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Dynamic linkages between transport energy and economic growth in Mauritius – implications for energy and climate policy

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Abstract

The consumption of fossil fuels in the transport sector represents the fastest growing source of greenhouse gases in the world – a major source leading to global warming. While action is needed to restrict the use of fossil fuels, such a conservation policy relies on the relationship between energy and economic growth. The paper investigates the causal relationship between economic growth and transport energy in Mauritius for the period 1970-2010 using an aggregate production framework with real investment. Gasoline and diesel are analyzed separately. The bounds test cointegration approach is applied and the error correction representation concludes that there is a unidirectional Granger causality running from economic growth to transport energy in the long-run. A rise in transport energy is, therefore, expected with economic progress. This result is attributed to discretionary mobility arising from high standard of living. However, bi-directional causality is found between transport energy and real investment. Restricting transport energy may therefore be detrimental to real investment and long-run growth in Mauritius.

1. Introduction

The society is currently dumping around 800 tonnes of carbon dioxide - the most important greenhouse gases (GHGs) - into the atmosphere each and every second, and forecasts indicate that the rate will increase to 1600 tonnes a second by about 2050 (Palmer 2008). Given the slow atmospheric carbon absorption, such emissions act as a stock pollutant and its concentration is likely to raise the earth average temperatures (Boko *et al*. 2007). Evidence from the Intergovernmental Panel on Climate Change (IPCC) clearly shows that changes in climatic conditions are expected as greenhouse gases accumulate (IPCC 2007). Greenhouse gases come mostly from the use of energy which is central to economic activity. There is, in fact, an overwhelmingly scientific consensus that action is needed to restrict the use of fossil fuels (Chapman 2007). The transport sector is among the main sectors which represent the fastest growing source of GHGs, partly because it plays an important role in economic activities (Wright & Fulton 2005; Abmann & Sieber 2005).

Given the role of the transport sector in the economy, development strategists face a dilemma since economic growth is desirable but not its negative effects. Sustainable transport strategy must take into account the rising demand for fossil fuels and the negative effects of carbon emissions at the same time (Abmann & Sieber 2005). Various measures have been proposed for sustainable transport to be in line with climate policy. Options for sustainable transport as reviewed by Abmann & Sieber (2005) include the use of renewable energy, such as bio-fuels, and the restriction of transport demand through economic instruments such as fuel or carbon taxes. In short, strategies for sustainable transport can be broadly classified into two policy measures –renewable energy development versus energy reduction. Both have one common aspect - they both come at a cost. However, as far as restricting energy is concerned, its implication relates to the effects of reducing fossil fuels on economic growth.

Policy makers are expected to be fully aware of the nexus between transport energy and economic growth for both energy and environmental policy (Oh & Lee 2004). If transport energy, such as gasoline and diesel, spurs economic growth, then restricting its use may impede economic growth. However, if such causality direction runs from economic growth to transport energy, then a conservation policy may be desirable. A bi-directional relationship would imply that a careful and selected policy instruments should be used to reduce energy without affecting growth.

The energy-economic growth nexus can be enlightened by analyzing the causal relationship between transport energy and economic growth. Using econometric tools and the Granger representation theorem, this paper investigates the dynamic relationship between transport energy and growth in a multivariate framework using an aggregate production function. Gasoline and diesel are analysed separately. The Autoregressive Distributed Lag (ARDL) bounds test is used to investigate the long-run relationship between transport energy and economic growth for a small island open economy, Mauritius, for the period 1970-2010. Policy issues which are related to energy and climate policy are eventually discussed.

The paper is organized as follows: in section 2, a brief review of literature on the energy-economic growth nexus is provided; section 3 gives a picture of economic development and transport energy in Mauritius; the methodological issues, data and econometrics framework are detailed in section 4 and section 5 provides the results. Section 6 presents the policy implications.

2. Economic growth and the transport sector in Mauritius

Mauritius is an island of approximately 1860 km^2 with a population of 1.24 million (CSO 2010). Investigating the relationship between energy and economic growth for the Republic of Mauritius provides an important case experiment mainly due to its strong economic performance and economic diversification since independence in 1968. Faced with deteriorating terms of trade and a rapidly growing population and labour force in the early 1970s, the island implemented various initiatives to diversify the economy and to raise the standard of the people (Wellisz & Saw 1994). Following the report of James Meade in the 1960s, the import substitution strategy and the establishment of an export-oriented manufacturing sector in the 1970s had contributed to the recovery of the economy. The island shifted from an agriculture mono-crop economy to an economy based on manufacturing sector in the 1980s, especially textile through the Export Processing Zone. Finally, the state developed a multi-sector base economy at the turn of the 21st century, with emphasis on service sectors such as tourism and Information Communication Technology (ICT). Table 1 shows the transformation of the economy from 1960 to 2010.

The Mauritian case is highlighted by many development economists and its record of sustained growth inspires many countries (Vandermoortele & Bird 2010). Since the 1970, economic growth rose to 5 percent per-annum on average and since the early 1980s growth rates have increased slightly to an average of 6 percent per-annum (Figure 1).

Alongside with economic development, the demand for transport has increased dramatically. Personal travel and vehicle ownership has been on the rise. There has also been a growing demand for movement of goods. This eventually led to an increase in gasoline and diesel consumption in the transport sector. Figure 2 shows the fuel consumption in the transport sector for the period 1970-2010 for gasoline and diesel. A number of factors may have contributed to the rise in demand for fuel, including the rise in population, an increase in household income, migration of the middle classes from rural to urban areas and greater participation of women in the labour force (Enoch 2003). The rise in fuel consumption in the transport sector is also linked with the rise in ownership of private vehicles which has more than quadrupled since the 1980s.

3. Energy and economic growth nexus: a brief review of literature

Energy economists have long been interested with whether energy is a stimulus to generate GDP (Chontanawat *et al*. 2010; Toman & Jemelkova 2003). 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) which postulates that energy is a causal factor to economic growth and restrictions on the use of energy may adversely affect economic growth. The growth hypothesis 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. However, this causal relationship relies on the interaction of energy with other variables such as capital and labour.

The relationship between transport energy and economic growth provides another facet of the dilemma and the direction of the causation between the two variables. Mobility is an important element for economic activities to take place. Following the theoretical foundation of Becker's theory of allocation of time, transport is intimately related to both consumption and the allocation of time among discretionary activities (Baker 1965). Hence, travelling and consequently the use of energy is a derived demand emanating from consumption and production activities. However, this fails to account of a fact that travelling can itself be regarded as an activity (Anas 2007). With economic growth, income increases and the demand for product variety grows. Consequently, consumers seek a larger diversity of opportunities to shop, purchase services and engage in recreation or leisure-related activities. Car ownership also increases and the availability of multiple private vehicles allows more discretionary mobility to take place. This eventually leads to a rise in transport energy. Based on the above reasoning, the causal relationship runs from economic growth to energy consumption.

From an empirical point of view, a number of studies aimed at finding causal relationship between energy and economic growth. The study of Kraft & Kraft (1978) is among the pioneers to test whether energy use causes economic growth or vice-versa. Over the last three decades, the energy-economic growth analysis has witnessed many different variations. Studies can be classified into whether aggregate energy or disaggregate energy is used. For instance, Masih & Masih (1996), Glasure & Lee (1997), Akinto (2008), and Odhiambo (2009) analyse aggregate energy consumption while Ziramba (2009), Fatai *et al*. (2004) examine disaggregate energy such as coal, gas, electricity separately. Studies such as Masih & Masih (1996), Fatai *et al*. (2004) and Odhiambo (2009) employ strictly two variables, energy consumption and income proxied by GDP in a dynamic econometric framework. Others such as Narayan & Smith (2005) and Wolde-Rufael (2010) have augmented the econometric analysis to account for more variables such as capital and employment in the analysis. The latter is referred to as the production-side analysis.

Results have been inconclusive. For the US, Yu & Choi (1985) find no causality between energy and GDP while Soytas & Sari (2006), using multivariate co-integration and ECM, find a unidirectional relationship running from energy to GDP. Bi-directional causality has been found for Venezuala and Columbia by Nachane *et al*. (1988), for Pakistan by Masih & Masih (1996), for Phillipine and Thailand by Asafu-Adjaye (2000), among others. Soytas & Sari (2006) also find bi-directional causal relationship for Canada, Italy, Japan and UK and Wolde-Rufael (2005) for Gabon and Zambia. Oh & Lee (2004) employs a VECM to test for Granger causality in the presence of cointegration among aggregate energy, GDP and real energy price for Korea for the period 1980-2000 and conclude that there is no causality between energy and GDP in the short-run and a uni-directional causal relationship from GDP to energy in the long-run. It also implies that a sustainable development strategy may be feasible with lower level of CO2 emissions from fossil fuel combustion. Odhiambo (2009) uses the bounds test approach to cointegration and concludes that for both the short-run and long-run, there is a uni-directional causality running from energy to GDP for South Africa and Kenya while casualty runs from GDP to energy for Congo (DRC).

4. Empirical investigation: data, methodology and models

4.1 Theoretical formulation

Studies which examine the energy consumption-economic growth nexus have used reduced-form time-series models to test for causal relationship (Bartleet & Grounder 2010). In our analysis, transport energy namely gasoline and diesel, is considered as an input in an aggregate production function. Following the conclusion of Stern & Cleveland (2004), that the empirical assessment must be free of specific structural linkages, this study examines the relationship between transport energy and economic growth by incorporating a capital stock variable. The neo-classical one-sector aggregate production model where capital formation as well as energy, are treated as separate factors of production, is shown as follows:

$$Y_t \equiv f(E_t, K_t, L_t) \qquad (1)$$

Where Y_t is aggregate output or real GDP, K_t is the capital stock, L_t is the level of employment and E_t is energy. The subscript *t* denotes the time period. Dividing by labour, we postulate the following

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

Where $y_t = \frac{Y_t}{L_t}, e_t = \frac{E_t}{L_t}, k_t = \frac{K_t}{L_t}$

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

$$\ln y_t \equiv \beta_0 + \beta_1 \ln e_t + \beta_2 \ln k_t + \varepsilon_t \tag{3}$$

Where the logarithmic form of the variables means that the variable is now in a growth rate form. The coefficients β_1, β_2, and β_3 refers to the elasticity of output with respect to energy and capital stock, respectively.

The relationship between aggregate real output, capital stock, and energy described by the production function in Eq.(2) indicates that in the long-run, real output, capital, and energy may move together (Soyta & Sari 2007). 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 (Wang *et al*. 2011). The estimation procedures rest on two basics: the cointegration techniques and the short and long-run dynamics.

4.2 Econometric formulation - The ARDL Cointegration approach

The ARDL bounds testing approach is employed to examine long-run equilibrium relationship among the three variables (all variables are in logarithms), namely real GDP (*LRGDP*), real investment (*LRINV*), and energy used in transport, i.e., gasoline (*LGAS*) and diesel (*LDIE*). All variables are in per capita level. An ARDL model is a general dynamic specification, which uses the lags of the dependent variable and the lagged and contemporaneous values of the independent variables, through which the short-run effects can be directly estimated, and the long-run equilibrium relationship can be indirectly estimated. Unlike other cointegration techniques, the ARDL does not impose a restrictive assumption that all the variables under study must be integrated of the same order. In other words, the ARDL approach can be applied regardless of whether the underlying regressors are integrated of order one [*I(1)*], order zero[*I(0)*] or fractionally integrated. The ARDL test is suitable even if the sample size is small and the technique generally provides unbiased estimates of the long-run model and valid t-statistics even when some of the regressors are endogenous (Harris & Sollis 2003).

The ARDL technique involves estimating the following unrestricted error correction model (UECM):

Model 1: Gasoline and economic growth nexus

$$\Delta LRGDP_t = a + \sum_{i=0}^{m} b_{igdp}\,\Delta LGAS_{t-1} + \sum_{i}^{q} c_{igdp}\,\Delta LRGDP_{t-i} + \sum_{i=0}^{n} d_{igdp}\,\Delta LRINV_{t-1} + \eta_{1gdp} LRGDP_{t-1} + \eta_{2gdp} LGAS_{t-1} + \eta_{3gdp} LINV_{t-1} + \varepsilon_{gdp,t} \tag{4}$$

$$\Delta LGAS_t = a_1 + \sum_{i=0}^{m} b_{igas}\,\Delta LGAS_{t-1} + \sum_{i}^{q} c_{igas}\,\Delta LRGDP_{t-i} + \sum_{i=0}^{n} d_{igas}\,\Delta LRINV_{t-1} + \eta_{1gas} LRGDP_{t-1} + \eta_{2gas} LGAS_{t-1} + \eta_{3gas} LINV_{t-1} + \varepsilon_{gas,\,t} \tag{5}$$

$$\Delta LINV_t = a_{inv} + \sum_{i=0}^{m} b_{iinv}\,\Delta LGAS_{t-1} + \sum_{i}^{q} c_{iinv}\,\Delta LRGDP_{t-i} + \sum_{i=0}^{n} d_{iinv}\,\Delta LRINV_{t-1} + \eta_{1inv} LRGDP_{t-1} + \eta_{2inv} LGAS_{t-1} + \eta_{3inv} LINV_{t-1} + \varepsilon_{inv,\,t} \tag{6}$$

Model 2: Diesel and economic growth nexus

$$\Delta LRGDP_t = a + \sum_{i=0}^{m} f_{igdp}\,\Delta LDIE_{t-1} + \sum_{i}^{q} g_{igdp}\,\Delta LRGDP_{t-i} + \sum_{i=0}^{n} h_{igdp}\,\Delta LRINV_{t-1} + \mu_{1gdp} LRGDP_{t-1} + \mu_{2gdp} LGAS_{t-1} + \mu_{3gdp} LINV_{t-1} + \zeta_{gdpt} \tag{7}$$

$$\Delta LDIE_{t} = a + \sum_{i=0}^{m} f_{idie}\,\Delta LDIE_{t-1} + \sum_{i}^{q} g_{idie}\,\Delta LRGDP_{t-i} + \sum_{i=0}^{n} h_{idie}\,\Delta LRINV_{t-1} + \mu_{1die} LRGDP_{t-1} + \mu_{2die} LGAS_{t-1} + \mu_{3die} LINV_{t-1} + \zeta_{die,t} \quad (8)$$

$$\Delta LINV_{t} = b_{inv} + \sum_{i=0}^{m} f_{iinv}\,\Delta LDIE_{t-1} + \sum_{i}^{q} g_{iinv}\,\Delta LRGDP_{t-i} + \sum_{i=0}^{n} h_{iinv}\,\Delta LRINV_{t-1} + \mu_{1inv} LRGDP_{t-1} + \mu_{2inv} LGAS_{t-1} + \mu_{3inv} LINV_{t-1} + \zeta_{inv,t} \quad (9)$$

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, gas, inv, emp)* for the gasoline system equation and $H_o : \mu_{1j} = \mu_{2j} = \mu_{3j} = \mu_{4j} = 0$ for *(j=gdp, die, inv, emp)* for the diesel system equation. The alternative is that $H_1 : \eta_{1j} \neq \eta_{2j} \neq \eta_{3j} \neq \eta_{4j} \neq 0$ and $H_1 : \mu_{1j} \neq \mu_{2j} \neq \mu_{3j} \neq \mu_{4j} \neq 0$.

The asymptotic distribution of the *F*-statistic is non-standard under the null hypothesis and it is originally derived and tabulated in Pesaran *et al.* (2001) but modified by Narayan (2005) to accommodate small sample sizes. Two sets of critical values are provided: one which is appropriate when all the series are *I(0)* and the other for all the series that are *I(1)*. If the computed *F*-statistic falls above the upper critical bounds, a conclusive inference can be made regarding cointegration without the need to know whether the series were *I(0)* or *I(1)*. In this case, the null of no cointegration is rejected. Alternatively, when the test statistic falls below the lower critical value, the null hypothesis is not rejected regardless whether the series are *I(0)* or *I(1)*. In contrast, if the computed test statistic falls inside the lower and upper bounds, a conclusive inference cannot be made unless we know whether the series were *I(0)* or *I(1)*. Causality tests in this framework can be undertaken as a first step of the ARDL approach.

An Error Correction Model provides two alternative channels of the interaction among our variables: short-run causality through past changes in the variable, and long-run causality through adjustments in equilibrium error. The ECM for our three variables case can be written as follows:

For gasoline

$$\begin{bmatrix} \Delta LRGDO_t \\ \Delta LGAS_t \\ \Delta LRINV_t \end{bmatrix} = \begin{bmatrix} a_1 \\ a_2 \\ a_3 \end{bmatrix} + \sum_{i=1}^{p}(1-L)\begin{bmatrix} b_{11}b_{12}b_{13} \\ b_{21}b_{22}b_{23} \\ b_{31}b_{32}b_{34} \end{bmatrix} . \begin{bmatrix} \Delta LRGDO_{t-i} \\ \Delta LGAS_{t=i} \\ \Delta LRINV_{t-i} \end{bmatrix} + \begin{bmatrix} \varphi_1 \\ \varphi_2 \\ \varphi_3 \end{bmatrix}\begin{bmatrix} ECT_{t-1} \\ ECT_{t=1} \\ ECT_{t-1} \end{bmatrix} + \begin{bmatrix} \xi_1 \\ \xi_2 \\ \xi_3 \end{bmatrix} \quad (10)$$

For diesel

$$\begin{bmatrix} \Delta LRGDO_t \\ \Delta LDIE_t \\ \Delta LRINV_t \end{bmatrix} = \begin{bmatrix} c_1 \\ c_2 \\ c_3 \end{bmatrix} + \sum_{i=1}^{p}(1-L)\begin{bmatrix} d_{11}d_{12}d_{13} \\ d_{21}d_{22}d_{23} \\ d_{31}d_{32}d_{34} \end{bmatrix} . \begin{bmatrix} \Delta LRGDO_{t-i} \\ \Delta LDIE_{t=i} \\ \Delta LRINV_{t-i} \end{bmatrix} + \begin{bmatrix} 1 \\ 2 \\ 3 \end{bmatrix}\begin{bmatrix} ECT_{t-1} \\ ECT_{t=1} \\ ECT_{t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \end{bmatrix} \quad (11)$$

ξ_i, ε_i (for i=1, 2, 3) are serially uncorrelated random error terms. The error correction terms denoted by $ECT_{r,t-1}$ are the cointegrating vectors and φ_i, (for *i=1,..3*) are the adjustment coefficients, showing how much disequilibrium is corrected. The deviation from long-run equilibrium is gradually corrected through a series of short-run adjustments. The size and statistical significance of $ECT_{r,t-1}$ is a measure of the extent to which the left hand side variable in each equation returns in each short-run period to its long-run equilibrium in response to random shocks.

Once the long-run relationships have been identified and an ECM is estimated, the next step is to examine the short-run and long-run Granger causality between the two proxies for transport energy and real output. The traditional Granger's definition of causality is based on the notion that the future cannot cause the past but that the past can cause the future. According to Granger's definition of causality, a time series X, causes another time series Y, if Y can be predicted better (in a mean-squared-error sense) using past values of X than by not doing so. That is, if past values of X significantly contribute to forecasting Y, then X is said to Granger cause Y (Odhiambo 2010). An error correction model enables one to distinguish between long- and short-run causality in addition to bringing the lost information due to differencing back into the system through the error correction terms. The Granger causality test can therefore be conducted from an error correction representation.

4.3. Variables specification and data sources

This study utilises time series data for the period 1970-2010 for gasoline and for diesel, from the Statistics office, Mauritius. For key variables, such as economic activities, we take as proxy the real GDP per capita (RGDP) and for energy, we take total gasoline (*GAS*) and total diesel (*DIE)* consumption in the transport sector in per capita unit. Data on GDP, deflators, capital formation and population were all obtained from the National Accounts, Statistics Office, Mauritius. Data on energy was obtained from the Digest of Energy statistics, Statistics Office, Mauritius. We use gross capital formation to proxy the stock of physical capital following the work of Soytas & sari (2006), Wolde-Rufael (2009) and Ouedraogo (2010). It is argued that since in the perpetual inventory method, the rate of depreciation is assumed to be constant, changes in investment are closely related to changes in capital stock.

5. Results and discussion

Table 2 provides tests of unit roots in level and first difference of the variables: $LRGAS$, $LDIE$, $LRGDP$ and $LRINV$ using the Augmented Dicker-Fuller (ADF) method and the Phillip-Perron (PP) test. We see that diesel and investment time series are *I(0)* from the ADF test but the PP test fails to reject the null hypothesis of unit roots in the level for all the variables above. The two tests are then applied to the first difference of the time series and the results are shown in table 2. We conclude that all variables are first-difference stationary and proceed to tests of cointegration.

The bounds test is appropriate for this study given that there is a mixture of *I(0)* and *I(1)* series and that no series are *I(2)*. The results are shown in table 3 and 4 for gasoline and diesel respectively. The basis for conducting the test relies on the Unrestricted Error Correction Model (UECM). The UECM models pass the diagnostic tests with respect to the Lagrange multiplier test for residual serial correlation, the Ramsey RESET test for functional form, the Jarque-Berra test of normality and the White hetrocedasticity test. The real GDP equation and real investment however shows a problem of functional form as depicted by the RESET test at 10%. For the diesel system analysis, the real GDP equation exhibits a normality problem. Various specifications were attempted, however, the problem persists. It is therefore important to interpret the economic growth causality with care. The critical values for the bounds test are taken from Narayan (2005) and table 3 and 4 show the lower bound and upper bound for 5% level of significance.

Table 3 concludes that a cointegration relationship exists when gasoline and investment are taken as dependent variables while table 4 shows the cointegration results for the diesel regression. The bounds test to cointegration can also be used to provide insight on the long-run causation between the variables. In the long-run, the causality runs from economic growth and real investment to gasoline and diesel. The results also show that real investment is endogenous for both the gasoline and diesel equation, adjusting to shocks in the long-run equilibrium.

The Granger causality analysis, based on an ECM within the ARDL is presented in table 5 and 6. The Wald test concludes that gasoline adjusts to changes in the long-run equilibrium – the coefficient of the error term has the correct sign and is highly significant (table 5). This is consistent with the bounds test results. Hence, it can be concluded that the real GDP per capita and real investment per capita Granger-cause gasoline consumption in the long-run. This result was rather consistent with the rise in mobility as a consequence of higher standard of living. Since private cars operate mostly with gasoline fuel, enhanced mobility for discretionary purposes leads to a rise in the consumption of fossil fuel.

In the short run, only per capita real investment influences gasoline consumption. Real GDP is Granger-caused by gasoline in the short-run but not in the long-run. The results conclude that gasoline is not a major input in the aggregate production function of the economy. Its effect can be traced from the investment regression where gasoline is found to Granger-caused real investment in the long-run and as well as in the short-run.

Table 6 gives the econometric result for the diesel regression and similar linkages are found. Growth is found to Granger-caused diesel consumption. Since the public bus transport system operates with diesel, such conclusion is also reflecting the rise in mobility of the population. As can be seen from table 6, bi-directional causality is found between real investment and transport energy in the long-run - consistent with the bounds test result - as well as in the short run. The Wald statistics concludes that the null-hypothesis of no causality can be rejected given the level of significance of coefficients.

The results suggest that with economic progress, the enhanced standard of living is likely to increase transport energy. Such conclusion is consistent with Anas (2007)'s concept of discretionary mobility that transport should not be viewed as only a derived demand. Mobility may be an end in itself. The important conclusion is the complementary between investment and energy. If a carbon or energy tax is imposed as part of climate policy to restrict the rise in fossil fuel consumption, economic growth may be affected through the effect of energy on investment. This policy will be detrimental to real investment and a negative shock to real investment is expected.

6. **Conclusions and policy implications**

The conclusions from the Granger causality tests reveal that gasoline and diesel have similar linkages in the economy. The cointegration relationships suggest that transport energy, real GDP per capita and real investment per capita form a long-run equilibrium. Both gasoline and diesel readjusts shocks to the equilibrium condition. This implies that we should expect a rise in transport energy as the economy progresses and as wealth is generated. In both the long-run and short-run, we also found that there is a bi-directional causality between the two types of transport energy and investment. Hence, we conclude that Mauritius exhibits an energy dependence economy such that an adequate supply of diesel and gasoline are essential for real investment.

The study shows the dilemma which is implied in the design of energy and climate policy. Policy makers can be trapped in reducing fossil fuels used in the transport sector, through restricting mobility as a climate and energy policy. For a small island state, Mauritius, a conservative strategy for transport energy would prove detrimental to investment and long-run economic growth. Policy instruments such as energy tax must be carefully analysed. The Granger-causality test concludes that energy and climate policies which are devoted towards a reduction in GHGs should emphasise the use of alternative sources rather than exclusively attempt to reduce overall energy consumption. The development of bio-fuels is, therefore, a promising avenue to ensure an adequate supply of energy to sustain economic performance.

We attribute the result that economic growth takes precedence over diesel and gasoline to discretionary mobility which is due to higher standard of living. Hence a change in behaviour towards sustainable mobility is vital. Since the population is expected to be highly mobile especially with higher participation of women in the labour force, the improvement of public transport could be a way to lessen the rise in private vehicles usage.

Such conclusion does not imply that a reduction in energy resulting from a shift of less efficient vehicles is not suitable. Studies have shown that efficient vehicles may raise energy productivity and hence, may establish a stimulus rather than an obstacle to economic development. In the transport sector, this may require the replacement of old and inefficient vehicles by new and efficient ones. Our analysis has been restricted through the availability of data on energy in Mauritius. A longer time period would definitely enhance the robustness of the analysis. Alternatively, the study has focused on an inbound causality relationship. Outbound causal studies using the Impulse Response Function and the Variance Decomposition Model may be possible avenues for further research.

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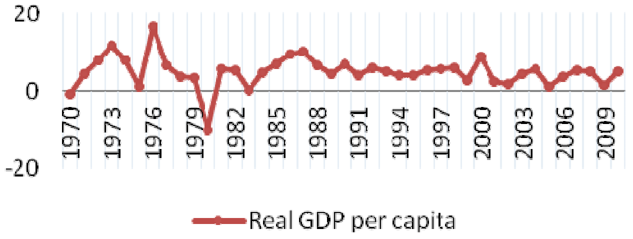
Figure 1 :Growth in real GDP per capita



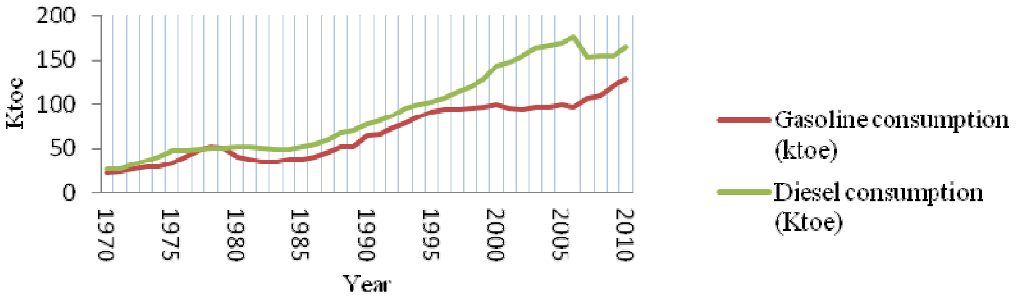
Source: Computed from the data from Statistics Office, Mauritius, World Bank Indicators and International Financial Statistics

Table 1: Sector distribution of GDP in Mauritius 1960-2010

	1960	1980	1990	2000	2010
	%	%	%	%	%
Agriculture	31.3	15.1%	11.8	6.7	3.6
Industrial	24.7	25.6	34.1	29.5	20.1
Services	44	59.3	54.1	63.8	76.3

Source: National Accounts of Mauritius CSO publication

Figure 2: Fuel consumption in the Transport sector



Source: Computed from the Digest of Energy Statistics, Statistics Office, Mauritius

Table 2. Unit root test result from the ADF and PP methods in annual data at level form and first difference form

Variables	Augmented Dicker Fuller test		Philip-Perron test (PP)	
Level form	ADF test statistics	Critical Values (LL)	PP test (Z(rho))	BW(LL)
$LRGAS_t$	-3.514	-3.539(2)	-2.327	-12.980(3)
$LDIE_t$	-3.781	-3.539(3)	-1.705	-12.980(3)
$LRGDP_t$	-3.405	-3.539(3)	-1.536	-12.980(3)
$LRINV_t$	-4.427	-3.539(3)	-4.161	-12.980(3)
First difference				
$\Delta LRGAS_t$	-3.504	-2.947(0)	-21.884	-12.948(3)
$\Delta LDIE_t$	-3.408	-2.947(1)	-30.658	-12.948(3)
$\Delta LRGDP_t$	-3.436	-2.947(1)	-50.545	-12.948(3)
$\Delta LRINV_t$	-3.296	-2.947(1)	-33.571	-12.948(3)

The null hypothesis for the ADF and PP tests is that the time series exhibit a unit root. The optimal lag length on the variables in ADF test equations are selected by Schwarz Information Criterion. The bandwidth for the PP test is selected with the Newey-West Barlett kernel method.
*, **, *** denote significance at 10% level, 5%, and 1% respectively.

Source: Computed from *Microfit 4.0*

Table 3. Results of the bounds tests: gasoline equation

Equation	Estimated F-statistics	5% critical value bounds		Evidence of cointegration
		I(0)	*I(1)*	
$F_{LRGDP}(LRGDP_t/,LGAS_t,LRINV_t)$	0.230	3.100	4.088	No
$F_{LGAS}(LGAS_t/,LRGDP_t,LRINV_t)$	4.607	3.100	4.088	Yes
$F_{LRINV}(LRINV_t/,LRGDP_t,LGAS_t)$	8.716	3.100	4.088	Yes

Notes: Critical values are for the model with intercept but no trend with k=3 regressors

Source: computed from *Microfit 4.0*

Table 4. Results of the bounds tests: diesel equation

Equation	Estimated F-statistics	5% critical value bounds		Evidence of cointegration
		I(0)	*I(1)*	
$F_{LRGDP}(LRGDP_t/,LDIE_t,LRINV_t)$	0.263	3.100	4.088	No
$F_{LDIE}(LDIE_t/,LRGDP_t,LRINV_t)$	5.0221	3.100	4.088	Yes
$F_{LRINV}(LRINV_t/,LRGDP_t,LDIE_t)$	6.17	3.100	4.088	Yes

Notes: Critical values are for the model with intercept but no trend with k=3 regressors

Source: Computed from *Microfit 4.0*

Table 5.Results from the Granger causality tests – gasoline and real output					
Dependent variables	Type of Granger causality				
	Short-run				Long-run
	$\Delta LGAS_t$	$\Delta LRDGP_t$	$\Delta LINV_t$		ECT_{t-1}
	Wald F-statistics				t-statistics
$\Delta LGAS_t$		0.532	13.193***		-0.316(0.067)***-
$\Delta LRDGP_t$	0.842		39.482***		-0.036(-0.065)
$\Delta LINV_t$	12.712***	28.662***			-0.822(0.112)***
Source: Computed from *Microfit 4.0*					

Table 6.Results from the Granger causality tests- diesel and real output

Dependent variables	Type of Granger causality				
	Short-run				Long-run
	$\Delta LDIE_t$	$\Delta LRDGP_t$	$\Delta LINV_t$		ECT_{t-1}
	Wald F-statistics				t-statistics
$\Delta LDIE_t$		0.002	7.768***		-0.161(0.006)***
$\Delta LRDGP_t$	0.059		16.737***		0.914(0.368)
$\Delta LINV_t$	0.387	16.216***			-0.467(0.103)***

Source: Computed from *Microfit 4.0*

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