# New evidences on the link between public capital and economic growth from a small island economy.

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**-Abstract-**

The contribution of public capital on economic growth has been the focus of only few studies and has to date focused mainly on developed countries. Moreover it is only lately that the link has been analysed in a dynamic framework, allowing for feedback effects. The empirical literature has hardly dealt with small economies such as Mauritius. The present paper builds on a production function approach, using a unique time series dataset over the period 1950 – 2000, to derive the association between public capital and economic performance and economic growth for Mauritius. Given the non-stationary characteristics of the data, a vector-error-correction mechanism (VECM) is used to model the dynamics. Public capital is shown to have significantly contributed to Mauritian economic performance. Moreover results suggest that there may be indirect effects via private capital accumulation as well.

**<u>Key words</u>**

Public capital, Economic Growth, Vector-error-correction mechanism.

# I. Introduction

Capital formation originates from both the private and public sectors of the economy. Economic studies have mostly concentrated on the link between private and total capital accumulation and development. The contribution of public capital in the above context has been the focus of only few studies. Even then the majority of these studies have been based on assessing the contribution of the public capital input in an extended Cobb-Douglas specification using a static framework (see Aschauer (1989), Munnell (1990, 1992)). It is only lately that scholars have analysed the link using dynamic econometric framework (see Pereira and De Fructos (1999), Sturm, Jacobs and Groote (1999), Lighhart (2000), Pereira (2000), Pereira and Andraz (2001) and Pereira and Roca Sagales (2003) among others). These studies have treated public input as an unpaid factor and have overall established positive impacts of public capital on economic growth. There have also been a few exceptions which reported insignificant effects (see Tatom (1991), Hulten and Schwab (1993) and Holz-Eakin (1994)). More importantly however, most of existing literature attempting to support the public capital-growth hypothesis has been based on developed economies' cases such as US and Western Europe. Among the very scarce studies on developing countries are those from Looney (1997) who studied the link for the case of Pakistan and Ghali (1998) for the case of Tunisia. In the first case public capital was reported not to have been instigating private sector expansion while in the second case public capital were even seen to have a negative effect on private investment and thus output.

The present study attempts to fill a gap in the literature by analysing the link between public capital accumulation and economic growth for the case of an island economy, namely, Mauritius. It uses a uniquely constructed time series dataset dating back since 1950 whereby the total capital stock has decoupled into public and private capital stock. Moreover both are allowed to enter simultaneously in an extended Cobb-Douglas production function, with public capital entering as an unpaid input. Dynamic econometric technique is used, namely a Vector Error correction model (VECM), to analyse feedback effects in the system. The paper addresses thus issues pertaining to exogeneity, crowding in and out and causality direction as well.

The structure of this paper is as follows

Section 2 describes the preferred modelling function used and elaborates on the proxies used and the data set construction. Section 4 investigates the empirical link between the public capital and economic growth for the case of Mauritius and section 5 concludes and discuses policy implications.

## II. Methodology and Analysis

**Dynamic feedback issues and VAR**

The analysis uses dynamic econometrics techniques in a Cobb-Douglas production function framework, namely a Vector Autoregressive model (VAR), following recent studies in public capital-economic growth debate (see Ghali (1998), Sturm, Jacobs and Groote (1999), Pereira and De Fructos (1999), Lighthart (2000) and Pereira and Roca Sagales (2003)) to model the hypothesis. It thus takes into account the possibility of dynamic feedbacks among the variable in the model. In fact public capital being an additional unpaid input in the production function, not only affects a country's output directly but also indirectly it may affect private capital and employment. Moreover the income level of a country can also be seen to translate into the creation of more public capital[1].

**Data construction and sources**

Since the overall and also decoupled private and public capital stock values for the country were unavailable, they had to be constructed using the Perpetual Inventory Method (PIM) as recommended by OECD (2001) and the US Bureau of Economic Analysis (1999). This approach has been widely used in the literature[2]. Construction of these capital stocks required disaggregated investment data series to feed the above methodology. The Penn-World table (6.1) only provided total investment figures since the 1950. In an attempt to separate the total investment into the above components, we gathered data on total government capital investment over the whole period under study (1950-2000). These were available from the various individual Accountant General

[1] See Pereira and De Fructos (1999) and Lighthart (2000) for a complete treatment of feedback effects.
[2] This methodology has also been widely used in both classical and recent literature) for instance by Munnell (1990) and Sturm and de Haan (1995)). More recently Jacob et al (1997), Lighhart (2000), Canning and Bennathan (2000), and Kamps (2003) among others also constructed capital stock using the PIM.

Annual Reports of the country and also from the Financial Accounts of the Mauritian Colony for period before independence (pre-1968).

To measure labour we used employment level figures available from the Central Statistical Office (CSO) and the Bi-annual Digest of Statistics (various issues). The dependent variable output was proxied by the real Gross Domestic Product at constant price and was generated from the Penn World Table (6.1).

**Model Specification and preliminary tests**

We extend a classical Cobb Douglas function and disaggregate the capital stock into private and public capital. It implies writing the following theoretical model

$$Q = A_t (K_t)^{\beta 1} (G_t)^{\beta 2} (L_t)^{\beta 3}$$ **---------- equation 1**

Q denotes the economy's output, $A_{(t)}$ the shift in the production function attributed to technical progress, which is assumed to be Hick neutral, $K_t$ the private capital stock, $G_t$ is the public capital stock and $L_t$ labour. Taking logs on both sides of the equation and denoting the lowercase variables as the natural log of the respective uppercase variable results in the following:

$$y = \alpha + \beta_1 k + \beta_2 g + \beta_3 l + \varepsilon$$ **---------- equation 2**

Before considering the appropriate specification of the VAR, the univariate properties of stationarity of the data series are investigated using the Augmented Dickey-Fuller (ADF) (1979) and Phillips-Perron (PP) (1988) unit-roots tests. The results are summarised in table 1 and 2.

Test for stationarity (refer to tables 1 and 2) shows that all our variables are integrated of order 1 (I(1)) and thus stationary in difference. Further analysis in term of cointegration using the Johansen Maximum Likelihood approach have been undertaken and is reported in table 3.

The Schwarz Bayesian criterion (SBC) suggested a VAR of order 2. Evidence from both trace and maximal eigenvalue tests suggests that there is at most a single cointegrating vector or analogously 2 independent common stochastic trends within the 3 variables equation. At the 5% level, trace value and maximum eigenvalue test[3] both shows there is one cointegrating vector. Engle and Granger (1987) showed by the error-representation theorem that cointegrated variables implies in effect an error correction model (ECM). He argued that regression of the first difference of cointegrated variables would result in misspecification error. Accordingly, the VAR was accordingly formulated in a Vector Error Correction model (VECM) to analyse the dynamics of the relationship. This involves the inclusion of the lagged errors of the cointegrating regression as one of the independent variables in the regression equation.

[3] For the maximum Eigen Values, the relevant computed statistic is 8.9252 as compared to 21.12 and for the trace values, computed statistic is 17.97 compared to critical 31.54.

## The Vector Error Correction Model

We derive the model following Johansen (1988, 1996), Hendry (1995), Enders (1995), and Ghali (1998) and specify the following

$$Z_t = \Psi_1 Z_{t-1} + \Psi_2 Z_{t-2} + \ldots\Psi_k Z_{t-k} + \mu + \eta_t \qquad t=1\ldots t \text{ ---------- } \textbf{equation 3}$$

Where $Z_t$ = vector of (n×k) dimension

$\Psi_k$ = vector of (n×n) dimension

$\eta_t$ = Vector of unanticipated impulses (movements in $X_t$) ~ niid(0,Σ)

Where n is the number of variables in the VAR, k is the dimension of the VAR, and t is time.

For the present analysis, our VAR consists of four endogenous variables (n=4), $Z_t = [y_t, g_t, k_t, l_t]$ and a constant term and the dummy variable[4]. The system features 2 lags (k=2) that were chosen using SBC.

So $z_t$ is a 4 x 1 vector containing y, k, l and g where again y is real GDP, k is private capital stock, l is the level of employment and g is our public capital stock.

[4]Estimates of a VECM without any dummy was undertaken for both specifications and showed that the residuals were not random and depicted a marked drop in the year 1960. Upon investigation we realised that this was due to cyclone Carol, the most devastating cyclone of all time. Thus a dummy variable was included to take this into account. Moreover the regression was also run including a time trend, dummy for other major cyclones and with a post independent dummy (independently and together). However their respective coefficients proved to be statistically insignificant and were judged not appropriate in our analysis. In any case the results obtained were not too different from the actual ones.

Since the variables are I (1) variables that are I (0) after applying the difference filter once and as it has been established they are also cointegrated of order 1, we may impose this constraint upon our unrestricted VAR to enable a Vector Error Correction Model formulation. The short run dynamics can be studied using the following general Vector Error Correction Model (VECM):

$$\Delta Z_t = \Gamma_1 Z_{t-1} + \Gamma_2 \Delta Z_{t-2} ....... + \Gamma_{k-1} \Delta Z_{t-k-1} + \Pi Z_{t-k} + \mu + \eta_t \qquad t=1....t \text{ ---------- } \textbf{equation 4}$$

Where $\Delta Z_t$ is the vector of growth rates of the above four variables, and the Γs are estimable parameters, Δ is a difference operator, $\eta_t$ is as defined above. Π is the long run parameter matrix with rank equal to r (in our case it is one), the number of cointegrating vectors such that $1<r<n-1$.

With r cointegrating vectors ($1< r< 4$), Π having a rank of r can be decomposed as $\Pi=\alpha'\beta$**,** with α and β both being (n x k), or 4 x 1 matrices. α is defined as the adjustment or loading coefficients which measure the strength of the cointegrating vectors in the VEC model or in other words the speed of adjustment. The βs are parameters in the cointegrating relationship and represent the long run coefficients. Small letters denote that the variables are in natural logarithmic terms. The system features 2 lags (k=2) that were chosen using SBC.

**Analysis**

The estimates of $\alpha$ and $\beta$ are presented in the following table.

The long run estimates of $\beta$ indicate that all the variables, including public capital have a positive and significant effect on the level of output of the country. In fact the output elasticity with respect to public capital is 0.356 and indicates that a 10% increase in public capital stock of the country is likely to bring a 3.56% increase in the economic growth. This value is not too far from what other scholars reported in their studies, for instance Aschauer (1989) and Munnell (1992) reported an elasticity of around 0.4, Eberts (1997) an elasticity of 0.38 and Pereira and De Frutos (1999) an elasticity of 0.65 for the case of USA and Lighthart (2000) observed an elasticity of 0.20 for Portugese case. Private capital stock's contribution, as expected, is reported to be the highest and a positive relationship for labour as well is observed.

Weak exogeneity tests on each of the equations below were also performed, that is testing respectively if $\alpha_1$=0, $\alpha_2$=0, $\alpha_3$=0 and $\alpha_4$= 0 (refer to system of equation below). The Wald-test yields Likelihood or Chi square values obtained are 15.58, 10.56, 4.0833, and 4.47 respectively. The results enable us to reject the null hypothesis of weak exogeneity at 95% significance level in all cases and we thus proceeded with an unchanged system of equation.

Now the vector error correction representation can be expanded in the following set of equations

$$\Delta y_t = \theta_0 + \sum_{s=1}^{1} \theta_{1,s} \Delta y_{t-s} + \sum_{s=1}^{1} \theta_{2,s} \Delta k_{t-s} + \sum_{s=1}^{1} \theta_{3,s} \Delta g_{t-s} + \sum_{s=1}^{1} \theta_{4,s} \Delta l_{t-s} + \alpha_1 \upsilon_{t-1} + \varepsilon_{1,t} \quad \text{--------5i)}$$

$$\Delta k_t = \delta_0 + \sum_{s=1}^{1} \delta_{1,s} \Delta y_{t-s} + \sum_{s=1}^{1} \delta_{2,s} \Delta k_{t-s} + \sum_{s=1}^{1} \delta_{3,s} \Delta g_{t-s} + \sum_{s=1}^{1} \delta_{4,s} \Delta l_{t-s} + \alpha_2 \upsilon_{t-1} + \varepsilon_{2,t} - \quad \text{--------5ii)}$$

$$\Delta g_t = \rho_0 + \sum_{s=1}^{1} \rho_{1,s} \Delta y_{t-s} + \sum_{s=1}^{1} \rho_{2,s} \Delta k_{t-s} + \sum_{s=1}^{1} \rho_{3,s} \Delta g_{t-s} + \sum_{s=1}^{1} \rho_{4,s} \Delta l_{t-s} + \alpha_3 \upsilon_{t-1} + \varepsilon_{3,t} \quad \text{-------5iii)}$$

$$\Delta l_t = \mu_0 + \sum_{s=1}^{1} \mu_{1,s} \Delta y_{t-s} + \sum_{s=1}^{1} \mu_{2,s} \Delta k_{t-s} + \sum_{s=1}^{1} \mu_{3,s} \Delta g_{t-s} + \sum_{s=1}^{1} \mu_{4,s} \Delta l_{t-s} + \alpha_4 \upsilon_{t-1} + \varepsilon_{4,t} \quad \text{-------5iv)}$$

where s is the number of featured lags θ ,δ ,ρ ,μ are the short term parameters of the lagged variables $\alpha_{1,}$ $\alpha_{2,}$ $\alpha_3$ and $\alpha_4$ are the adjustment coefficients and ν is the cointegrating vector.

**Estimates of the Error-Correction Model**

OLS estimates of the error-correction model are presented in table 5.

The system of equation passes the diagnosis tests related to serial correlation (based on Lagrange multiplier test of residual serial correlation) and heteroscedasticity (based on the regression of squared residuals on squared fitted values).

The VECM model reveals that the short run parameters in private capital, public capital and employment has a positive and significant effect on the level of output of the country. The analysis shows that public capital (with an output elasticity of 0.223) indeed contributes to economic performance, though not to the same extent as private capital (with an output elasticity of 0.72). Referring to column 2 above, it is also interesting to note that public capital seems also to impact positively on private capital thus concluding that some indirect effects might also be present. These results are in line with theoretical rationales. Moreover it can be observed that the adjustment parameter is -0.215 which indicates a relatively average adjustment speed of the system to its long run equilibrium. It reflects the speed at which the disequilibrium is made for in the next period. This adjustment speed coupled with the fact that the short run parameter is smaller than the long run parameter might indeed also suggest that public capital takes time to attain its full impact on the economy.

**ECM based Causality tests**

In our setting (refer to the system of equation 5i – 5v), the analysis of a Granger-causal relation from infrastructure on GDP boils down to testing whether the sum of the $\theta_{3,s}$ (or $\theta_{3,1}$ in equation 5i) elements in above equation differs from zero. However, we cannot use ordinary F-tests, which apply to the individual equations, because the error terms may be correlated over the equations, and *g* affects *y* through these correlated error terms. Following Geweke et al (1983), who indicated that the Granger procedure conducted using a Wald chi-square test statistic outperforms other causality tests in a series of

Monte-Carlo experiments, we accordingly apply Wald tests to test series of pair-wise causality.

Thus to test whether public investment Granger causes growth, we test the null hypothesis $H_0$: $\theta_{3,1} = 0$ using a Chi square statistic. In equation 5i, restricting $\theta_{3,1} = 0$, yields a Chi Square statistic of 5.4988, and is statistically significant at 95% significance. This rejects the null hypothesis and confirms a causality effect from public capital to GDP[5]. Same direction of causality is observed for the case of private capital accumulation and employment and economic growth (refer to table 6)

**Reverse Causality**

Testing for reverse causality, would be to examine if growth Granger cause public investment and this would mean testing the null hypothesis $H_0$: $\rho_{1,1}= 0$ in the third equation (in equation 8 iii). The Wald test for the above gave a Chi Square statistics of 0.775. The null hypothesis is thus accepted and implies non-causal effects from growth to public capital. So decisions to invest seem to be independent of economic state of the economy. On the other hand, there is evidence of reverse causation from GDP to private investment and bi-directionality between these two variables.

**Crowding-in or Crowding-out?**

[5] We also performed block causality test and it confirm the result.

The null hypothesis $H_0$: $\delta_{3,1} = 0$, using equation 5ii above, is tested to investigate whether public investment Ganger causes private investment. is a test of A Wald test resulted in a Chi Square value of 2.9042 which is more than the critical value at 90% significance level thus indicating that public capital attracts private investment. However there is no indication of causality from private to public capital accumulation.

The results of ECM based causality are summarised in table 6.

Results obtained from the ECM based causality have been found in general to consolidate those from the VECM approach. Moreover impulse response analysis performed is also in line with the above findings[6].

## IV. Summary of results

The study attempted to fill a gap in the literature by using a multivariate dynamic framework to study link between public capital and economic performance for a small island economy. Results from the analysis revealed that public capital has been an instrumental element in the economic progress of the economy over the period of study. The output elasticities are estimated to be 0.228 in the short run and 0.356 in the long run suggesting that public capital takes some time to be fully productive. The ECM based causality and impulse response analysis also tend to confirm the above link. Further analysis of variables indicates that there exist no feedback from the country' s level of

[6] Detailed analysis of impulse response functions are available from the author upon request.

output to the investment in public capital and also that public capital seems to attract private capital thus suggesting the possibility of crowding in effects. However the study could not establish reverse causation effects in both of the above case thus indicating that the public capital is possible an exogenous item for the case of Mauritius.

It is recommended above all that government refrains itself in undergoing drastic cuts, particularly in transport capital expenditure, even in difficult times. It is believed that the government would be better off in taking advantage of World Bank's and other international institutions infrastructural and developmental loans instead of capital expenditure cuts from the budget.

Government needs to take immediate action to formulate and adopt a long term vision and spell out integrated infrastructural policies involving all stake holders. Broad participation of different interest groups and consumers is essential for the effectiveness of such planning. The long term plan should also incorporate the development of a land management regime to avoid misuse of land.

Given government's budget constraint and in the light of our empirical analysis, the case of private financing and joint public/private financing arrangements should be less ambiguous so long there is addition to the country's stock capital, no matter who is financing it. Government should ensure that the private sector have sufficient incentive to invest in transport capital and in its services as well. To this end, the government needs to develop a efficient institutional framework and further improvements are also required in a number of areas to create a conductive environment: These include improving the legislative and regulatory environment, including the formulation of a BOT law, removing unnecessary bureaucratic procedures and practices, marketing the potential of Mauritius to the international investor community.

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**Table 1: Summary results of Unit Root Tests in level form: Dickey-Fuller and Phillips/Perron Test**

| Variables (in log) | Lag selection | Aug. Dickey Fuller | Phillips Perron | Critical Value | Variable Type | Aug Dickey Fuller (time trend (t) | Critical Value | Variable Type |
|---|---|---|---|---|---|---|---|---|
| $y$ | 1 | +1.46 | +2.59 | -2.924 | ***I(1)*** | -2.2 | -3.51 | ***I(1)*** |
| $k$ | 1 | +1.18 | -2.284 | -2.924 | ***I(1)*** | -1.34 | -3.51 | ***I(1)*** |
| $g$ | 1 | -0.09 | +0.23 | -2.924 | ***I(1)*** | -1.49 | -3.51 | ***I(1)*** |
| $l$ | 1 | -1.13 | -0.83 | -2.924 | ***I(1)*** | -2.11 | -3.51 | ***I(1)*** |

**Table 2: Summary results of Unit Root Tests in first difference : D/F and Phillips/Perron Test**

| Variables (in log) | Lag selection | Aug. Dickey Fuller | Phillips Perron | Critical Value | Variable Type | Aug Dickey Fuller(with time trend(t) | Critical Value | Variable Type |
|---|---|---|---|---|---|---|---|---|
| $\Delta y$ | 0 | -8.57 | -8.78 | -2.936 | ***I(0)*** | -8.98 | -3.508 | ***I(0)*** |
| $\Delta k$ | 0 | -8.77 | -5.29 | -2.936 | ***I(0)*** | -8.65 | -3.508 | ***I(0)*** |
| $\Delta g$ | 0 | -4.03 | 4.94 | -2.936 | ***I(0)*** | -4.03 | -3.508 | ***I(0)*** |
| $\Delta l$ | 0 | -5.02 | -3.42 | -2.936 | ***I(0)*** | -5.17 | -3.508 | ***I(0)*** |

**Table 3: Test result from Johansen procedure**

**Johansen Maximum Likelihood procedure of the cointegrating regression y= (k,g,l) :number of cointegrating vectors(s) using the cointegration likelihood ratio.**

| | Null Hypothesis | Alternative Hypothesis | Test Statistic | Critical Value 5% | Critical Value 10% |
|---|---|---|---|---|---|
| *Maximal eigenvalue of the stochastic matrix* | *r=0* | *r=1* | *54.73* | *27.42* | *24.99* |
| | *r<=1* | *r=2* | *8.92* | *21.12* | *19.02* |
| | *r<=2* | *r=3* | *6.89* | *14.88* | *12.98* |
| *Trace of the stochastic matrix* | *r=0* | *r>=1* | *72.70* | *48.88* | *45.70* |
| | *r<=1* | *r>=2* | *17.97* | *31.54* | *28.78* |
| | *r<=2* | *r>=3* | *9.05* | *17.86* | *15.75* |

**Table 4: α and β vectors**

| ***Variables*** | $\beta$ | ***t-ratios*** | $\alpha$ | ***t-ratios*** |
|---|---|---|---|---|
| $y$ | *1* | - | *-0.435**** | *-3.95* |
| $k$ | *-0.791**** | *-17.5* | *0.164**** | *3.25* |
| $g$ | *-0.356**** | *-4.11* | *-0.193*** | *-2.22* |
| $l$ | *-0.155** | *-1.72* | *0.204*** | *2.11* |

significant at 10%, ** significant at 5%, ***significant at 1%

**Table 5 :Estimates of the Error-Correction Model**

| ***Variables*** | ***Δy*** | ***Δk*** | ***Δg*** | ***Δl*** |
|---|---|---|---|---|
| *Constant* | *-2.011**** | *0.767**** | *-0.289* | *0.972*** |
| $\Delta y_{t-1}$ | *-0.082* | *0.095** | *0.053* | *-0.259* |
| $\Delta k_{t-1}$ | *0.719**** | *0.746**** | *0.131* | *-0.107* |
| $\Delta g_{t-1}$ | *0.228** | *0.111*** | *0.487**** | *0.266** |
| $\Delta l_{t-1}$ | *0.125** | *0.011* | *-0.063* | *0.314*** |
| *Dum* | *-0.326**** | *0.037** | *0.022* | *0.090*** |
| $\upsilon_{t-1}$ | *-0.215**** | *-0.164**** | *-0.194*** | *0.204**** |
| $R^2$ | *0.727* | *0.722* | *0.365* | *0.33* |

*significant at 10%, ** significant at 5%, ***significant at 1%

**Table 6 : Summary of ECM-based causality test**

| ***Direction of causation*** | ***$X^2$ statistics*** | ***Conclusion*** |
|---|---|---|
| *g causes y* | $X^2 = 5.49$ | Causality exists |
| *k causes y* | $X^2 = 17.3$ | Causality exists |
| *y causes g* | $X^2 = 0.775$ | Causality does not exist |
| *y causes k* | $X^2 = 3.406$ | Causality exists |
| *g causes k* | $X^2 = 2.9$ | Causality exists |
| *k causes g* | $X^2 = 1.51$ | Causality does not exist |