the provision of electricity services, is increasingly acknowledged as one key factor in generating a conducive environment for industrial and economic development and particularly exports (Weisser, 2004; Rud, 2012; Winkler *et al*., 2011)

The electricity sector is also among the most polluting sectors in the world, particularly because of its intensive use of fossil fuels such as diesel, coal, among others (IPCC, 2007; Emanuel, 2007). In recent years, environmentalists have increased their pressure on governments to reduce carbon emissions in order to slow down climate change. Among the options available to policy makers, include a conservation policy towards the use of electricity, through economic instruments. Thus, a major issue is the role of electricity in economic growth and exports. Is electricity usage a stimulus to economic growth and exports or does economic growth lead electricity consumption? If a unidirectional causality running from electricity usage to GDP growth and exports is found, then electricity conservation policy could hamper economic growth as well as exports. Such economy is said to be energy-dependent, and climate policy along a conservation strategy may impact on the

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effectiveness of trade policy. However, if there is a unidirectional causality running from GDP growth and exports to electricity consumption, then electricity conservation usage may be justified with little or no negative repercussions on economic growth and exports. In case the feedback mechanism holds, that is, there is a bi-directional causality between economic growth and exports, and electricity, the economy is trapped in a vicious cycle where more economic growth and exports may require electricity. The lack of causal relationship between electricity and GDP growth and exports would suggest the neutrality hypothesis such that the economy is not dependent on electricity.

A number of studies in the literature have also examined the 'export-led economic growth hypothesis' which postulates that export actively leads to economic growth (Giles and Williams, 2000a; 2000b). Within the exports-economic growth nexus, researchers have also postulated the 'Growth-driven export hypothesis'. Accordingly, economic growth itself promotes trade flows.

However, few studies have analysed the exports-economic growth and the electricity-growth nexus simultaneously (Narayan and Smyth, 2009; Lean and Smith, 2010a; 2010b; Sadorsky, 2011; Sami, 2011). This paper fills the gap by investigating the channels through which fossil fuel energy, economic growth and exports are interrelated. The analysis is conducted for a small island state, Mauritius, which has adopted an outward-oriented development model since the 1970s and has successfully diversified its economy. Electricity provision was also available and hence, Mauritius provides a case study to re-examine the export-led growth hypothesis together with the energy-economic growth nexus in the attempt to examine whether the island is an energy-dependent economy. The conclusion may eventually assist in energy, climate and trade policy.

The paper uses a neo-classical production function framework and applies the Autoregressive Distributed Lag (ARDL) bounds test as well as the Johansen-Juselius test for cointegration. The short-run and long-run dynamics are analysed through the Vector Error Correction Model (VECM) and the Granger multivariate test.

The paper is structured as follows: section 2 provides a brief review of literature on the export-led growth and the energy-growth nexus. It concludes with the recent studies on combining exports, electricity and economic growth in a single system of equations. Section 3 gives a brief outline of exports, electricity and economic growth in Mauritius. The empirical methodology is detailed in section 4 and section 5 provides the empirical results. The conclusion and policy implications are provided in section 6.

2. Export, Energy and Output – A Brief Review of Literature

2.1. Exports – Economic growth nexus

Many scholars have postulated that exports play a significant role in economic growth of various countries (Vamvoukas, 2007). This is consistent with macroeconomic theory since exports are injections to the economy (Kaldor, 1967; Romer, 1989; Krueger, 1990; Ahmed *et al.*, 2000). The export sector has also spillover effects on the production process of the rest of the economy which contribute to greater total productivity. Moreover, through a higher degree of specialization, the country can reap the fruits of economies of scale and comparative advantage.

Increasing exports may help the country to import high value inputs, products and technologies that may have a positive impact on economy's overall productive capacity (Jung and Marshall, 1985; Krisna *et al.*, 2003; Vamvoukas, 2007). Exports, thus, loosen the biding foreign exchange constraint and allow increases in productive intermediate imports. They may also speed up the adoption of new practices since firms that operate in the world economy are forced to remain efficient and competitive by adopting the latest technological developments in their production process. Moreover, firms have incentives to increase R&D in order to keep up with foreign competition.

However, exports may not add to GDP growth if they crowd out growth in domestic consumption and investment. Moon (1998) argues that the excessive specialisation of a particular product, which emanates from an outward-oriented paradigm, may harm economic growth.

The empirical evidence between exports and growth has led to inconclusive results. Jung and Marshall (1985) apply a bivariate causality test between real GDP and exports for 37 countries and conclude that export-led hypothesis is found only for Indonesia, Egypt, Costal Rica and Ecuador.

Chow (1987) uses Sim's test of causality and concludes that there is strong bi-directional causality between the growth of exports and industrial development measured as the growth of the manufacturing sector, for the newly industrialising countries (NICs), including Brazil, Hong-King, Argentina, Israel, Korea, Mexico, Singapore, and Taiwan. Bahmani-Oskooee *et al*. (1991) in turn use the Hsiao two-step procedure of combining the Granger's causality test with the Akaike's (1969, 1970) Final Prediction Error criterion to the test the export-led hypothesis and conclude that there is support in favour of export promotion development strategy in East Asian NICs such as Korea and Taiwan.

2.2. Energy (electricity) – Economic growth nexus

The electricity-growth nexus has been the subject of interest of many researchers since the pioneering of Kraft and Kraft (1978). The theoretical foundation of considering energy as a determinant of real output can be found in the Solow growth model (Solow, 1956) with exogenous technical progress. This is commonly referred to as the growth hypothesis of energy (Ozturk, 2010) and suggests that energy consumption plays an important role in economic growth both directly and indirectly in the production process as a complement to labour and capital. Restrictions on the use of energy may adversely affect economic growth while increases in energy may contribute to economic growth.

Studies which are aimed at unravelling the linkages between the two variables differ according to the econometrics methods, methods used for both the cointegration relationship and the causality tests, the variables included in the analysis and the time periods in their analysis. In many studies, the Vector Error Correction model (VECM) for Granger-causality test has been used (Ghosh, 2002; Jumbe, 2004). The Hsiao's test (Aqeel and Butt, 2001; Yoo, 2006) and the Toda-Yamamoto's test (Wolde-Rufael, 2006; Squalli, 2007) have also been used for causality tests. Studies also differ in relation to their cointegration technique since some researchers use the Johansen-Juselius cointegration method while others such Lean and Smyth (2010a, b; Ozturk and Acaravci, 2011) apply the Autoregressive Distributed Lag bounds test. .

Results from the cited studies do not make it possible to conclude the direction of causality between electricity and economic activity. Thus, bi-directional causality between electricity and economic growth is found for Taiwan by Yang (2000), Malawi by Jumbe (2004), Malaysia by Chandran *et al*. (2010), and South Africa by Odhiambo (2009). Unidirectional causality from economic growth to electricity consumption is found for India (Ghosh, 2002), Australia (Narayan and Smyth, 2005), Indonesia (Yoo and Kim, 2006), among others. In contrast, electricity consumption is found to lead to economic growth in Turkey by Altinay and Karagol (2005), Taiwan (Lee and Chang, 2005) and Botswana (Adebola, 2011).

2.3. Exports, electricity and economic growth

Based on the growth-led hypothesis of energy, electricity may be a causal factor to exports as well as to economic growth. If this is hypothesis is proven, then the provision of electricity and issues relating to the generating of electricity (renewable versus non-renewable and energy reform) matter to trade policy. Lean and Smyth (2010a) employ annual data for Malaysia from 1970 to 2008 to examine the causal relationship between economic growth, electricity generation, exports and prices in a multivariate model and conclude that there is a unidirectional Granger causality running from economic growth to electricity generation and the exports led hypothesis is not supported. Lean and Smyth (2010b), however, use a production function framework with capital and labour for Malaysia and conclude there is evidence for the export-led hypothesis. Electricity conservation policies may be designed without affecting economic growth. Sadorsky (2011) uses a panel cointegration data estimation technique to examine the impact of trade on energy consumption for a sample of 8 Middle Eastern countries and conclude that in the short-run, there is evidence of Granger causality running from exports to energy consumption.

3. Electricity Consumption, Exports and Economic Growth in Mauritius

Mauritius is an island of approximately 1860km^2 with 330 km of coastline. With a population of around 1.2 million, it ranks among the top African countries in terms of income and employment. After independence in 1968, the island was based on a mono-crop economy with sugar as the main foreign exchange earner. The economy experienced a boom period with the rise in sugar prices and good crops in the early 1970s but eventually suffered an economic crisis, with high government deficit, huge outstanding foreign debt, high inflation and massive unemployment in the late 1970s.

This eventually led to a devaluation of the Mauritian currency on October 23, 1979 by about 22.9% (Wellisz and Saw, 1994). Real investment, however, was relatively more vulnerable to the

1970s crisis. A distinctive feature of the Mauritian economy has been the rapid and sustained growth of its exports during the last four decades (table 1). In the late 1960's, exports comprised mainly of sugar and molasses (98%) while foreign direct investment was virtually non-existence (Wellisz and Saw, 1994). The wave for economic versification and trade liberalisation touched the economic and social fabric of Mauritius since the 1970s and the island followed a pragmatic development strategy in which trade liberalisation was tailored to its competitive advantages and weaknesses (Vandermoortele and Bird, 2010).

Table 1. Economic indicators: export-oriented enterprises in Mauritius

	1973	1980	1990	2000	2010
GDP per capita (US$)	600	1177	2506	3651	7591
Number of enterprises	32	100	568	518	372
Employment	5800	21344	89906	90682	55828
% share in manufacturing	Na	28.5	51.1	50.7	37.3
% share in GDP	Na	3.7	12.5	11.4	6.9
Source: CSO publications					

As far as electricity is concerned, after a slowing down in the early 1980s, its consumption per capita rose steadily during last three decades. Mauritius is currently witnessing an increase reliance on coal for the production of electricity. Coal accounts for more than 25% of Mauritian's primary energy requirement and is particularly required by the Independent Power Producers (IPP). In 2007, the production of IPP exceeded the Central Electricity Board (CEB) supply of electricity which is the first generator of the electricity for Mauritius, implying that the CEB might cater mainly for peak and semi-peak demand, leaving the more lucrative base-load supply-side to IPPs (Elahee, 2010).

Mauritius's strong economic performance of recent years requires continuing effort to maintain and also widen the ambit of economic reform. As one of these efforts, the Government of Mauritius has given higher priority for energy development projects. In spite of the given higher priority, the energy sector is struggling hard to achieve its target due to the major expenses involved in the imported fossil fuels (Palanichamy *et al*., 2004).

4. Econometric Methodology

To investigate the linkages between electricity, exports and economic growth, a neo-classical one-sector aggregate production model where capital formation, as well as exports and electricity are treated as separate factors of production:

$$Y_t \equiv f(X_t, E_t, K_t, L_t) \tag{1}$$

where Y_t is aggregate output or real GDP; X_t real exports; K_t is the capital stock; L_t is the level of employment and E_t is aggregate electricity. The subscript t denotes the time period. Dividing by labour, we postulate the following equation:

$$y_t \equiv f(x_t, e_t, k_t) \tag{2}$$

Where $y_t = \dfrac{Y_t}{L_t}, x_t = \dfrac{X}{L_t}, e_t = \dfrac{E_t}{L_t}, k_t = \dfrac{K_t}{L_t}$

Taking the log linear form of Eq. (2), we can obtain:

$$ln\, y_t \equiv \alpha_0 + \beta_1\, ln\, x_t + \beta_2\, ln\, e_t + \beta_3\, ln\, k_t + \varepsilon_t \tag{3}$$

where the logarithmic form means that the variables are now in a growth rate form. The coefficients $\beta_1, \beta_2, \text{and} \beta_3$ refers to the elasticity of output with respect to real exports, electricity consumption, and capital stock, respectively.

The relationship between GDP per capita, real exports, capital stock, and electricity consumption described by the production function in Eq.(2) indicates that in the long-run, real output, capital, real exports and electricity consumption may move together (Ghali and El-Sakka, 2004; Soytas and Sari 2007; Wang *et al*., 2011). Hence, there may be a long-run equilibrium relationship between the variables of concern, and can be easily examined using tests for multivariate cointegration and Granger-causality. If we allow for short-run dynamics in factor-inputs behaviour, the analysis above would also suggest that past changes in real exports, and electricity consumption could contain useful information for predicting the future changes of output, *ceteris paribus* (Wang *et al.*, 2011). The estimation procedure is based on two elements: the cointegration techniques and the econometrics to unravel the short- and long-run dynamics. If two non-stationary series form a stable linear relationship, then they are said to be cointegrated and according to the Representation Theorem, there is an error correction representation. The next step is to estimate the error correction model which identifies the short run dynamics of the system as well as the long-run linkage. The procedures are described below.

4.1. The ARDL bounds test approach to cointegration

The autoregressive distributed lag (ARDL) approach of Pesaran and Pesaran (1997) and Peseran *et al.* (2001) is used to test for existence of the long-run equilibrium relationship between energy data, real GDP and exports. This approach can be applied to series irrespective of whether they I(0) or I(1) or mutually cointegrated. Another commonly used approach was developed by Johansen (1988) and Johansen and Juselius (1990) and is more efficient in multivariate systems. The ARDL approach has some advantages over these other approaches. First, the series used do not have to be I(1) (Pesaran and Pesaran, 1997). Second, even with small samples, more efficient cointegration relationships can be determined (Ghatak and Siddiki, 2001).

$$\begin{aligned}\Delta LRGDP_t &= a + \sum_{i=0}^{m} b_{igdp}\,\Delta RGDP_{t-1} + \sum_{i}^{q} c_{igdp}\,\Delta LINV_{t-i} + \sum_{i=0}^{n} d_{igdp}\,\Delta LELEC_{t-1}\\ &+ \sum_{l=i}^{k} e_{igdp}\,\Delta LEXPO_{t-i} + \eta_{1gdp}\,LRGDP_{t-1} + \eta_{2gdp}\,LINCV_{t-1} + \eta_{3gdp}\,LELEC_{t-1}\\ &+ \eta_{4gdp}\,LEXPO_{t-1} + \varepsilon_{gdp,t}\end{aligned} \tag{4}$$

$$\begin{aligned}\Delta LINV_t &= a_{inv} + \sum_{i=0}^{m} b_{i,inv}\,\Delta LRGDP_{t-1} + \sum_{i}^{q} c_{i,inv}\,\Delta LINV_{t-i} + \sum_{i=0}^{n} d_{i,inv}\,\Delta LELEC_{t-1}\\ &+ \sum_{l=i}^{k} e_{i,inv}\,\Delta LEXPO_{t-i} + \eta_{1inv}\,LRGDP_{t-1} + \eta_{2inv}\,LINV_{t-1} + \eta_{3inv}\,LELEC_{t-1}\\ &+ \eta_{4inv}\,LEXPO_{t-1} + \varepsilon_{inv,t}\end{aligned} \tag{5}$$

$$\begin{aligned}\Delta LELEC_t &= a_{ele} + \sum_{i=0}^{m} b_{i,elec}\,\Delta LRGDP_{t-1} + \sum_{i}^{q} c_{i,ele}\,\Delta LINV_{t-i} + \sum_{i=0}^{n} d_{i,elec}\,\Delta LELEC_{t-1}\\ &+ \sum_{l=i}^{k} e_{iele}\,\Delta LEXPO_{t-i} + \eta_{1ele}\,LRGDP_{t-1} + \eta_{2elec}\,LINV_{t-1} + \eta_{3elec}\,LELEC_{t-1}\\ &+ \eta_{4elec}\,LEXPO_{t-1} + \varepsilon_{elec,t}\end{aligned} \tag{6}$$

$$\begin{aligned}\Delta LEXPO_t &= a_{exp} + \sum_{i=0}^{m} b_{i,exp}\,\Delta LRGDP_{t-1} + \sum_{i}^{q} c_{i,exp}\,\Delta LINV_{t-i} + \sum_{i=0}^{n} d_{i,exp}\,\Delta LELEC_{t-1}\\ &+ \sum_{l=i}^{k} e_{iexp}\,\Delta LEXPO_{t-i} + \eta_{1exp}\,LRGDP_{t-1} + \eta_{2exp}\,LINV_{t-1} + \eta_{3exp}\,LELEC_{t-1}\\ &+ \eta_{4exp}\,LEXPO_{t-1} + \varepsilon_{exp,t}\end{aligned} \tag{7}$$

The cointegration analysis is carried out by testing the joint significance of the lagged levels of the variables using the F-test where the null of no cointegration is defined by $H_o : \eta_{1j} = \eta_{2j} = \eta_{3j} = \eta_{4j} = 0$ *(for j=gdp, inv ,ele, exp)* for the system equations. The alternative that is $H_1 : \eta_{1j} \neq \eta_{2j} \neq \eta_{3j} \neq \eta_{4j} \neq 0$.

According to Pesaran *et al.* (2001), under the null hypothesis of no co-integration and regardless of the degree of integration of the variables, the asymptotic distribution of the obtained F-statistic is non-standard. This depends upon whether variables included in the ARDL model are I(0) or I(1), the number of regressors, whether the ARDL model contains an intercept and/or a trend, and (d) the sample size. Two sets of critical F values, representing the lower bound and the upper bound critical values have been provided by Pesaran *et al.* (2001) for large samples. Narayan (2005) presents the critical F values for sample size ranging 30–80. If the computed F-statistic for a chosen level of significance lies outside the critical bounds, a conclusive decision can be made regarding co-integration of the regressors. If the F-calculated is higher than the upper bound, the null hypothesis of no cointegration can be rejected.

4.2. The Johansen-Juselius test

According to Johansen and Juselius (1990), if $Y_t = (LRGDP_t, LINV_t, LELEC_t, LEXPO_t)$ represents a sequence of non-stationary random vectors, then Y follows a vector autoregressive (VAR) process of order k, such that

$$Y_t = \Pi_1 Y_{t-1} + \dots + \Pi_k Y_{t-k} + V_t \qquad t = 1 \dots T, \tag{8}$$

with V_t as the corresponding vector of Gaussian innovations. Eq. (1) is equivalently written as a vector-error-correction model (VECM).

$$\Delta Y_t = \Gamma_1 \Delta Y_{t-1} + ... + \Gamma_k \Delta Y_{t-k+1} - \prod Y_{t-k} + V_t \tag{9}$$

where Δ is the first-difference operator. The 4x4 matrix $\prod$ conveys information about the long-run relations among energy prices, In particular, $rank(\prod = r < 4)$ suggests the existence of r cointegrating relations among the three variables.

The Johansen cointegration strategy allows estimating the cointegrating vectors between the non-stationary variables of the model, using a maximum likelihood technique which tests the cointegrating rank. The presence of a cointegrating relation among the four variables forms the basis for the specification of the vector-error-correction model (VECM). We are primarily interested in the error-correction model (ECM) for real GDP, electricity consumption, capital formation and real exports to capture their dynamic relations. The ECM represents the change in one variable as a linear function of its past changes, past changes in the other variables, and an error-correction term. For a cointegrated system, the error-correction term represents the deviation from the equilibrium relationship. Thus, an ECM provides two alternative channels of the interaction among electricity prices, aggregate electricity and GDP: short-run causality through past changes in the variable, and long-run causality through adjustments in equilibrium error. According to the Granger representation theorem, if two or more variables are cointegrated they can always be transformed into an error correction mechanism (ECM). A Vector Error Correction Model (VECM) is particularly useful in time series analysis since they investigate the short- and long-run properties of the system variables. The variables in their differenced form reflect the short-run dynamics of the model, while the long-run relationship is incorporated in the estimation procedure by including the lagged cointegrating vector. The VECM for our four variables case can be written as follows:

$$\begin{aligned}\Delta LRGDP_t = \alpha_1 &+ \sum_{i=1}^{t} \beta_{1i} \Delta LRGDP_{t-1} + \sum_{i=1}^{m} \gamma_{1i} \Delta LINV_{t-i} + \sum_{i=1}^{n} \partial_{1i} \Delta LELEC_{t-1} \\ &+ \sum_{i=1}^{o} \kappa_{i1} \Delta LEXPO_{t-1} + \varphi_1 ECT_{r,t-1} + \varepsilon_{it}\end{aligned} \tag{10}$$

$$\begin{aligned}\Delta LINV_t = \alpha_2 &+ \sum_{i=1}^{t} \beta_{2i} \Delta LRGDP_{t-1} + \sum_{i=1}^{m} \gamma_{2i} \Delta LINV_{t-i} + \sum_{i=1}^{n} \partial_{2i} \Delta LELEC_{t-1} \\ &+ \sum_{i=1}^{o} \kappa_{2i} \Delta LEXPO_{t-1} + \varphi_2 ECT_{r,t-1} + \varepsilon_{2t}\end{aligned} \tag{11}$$

$$\begin{aligned}\Delta LELEC_t = \alpha_3 &+ \sum_{i=1}^{t} \beta_{3i} \Delta LRGDP_{t-1} + \sum_{i=1}^{m} \gamma_{3i} \Delta LINV_{t-i} + \sum_{i=1}^{n} \partial_{3i} \Delta LELEC_{t-1} \\ &+ \sum_{i=1}^{o} \kappa_{3i} \Delta LEXPO + \varphi_3 ECT_{r,t-1} + \varepsilon_{it}\end{aligned} \tag{12}$$

$$\begin{aligned}\Delta LEXPO_t = \alpha_4 &+ \sum_{i=1}^{t} \beta_{4i} \Delta LRDGDP_{t-1} + \sum_{i=1}^{m} \gamma_{4i} \Delta LLINV_{t-i} + \sum_{i=1}^{n} \partial_{4i} \Delta LELEC_{t-1} \\ &+ \sum_{i=1}^{o} \kappa_{4i} \Delta LEXPO_{t-1} + \varphi_4 ECT_{r,t-1} + \varepsilon_{it}\end{aligned} \tag{13}$$

The F- test is applied to the $\sum_{i=1}^{t} \beta_{mi}, \sum_{i=1}^{m} \gamma_{mi}, \sum_{i=1}^{n} \partial_{mi},$ and $\sum_{i=1}^{o} \kappa_{mi}$ for m=1,..,4 for short-run causality while the t-test is applied to the coefficient of the ECM, φ_n for n=1,...4 for long-run causality.

5. Data and Empirical Results

5.1. Data sources

The data used in this study are taken from the Annual Digest of Statistics, National Accounts of Mauritius, Annual Report of Central Electricity Board and Digest of Energy Statistics. We have annual observations that cover the period 1970-2009. GDP is obtained from the Annual Digest of

Statistics and is deflated by GDP deflator; capital formation is proxied by GDFCF from National Accounts of Mauritius. Real exports are obtained from the Trade Digest and are deflated by the consumer price index. Exports relate to merchandised exports only. The collection of data set is governed by the availability of sufficient observations to ensure adequate degrees of freedom for the estimation procedure. Table 2 shows the descriptive statistics for the variables.

Table 2. Descriptive Statistics

Variables	Description	Number of observation	Mean	Standard deviation	Minimum	Maximum
$LRGDP_t$	Real GDP per capita	40	11.342	0.450	10.548	12.036
$LELEC_t$	Electricity per capita	40	6.258	0.772	4.884	7.392
$LEXPO_t$	Real Exports per capita	40	10.358	0.425	9.408	10.911
$LINV_t$	Real investment per capita	40	6.703	0.654	5.042	7.677
Notes: all variables are in logarithm						
Source: author's calculation						

5.2. Unit root tests

Table 3 provides tests of unit roots in level and first difference of the variables: $LRGDP_t$, $LINV_t$, $LELEC_t$ and $LEXPO_t$ using the Augmented Dicker-Fuller (ADF) method and the Phillips-Perron (PP) test. The ADF test shows that real GDP per capita and capital formation are stationary at level form but the remaining variables electricity per capita and real exports per capita are not. However, the first differences of all the four variables are stationarity. The conclusions are consistent for the Phillip-Perron test where all variables at first difference are stationary. Hence, we conclude that the variables are *I(1)* and proceed with the cointegration test.

Table 3. Unit Root Test

Variables	Augmented Dicker Fuller (ADF) Unit root test		Phillip-Perron (PP) test	
Level form	ADF test statistics	Critical Values (LL)	PP test statistics (Z(rho))	BW(LL)
$LRGDP_t$	-5.705	-3.525(3)	-1.553	-12.948(3)
$LINV_t$	5.607	-3.525(3)	-4.064	-12.948(3)
$ELEC_t$	-2.306	-3.525(2)	-0.440	-13.108(3)
$LEXPO_t$	-1.691	-3.525(0)	-3.712	-12.948(3)
First Difference form				
$\Delta LRGDP_t$	-3.587	-3.528(1)	-52.936	-12.948(3)
$\Delta LINV_t$	-3.315	-2.938(3)[1]	-37.377	-12.948(3)
$\Delta LELEC_t$	-2.960	-2.936(0)[1]	-17.399	-13.076(3)
$\Delta LEXPO_t$	-6.869	-3.528(0)	-42.650	-12.948(3)
Notes: The second and fourth column show the critical values at 5% level. The critical values are calculated from MacKinnon (1991). LL stands for lag lengths and BW stands for bandwidth. The lag lengths are selected using the Schwarz Bayseian criterion while the bandwidth is selected using the Newey–West Bartlett kernel. Both tests were conducted including an intercept and linear deterministic trend unless it is mentioned otherwise. [1]The ADF test does not include the trend.				
Source: computed from Microfit 4.0.				

5.3. The ARDL bounds test results

The results of the ARDL bounds test are shown in table 4. Based on the critical values from Narayan (2005), we found that there is a cointegrating relationship when the differenced GDP per capita, investment and electricity is used as dependent variables.

Table 4. Results of The Bounds Tests

Equation	Estimated F-statistics	5% critical value bounds		Evidence of cointegration
		I(0)	I(1)	
$F_{LRGDP}(LRGDP_t/, LINV_t, LELEC_t, LXPO_t)$	4.232	2.907	3.982	Yes
$F_{LINV}(LRINV_t/, LRGDP_t, LELEC_t, LEXPO_t)$	7.267	2.907	3.982	Yes
$F_{LELEC}(LELEC_t/, LRGDP_t, LXEXPO_t, LINV_t)$	5.210	2.907	3.982	Yes
$F_{LEXPO}(LEXPO_t / LRGDP_t, LINV_t, LELEC_t)$	1.638	2.907	3.982	no
Notes: Critical values are for the model with intercept but no trend with k=4 regressors The estimation is made for the period 1970 to 2009.				
Source: computed from Microfit 4.0.				

Table 5 provides the diagnosis tests which form the basis for the ARDL bounds test. All the regressions pass the diagnosis tests with the exception of the GDP equation where a problem of Heteroscedasticity is seen which implies that results must be interpreted with care.

Table 5. Diagnosis Test For The ARDL Bounds Regressions

Dependent variables on first difference	R bar square	LM test	Ramsey RESET test	Normality test	Heteroscedasticity tests
Real GDP per capita	0.618	2.394(0.133)	2.364(0.135)	1.745((0418)	7.982(0.008)
Capital formation	0.623	2.809(0.107)	1.338(0.259)	1.502(0.472)	0.250(0.620)
Electricity consumption per capita	0.629	1.010(0.323)	0.003(0.96)	1.008(0.604)	2.600(0.115)
Real exports per capita	0.232	0.680(0.416)	0.951(0.338)	0.912(0.634)	0.321(0.574)
The LM test is the Lagrange Multiplier test for serial correlation; the normality test is based on Bera and Jarque (1981); The RESET test os the Ramsey (1969) test of fitting the square of fitted values; the Heteroscedasticity test is based on the LM test. Probability values are in bracket.					
Source: computed from *Microfit 4.0*					

5.4. The Johansen-Juselius cointegration test

We supplement the bounds test results with the Johansen-Juselius cointegration test and the results are shown in table 6. The choice of lag length is made according to the SBC criterion. Table 6 concludes that there is one cointegration rank (long-run relationship). Hence, we proceed with estimating the VECM.

5.5. Results from the VECM

Table 7 provides the results from the VECM. Before proceeding with further analysis, it is important to check the robustness of the estimates. The regression results are subject to a series of diagnostic tests (*see notes of table 7*). The GDP regression and investment results show a problem of functional form as seen by the RESET test while exports exhibit a potential for heterocedascity. However, the regressions are the best estimates which can be derived with the data and hence we proceed with the Granger-causality test.

Table 6. Results from Johansen-Juselius test

Number of observation =40 List of variables: $LRGDP_t, GDFCF_t, ELEC_t, REXP_t$				
LR test maximal Eigenvalue of the stochastic matrix				
Null: no coinetration	Alternative: r = number of cointegrating vectors	Statistics	95% critical value	Conclusion
$r = 0$	$r = 1$	36.999	27.420	Reject the null hypothesis
$r \leq 1$	$r = 2$	19.302	21.120	Do not reject the null hypothesis
$r \leq 2$	$r = 3$	8.956	14.880	Do not reject the null hypothesis
LR test based on Trace of the stochastic matrix				
$r = 0$	$r \geq 1$	66.282	48.880	Reject the null hypothesis
$r \leq 1$	$r \geq 2$	29.283	31.540	Do not reject the null hypothesis
$r \leq 2$	$r \geq 3$	9.981	17.860	Do not reject the null hypothesis
r indicates numbers of cointegrating relationships.				
Source: computed from Microfit 4.0.				

Table 7. Results From VECM

	$\Delta LRGDP_t$	$\Delta LINV_t$	$\Delta LELEC_t$	$\Delta LEXPO_t$
Constant	1.051(0.253)***	1.772(0.622)***	-0.069(0.196)	2.196(0.587)***
$\Delta LRGDP_t$	-0.538(0.146)***	0.210(0.126)	-0.293(0.112)***	-0.596(0.339)*
$\Delta LINV_t$	0.314(0.051)***	0.066(0.126)	0.086(0.040)**	0.335(0.119)**
$\Delta LELEC_t$	0.685(0.247)***	1.512(0.607)***	0.706(0.191)***	0.258(0.572)
$\Delta LEXPO_t$	-0.064(0.065)	0.499(0.161)***	0.077(0.050)	-0.340(0.151)**
ECM_t	0.169(0.042)***	0.299(0.103)***	-0.005(0.033)	0.362(0.098)***
$\overline{R}^2$	0.578	0.544	0.461	0.357
DW	2.369	2.225	2.092	1.759
LM test	1.850	2.218	0.323	0.113
RESET-F statistics	7.569	3.672*	0.007	0.092
Normality test (Chi-square)	1.273	0.312	0.437	1.522
Heteroscedasticity test	6.288	0.039	0.389	4.503**
$ECM_{t-1} = -0.817LRGDP_{t-1} - 0.996LINV_{t-1} + 1.23LELEC_{t-1} - 0.711LEXPO_{t-1})$				
Note: DW is the Durbin-Watson statistics; LM test is the Lagrange Multiplier test for serial correlation; the normality test is based on Bera and Jarque; The RESET test is the Ramsey test of fitting the square of fitted values; the Heteroscedasticity test is based on the LM test. Standard errors are in bracket. * and ** means significant at 1% and 5%.				
Source: computed from Microfit 4.0				

5.6. Multivariate Granger-causality test

Table 8 shows the Multivariate Granger-causality tests based on the VECM estimates. The F-test is applied to the coefficients of each relevant variable to test for causality.

Table 8. Granger Multivariate Causality F-Tests, 1970-2009

	Short-run (SR) causality(F-test)		Long-run (LR) causality (ECM)	
$LRGDP_t \rightarrow LELEC_t$	6.718(0.010)	SR causality	-0.005(0.882)	No LR causality
$LELEC_t \rightarrow LRGDP$	7.723(0.005)	SR causality	0.169(0.000)	LR causality
$LRGDP_t \rightarrow LEXPO_t$	3.090(0.079)	SR causality	0.36(0.001)	LR causality
$LEXPO_t \rightarrow LRGDP_t$	0.954(0.329)	No SR causality	0.169(0.000)	LR causality
$LELEC_t \rightarrow LEXPO_t$	0.203(0.653)	No SR causality	0.36(0.001)	LR causality
$LEXPO_t \rightarrow LELEC_t$	2.338(0.126)	No SR causality	-0.005(0.882)	No LR causality
Note: The F-test is applied to the coefficients of the relevant difference variables to examine SR causality while the t-statistics of the coefficients of the ECM is used for LR causality. Figures in parenthesis are probability values				
Source: Computed from Microfit 4.0				

The hypothesis that electricity Granger-causes GDP per capita is not rejected in the short-run. There is evidence that in the short-run, there is a bi-directional causality between electricity and GDP since GDP also Granger-causes electricity. Again, in the short-run, the results show that the GDP per capita Granger-causes real exports. The hypothesis that exports lead GDP per capita or electricity is not supported in the short-run.

In the long-run, however, we found that electricity Granger-causes both GDP per capita as well as real exports. Our conclusion is that electricity is a vital input in the production function of the economy in determining variations in GDP per capita and real exports. In the long-run, the evidence also supports the bi-directional causality between exports and GDP per capita. However, electricity is not Granger-caused by any of these variables in the long-run.

Table 9. Granger multivariate causality tests, 1970-2009

	Short-run (SR) causality (F-test)		Long-run causality (ECM)	
$LINV_t \rightarrow LELEC_t$	4.707(0.030)	SR causality	-0.005(0.882)	No LR causality
$LELEC_t \rightarrow LINV$	6.213(0.013)	SR causality	0.299(0.007)	LR causality
$LINV_t \rightarrow LEXPO_t$	7.880(0.005)	SR causality	0.36(0.001)	LR causality
$LEXPO_t \rightarrow LINV_t$	8.112(0.004)	SR causality	0.299(0.007)	LR causality
Note: The F-test is applied to the coefficient of the relevant difference variables to examine SR causality while the t-statistics of the coefficients of the ECM is used for LR causality. Figures in parenthesis are probability values				
Source: computed from Microfit 4.0				

Table 9 investigates an additional channel through which exports and electricity may influence economic activities. We conclude that exports and electricity both Granger-cause investment in the short-run as well as in the long-run. We also witness reverse causation from investment to exports in the short-run as well as in the long-run.

6. Conclusion and Policy Implications

The previous section concludes that real GDP per capita, capital formation, real exports and electricity consumption are cointegrated, implying that there is long-run steady state equilibrium among these variables. The long-run causality test concludes that real GDP per capita, capital formation and real exports all adjust to shocks in the long-run cointegrating equation and are likely to be negatively affected by electricity conservation strategy. In the long-run, we also found that electricity as well as real exports, both Granger-cause capital formation. Electricity, however, is not found to be affected by shocks in the cointegrating vector. Hence, the feedback hypothesis does not hold for electricity. The short-run Granger causality test indicates that real income per head is Granger-caused by electricity consumption and investment. It may be concluded that the impact of exports in the economy is channelled through its effect on investment in the short-run. The effect of electricity consumption on investment is worth emphasising. Electricity consumption is found to be important for both economic growth as well as for capital formation in the short-run.

This study highlights the importance of electricity provision as an infrastructural service for economic growth, investment as well as for real exports and leads to the conclusion that Mauritius might have benefitted from the availability of electricity as a source of competitiveness to facilitate its export performance. The electricity sector is also closely linked with climate change mitigation policy. Within the spectre of global climate change, the implementation of renewable energy technology in the electricity sector should be given critical priority, rather than the adoption of a conservation policy. The use of renewable for electricity generation results in less greenhouse gas emissions compared to fossil fuel energy systems and often offers additional synergistic benefits. For instance, Mauritius has substantial potential to utilize many renewable energy alternatives such as Photovoltaic and solar systems, small and micro hydro systems, biomass technologies, and wind energy (Palanichamy *et al*., 2004). However, it is seen that despite the large potential for development of renewable energy source, currently their contribution to electricity generation remains low. The commercialisation and deployment of these technologies is impeded by many barriers. Renewable energy costs remain considerably higher than those of fossil energy, meaning that the price of electricity produced by using these technologies is still significantly higher than the price of electricity produced by using conventional technologies.

Recent progress in economic integration, trade and globalisation has led to rising debate on the linkages between the environment and liberalised trade. While energy infrastructure is vital for trade competiveness, clean energy is necessary for climate policy. The debate continues despite vast research and poses a challenge for researchers and policy-makers. The recent complaint made by the United State Trade Representatives in December 2010 against China at the WTO that China's wind power manufacturing support programme violates the WTO's subsidy agreement is an indication that issues are not clear as far as trade and climate policy are concerned.

Given the conclusion emanating from this study, the electricity sector provides one option where trade and climate change policy can be mutually reinforcing and provides opportunity for dialogue. If electricity is found to be a key ingredient as an infrastructural requirement for trade, climate change policy requires the implementation of renewable sources of energy. Hence, trade and climate debate and dialogue could well look into a win-win situation of creating the proper environment for trade to take place at the same time, leading investment in environmental-friendly products. The Clean Development Mechanism (CDM) provides an avenue for synergy to clean energy investment which will contribute to trade. Moreover, aid for trade can be directed towards green energy for trade competitiveness.

With rapid changes in the electricity sector, combined with challenges of climate change, a more comprehensive discussion at the international level would be useful. Trade policy aiming at reducing trade barriers and open markets in energy technology, including environmentally-friendly goods and services, would be a possible solution as the global community looks for solutions to the challenge of climate change.

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