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The Direct Productivity Impact of Infrastructure Investment:
Dynamic Panel Data Evidence From Sub Saharan Africa

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Abstract

The paper aimed at isolating the direct productivity of economic infrastructure using a production function approach. Based on an extension of endogenous growth theory with public finance, infrastructure could have either a negative or positive effect on economic growth. The empirical analysis utilises a panel of 19 countries from Sub Saharan Africa (SSA). With SSA infrastructure being less developed both in terms of quantity and quality, the a priori expectation was that all types of infrastructure have a positive and significant effect on aggregate income level. It is found that, like static estimation techniques, dynamic panel data (DPD) estimation techniques could also produce counterintuitive results if endogeneity of infrastructure is not accounted for. Positive and significant direct productive effects of infrastructure (total roads, electricity generation capacity, and telephones) were obtained using the Pooled Mean Group (PMG) estimator (a form of DPD analysis) after instrumentation for infrastructure. Representing infrastructure with an index constructed from the three infrastructure types also produced similar results. The results are confirmed with the use of the System General Method of Moments (SYS GMM) which constructs instruments for infrastructure using appropriate lags of the variables in first differences and in levels. Thus, it would appear that the negative and counterintuitive productivity results that are sometimes obtained in the literature could be partly due to limitations in methodologies that do not appropriately account for time varying fixed effects and the endogeneity of infrastructure in the economic growth process, especially for developing countries. Control variables for the macroeconomic environment and level of political and civil rights are also found to have a positive and significant effect on aggregate output.

1   INTRODUCTION

The productive impact of infrastructure has long been recognised in the literature on economic growth.[1] This paper is aimed at isolating the productive impact of infrastructure through its contribution to aggregate output using a sample of countries from Sub Saharan Africa (SSA). Using

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[1]Early contributions to this literature are surveyed in Gramlich (1994) and the World Bank (1994) provides a comprehensive analysis of the economic growth effects of infrastructure. A more recent survey is provided in Romp and de Haan (1005).

the Database of World infrastructure stocks by Canning (1998), and the World Banks' World Development Indicators, we estimate an empirical production function augmented with infrastructure and a standard set of control variables that are often used in the literature.

With aggregate output dependent on inputs and their productivity, infrastructure's growth effect could be argued to arise from its use as an input to production as well as its enhancement of the productivity of other inputs of production.[2] Based on the growth model of Barro (1990), infrastructure capital can be considered to be an input into aggregate production. This allows for the derivation of an optimal level of infrastructure which maximizes economic growth. Hence, the growth effect of positive shocks to infrastructure depends on whether the existing stocks are at, below, or above their optimal level. If below their optimal level, additional infrastructure will enhance growth, while the reverse is true if existing stocks are above the optimal level.

In attempting to explain the decline in productivity in the United States of America (USA) in the 1970s, Aschauer (1989) and Munnell (1990a) used production function based approaches to estimate output elasticities with respect to infrastructure that range from 0.30 to 0.40. Since then, the role of infrastructure in economic activity has received increased attention. For example, Holtz-Eakin (1994), Garcia-Mila, McGuire and Porter (1996), Sánchez-Robles (1998), Canning (1999), Demetriades and Mamuneas (2000), Canning and Bennathan (2000), Calderón and Servén (2004), Canning and Pedroni (2004) Fedderke and Bogetic (2006) and many others have estimated production function or growth models that are augmented with infrastructure.

While this paper is related to these previous studies, it extends them along some dimensions. Firstly, unlike most of the previous studies that focus on one specific infrastructure sub sector, in this paper three sub sectors, viz roads, electricity and telecommunications, are investigated. This will allow a comparison of the impacts of the individual types of infrastructure. Secondly, this paper also considers two alternative ways of including infrastructure in the production function. One way is to augment the production function with individual types of infrastructure and the other way is to use an index of infrastructure constructed from the individual types. In this way, unlike most previous studies, this paper also addresses the issue of whether the impact of infrastructure is dependent on whether individual types or a combination thereof is used in the analysis. Thirdly, we also explore the possibility of whether the output effects of infrastructure are dependent on the use of static or dynamic estimation methods. This is intended to contribute to the discussion on the robustness of the results of many previous studies. Finally, this study uses a cross-country time-series data set of infrastructure stocks exclusively for SSA countries. The rest of the paper is organised as follows. The next section provides an extension of the endogenous growth literature as a theoretical basis for analysis, and then section three briefly reviews the empirical literature on the subject. Section four focuses on the empirical methodology and estimation results, and finally section 5 concludes.

2 THEORETICAL FRAMEWORK

The Ramsey (1928), Cass (1965) and Koopmans (1965) model of growth provides a natural starting point for discussing growth models that extend the Solow (1956) growth model with household optimization behaviour. This model assumes a number of infinitely lived households that supply labour, own capital, consume and save. In addition, firms are assumed to be competitive and hire

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[2]See Hall and Jones (1999) and Fedderke, et al (2005) for the contribution of infrastructure in enhancing the productivity of workers.

the services of both labour and capital to produce and sell output. These assumptions therefore imply that the model abstracts from all market imperfections and heterogeneity of households as well as from issues raised by inter-generational links. The dynamics of the economic aggregates are determined by the optimizing behaviour of the economic agents (households and firms) at the microeconomic level. Eventually, this model concludes that growth is based on the accumulation of capital and technological progress or total factor productivity.

Endogenous growth models[3] as popularized by Romer (1986, 1990) and Lucas (1988), and then by Barro (1990) and Barro and Sala-i-Martin (1992) extended the framework of optimizing economic agents that allows for the inclusion of a public sector variable in the production function. This public sector variable we can interpret as economic infrastructure that is provided by the government. Furthermore, we assume that infrastructure is not in the utility function of households. Following this line of reasoning, we posit the following model.

2.1 Consumption

Consider a representative household (implicitly assuming homogenous households) that is infinitely lived and chooses consumption (c) to maximize utility given by;

$$U = \int u(c) e^{-\rho t} dt \tag{1}$$

where is the household's rate of time preference. We shall further assume that the instantaneous utility function is of the constant inter-temporal elasticity of substitution (CIES) form

$$U(c) = \frac{c^{1-\sigma} - 1}{1 - \sigma} \tag{2}$$

where $\sigma > 0$ and hence marginal utility has constant elasticity of σ. The inter-temporal elasticity of substitution in this case is $1/\sigma$ and is constant.

2.2 Production

Non-rival and non-excludable infrastructure implies that the aggregate quantity of public investment on the infrastructure is available equally to all households and firms. We shall assume that infrastructure is included in our broad capital concept and therefore may either be used directly as an input into production or that it complements the services of other production inputs. However, we also assume that infrastructure does not directly affect the consumption pattern of households.

Assuming Cobb Douglas production function, the representative firm's per capita production function can be specified as

$$y = f(k, g) = \beta k^a g^{1-a} \tag{3}$$

where y is per capita aggregate output, B is a technology augmenting parameter, k is per capita capital which is interpreted to include both physical and human capital, $g = \prod_{i=1}^{m} g_i$, with g_i representing a component of infrastructure services, m being the number of such services, and $0 < a < 1$. Our production function exhibits constant returns to scale and emphasizes the need for capital to grow along with at least one type of infrastructure.

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[3]For a wider Schumpeterian context, also see Aghion and Howitt (1992).

2.3   Public Sector

Assuming that government maintains a balanced budget and that it finances its infrastructure investment through a flat tax rate τ on total output y, the government budget constraint can be represented as
.

$$\tau y = g \tag{4}$$

2.4   Household Optimization

Given the government's determination of the tax rate and allocation of its revenue amongst g_i, our representative household will chose c to maximize equation (1) subject to the production function in equation (3), income allocation between investment and consumption, and the government's budget constraint in equation (4). Therefore, using equations (1), (2), (3) and (4) we can formulate the household's maximization problem as follows;

Maximize

$$U = \int \frac{c^{1-\sigma} - 1}{1 - \sigma} e^{-\rho t} dt \tag{5}$$

Subject to

$$y = Bk^a g^{1-a} \tag{6}$$

$$\tau y = g \tag{7}$$

$$\dot{k} = (1 - \tau) y - c \tag{8}$$

It can be shown that the above problem leads to steady state growth of the economy that can be represented by the following expression.

$$\phi = \frac{B(1-\tau)\left(\frac{g}{k}\right)^{1-a} - r - \rho}{\sigma} \tag{9}$$

where r is a discount factor and all other variables are as defined before. Given the tax rate and the level of capital, differentiation of (9) yields:

$$\frac{\partial \phi}{\partial g} = B(1-\tau)(1-a)\frac{g^{-a}}{\sigma k^{1-a}} = \frac{B(1-\tau)(1-a)}{\sigma k}\left(\frac{k}{g}\right)^a > 0 \tag{10}$$

.

$$\frac{\partial^2 \phi}{\partial g^2} = -\frac{Ba(1-\tau)(1-a)}{\sigma kg}\left(\frac{k}{g}\right)^a < 0 \tag{11}$$

This implies that the growth of the economy is concave in g and hence it could be maximised. The condition for optimal g therefore requires the maximization of equation (9) with respect to g subject to the government budget constraint. We can therefore impose the government budget constraint on equation (9) so that we obtain equation (12) which we then proceed to investigate its behaviour with respect to g.

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$$\phi = \frac{B\left(1 - \frac{g}{y}\right)\left(\frac{g}{k}\right)^{1-a} - r - \rho}{\sigma} \tag{12}$$

First order condition for maximization of equation (12) with respect to g gives us the following expression.

$$\frac{\partial \phi}{\partial g} = \frac{B(1-a)\left(1 - \frac{g}{y}\right)}{\sigma k}\left(\frac{k}{g}\right)^{a} - \frac{B\left(\frac{g}{k}\right)^{1-a}}{\sigma y}\left(1 - \frac{g}{y}\frac{\partial y}{\partial g}\right) = 0 \tag{13}$$

Simplification of (13) leads to the following.

$$(1-a)\left(1 - \frac{g}{y}\right)\frac{1}{g} - \frac{1}{y}\left(1 - \frac{g}{y}\frac{\partial y}{\partial g}\right) = 0 \tag{14}$$

Focusing on the left hand side (LHS) of (14), the first term is positive but the second term can be positive, negative or zero. This leads to a deduction of three possible scenarios.

First, if the second term is negative, then the whole of the LHS of (14) becomes positive and greater than zero. Therefore, the growth effect of g is positive if,

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$$1 - \frac{g}{y}\frac{\partial y}{\partial g} < 0 \text{ and this implies that } \frac{g}{y}\frac{\partial y}{\partial g} > 1 \tag{15}$$

Expression (15) posits that the growth effect of public services is positive if the public good elasticity of output is greater than one. This implies that, the growth in public services should not exceed the growth in aggregate output if public services' contribution to economic growth is to be positive.

Second, if the second term on the LHS of (14) is zero, then only the first term of the LHS of (14) remains and this is positive as indicated earlier. Therefore, the growth effect of g is still positive but less than in the first scenario if

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$$1 - \frac{g}{y}\frac{\partial y}{\partial g} = 0 \text{ and this implies that } \frac{g}{y}\frac{\partial y}{\partial g} = 1 \tag{16}$$

Condition (16) implies that the growth effect of public services is positive but reduced to a minimum if the public service elasticity of aggregate output is equal to one. Therefore, further increases in the public services in this case will lead to a decreased growth effect although positive – diminishing growth effects.

Third, if the second term on the LHS of (14) is positive, then we have three other possibilities depending on whether it is less than, equal to, or greater than the first term. If it is less than the first term, the growth effect of g will still be positive but less than the first two scenarios. If it is equal to the first term, then we have equation (14) holding. This will be the point at which the growth effect of public services are maximised. If it is greater than the first term, then the growth effect of g is negative. The second of the three alternatives in the third scenario embodies two conditions for optimal provision of public goods and/or services. Specifically, optimal g initially requires that,

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$$1 - \frac{g}{y}\frac{\partial y}{\partial g} > 0 \text{ and this implies that } \frac{g}{y}\frac{\partial y}{\partial g} < 1 \tag{17}$$

In addition, it also requires equality of both expressions on the LHS of (14). We could therefore interpret condition (17) as the necessary condition for optimal provision of public services but it is not sufficient. To derive the sufficient condition, we equate the two terms in question and solve for it. This gives us the following;

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$$(1-a)\left(1-\frac{g}{y}\right)\frac{1}{g} = \frac{1}{y}\left(1-\frac{g}{y}\frac{\partial y}{\partial g}\right) \tag{18}$$

Since we are trying to locate the point at which the growth effect of g is zero, then we can safely assume that at that point the output effect of g will also be maximised. In that case we can set $(\partial y/\partial g) = 0$ so that (18) becomes

$$(1-a)\left(1-\frac{g}{y}\right)\frac{1}{g} = \frac{1}{y}\text{and this implies that } (1-a)\left(1-\frac{g}{y}\right) = \frac{g}{y}$$

This solves to

$$\frac{g}{y} = \frac{(1-a)}{(2-a)} = \tau^* \tag{19}$$

Equation (19) represents the optimal tax rate, given the balanced budget assumption and optimal public investment in infrastructure.

In general, this model solution implies a nonlinear relationship between aggregate output and infrastructure.[4] Below the output growth maximizing level, positive shocks to infrastructure investment will tend to increase the level of output at an increasing rate, while above the optimal level, positive shocks could increase output but at a decreasing rate. A similar intuition is used by Canning and Pedroni (2004) in the connection between infrastructure and growth with a similar focus on the sign of the effect of infrastructure on aggregate output.[5] Meanwhile, we briefly discuss some of the empirical literature.

3   EMPIRICAL EVIDENCE

There have been several attempts to investigate the impact of public capital in the form of economic infrastructure on economic growth. For example, Barro (1991) used data from 98 countries to highlight empirical regularities in relationships between growth and other factors identified from theory. In this study, a positive relationship between GDP growth rate and public investment was identified, although it was not statistically significant. However, when Aschauer (1989) disaggregated government expenditure and used non military capital stock time series data from the USA, 'core infrastructure'[6] which accounted for 55% of total non military capital, was found to be highly significant in explaining productivity improvement and hence economic growth.

This finding by Aschauer, triggered intense research on this area with econometric studies carried out by for example Aschauer (1990), Holtz-Eakin (1994), Munnell (1990a, 1990b, 1992), Kessides

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[4]The 'g' in our model can be interpreted as public expenditure, infrastructure stocks or macroeconomic policy or institutional factors depending on the specifics that one needs to be referred to for clarification.

[5]While this approach is simple, it does not account for the net effect on individual countries. Another limitation of this approach in this paper is on its focus on the quantity of infrastructure, not accounting for quality

[6]Core infrastructure in this study was defined to comprising of highways, mass transit, airports, electrical and gas facilities, water and sewers.

(1993) and Fernald (1993). These early studies attracted econometric and other methodological criticisms from other studies such as Aaron (1990), Hulten and Schwab (1991), Rubin (1991), and Tatom (1991). Gramlich (1994) reviewed some of these early contributions and rightly concluded that there are mixed results.[7] Moreover, this review also found that the disaggregated time series studies provided more insight than aggregated needs assessments and macro time series studies in terms of the type of infrastructure and whether they are optimally provided or not. The inference drawn is that authorities should be made to determine their optimal levels of types of infrastructure. In general, the World Bank (1994) recognised the role of infrastructure in development and emphasised that policy can and should be used to improve both the quantity and quality of infrastructure services in developing countries.

As the debate continues, the focus has been on questions of how to identify a shortage of infrastructure investment, whether there was a shortage, and whether the shortage had an adverse effect on productivity and hence its decline in industrialised countries. Models used in the investigations included regional production functions, cost functions of manufacturing firms, as well as sectoral or national labour productivity models. For example, recently, Destefanis and Sena (2005), investigated the relationship between infrastructure and factor productivity in the 20 Italian regions, accounting for human capital accumulation. The study used panel data analysis and confirmed that public capital (especially core infrastructure defined as roads, airports, harbours, railroads, water, electricity, and telecommunications) significantly impacts on factor productivity, especially in the southern regions. Similarly, Brox and Fader (2005), Paul, Sahni, and Biswal (2004), and Paul (2003), all concluded that in terms of both cost-saving and output-augmenting measures, public infrastructure is found to have a positive and significant impact on productivity in the private sector. In addition, public capital is found to be a substitute for both private capital and labour, and that the rates of return to public capital are significant although they vary over the sample period. Other evidence on the positive contributions of infrastructure to economic growth are also provided by Canning and Pedroni (2004), Calderon and Serven (2004), and Paul (2003).

Makin and Paul (2003), provides an overview of the literature on the productive effects of public infrastructure. They concluded that early aggregate studies based on restrictive functional forms of production functions provide controversial estimates of public infrastructure impact on productivity and growth. Recent studies based on flexible forms of cost and profit functions that use disaggregated data find that public capital significantly contributes to productivity growth and with high rates of return. Moreover, most economies are found to have less than optimal levels of public capital implying a need for further investment in public infrastructure.[8]

African studies in this area include, Akinbobola and Saibu (2004) who used a vector autoregressive approach to analyse the trend of public investment in relation to human development and unemployment. They found that an increase in the growth of public capital expenditure is associated with a decrease in unemployment and an improvement in the human development index.[9]

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[7] For example while Aschauer (1989) and Munnell (1990a) reported a positive effect of non-military public capital on growth, Holtz-Eakin (1994) reported no role for public capital in growth and this is later supported by Garcia-Mila, et al (1996).

[8] Other global evidence on the productivity of infrastructure include Stephan (2003), Fernandez and Montuenga-Gomez (2003), Salinas Jimenez (2003), Kalyvitis (2003), Ramirez (2002), Rovolis and Spence (2002), Ghafoor and Yorucu (2002), Frutos, Gracia-Diez, Perez-Amaral (1998), Sanchez-Robles (1998), Miller and Tsoukis (2001), Seung and Kraybill (2001), Nourzad (2000), Ramirez (2000), Pereira and Sagales (1999), Delorme, Thompson and Warren (1999), Hurlin (1999), Lachler and Aschauer (1998), Prud'humme (1996), Hakfoort (1996), Fernald (1999), Fedderke and Bogetic (2006). A recent review of the literature is also provided by Romp and de Han (2005).

[9] It is important to note here that the same effect on employment and human development could also be obtained from public works programmes that are mainly focused on providing employment to unskilled workers. Therefore,

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Similarly, Badawi (2003) used a co-integrated vector autoregressive model to conclude that both private and public capital investment are found to have stimulated economic growth in Sudan for the period 1970-1998. Furthermore, private capital is found to have a more pronounced effect on growth than public capital possibly because the crowding out effect of public capital weakens the positive effects it has on growth.

In another African investigation, Ayogu (1999, 2000) used regional panel data from Nigeria to estimate regional production functions. He concludes that the evidence show a strong association between infrastructure and output. A similar conclusion was also reached by the African Development Bank with the addition "that investment in infrastructure has a very high return" and therefore attractive (ADB 1999: 99).[10]

More recently, Fedderke, et al (2005) used a VECM model to investigate the long run growth effects of public infrastructure in South Africa. They found that investment in infrastructure positively contributes to growth in the country both directly and indirectly through enhancing the productivity of private capital. A similar conclusion was also reached by Bogetic and Fedderke (2006) although with the qualification that infrastructure has a more limited impact on factor productivity. Furthermore, in an analysis of urban dynamics in Cote d'Ivoire, Bogetic and Sanogo (2005:26) found that poor infrastructure (as in a poor network of roads) constrains productivity in both primary and tertiary industries. This is could be due to the implied limitations involved in the transportation of goods from rural to urban areas.

The foregoing empirical evidence of both positive and negative impact of infrastructure variables points to our theoretical conclusion in section two that there are optimal levels of public capital provision. Below this level, public investment can positively contribute to growth, but beyond which the contribution to growth decreases and eventually becomes negative. Regardless of this, a limitation in comparing previous studies is that they differ in many dimensions such as different country samples, cross country as against single country framework, and also differences in time periods for estimation. Moreover, while some uses aggregate per capita output as their outcome measure, others use economic growth rates, and others use total factor productivity. Similarly, various studies use different measures of infrastructure. These differences imply that it is difficult to assess and/or compare their results directly.

Additionally, it could also be argued that the methodology used in these studies may have contributed to the differences in their findings. For example, it has been revealed by the empirical literature that there has been a bias towards static cross section or panel data analysis, as well as periodic averaging and aggregation of data in panels. This paper will attempt to address these issues identified above through focusing explicitly on infrastructure stocks both individually measured and as an index in the form of a factor. We then compare the sign and significance of the infrastructure types as well as their factor using different methods of dynamic panel data models as detailed in the following section.

the findings of the study referred to above should be read and interpreted with caution.

[10] Other African evidence is provided by Reinikka and Svensson (1999), who used unique microeconomic evidence to show the effects of poor infrastructure services on private investment in Uganda. They found that poor public capital, proxied by an unreliable and inadequate power supply, significantly reduces productive private investment. Similarly, Weiss, (1998) as referred to in ADB (1999), is indicated to have used a growth accounting approach with data from 31 developing countries to demonstrate that infrastructure is positively related to output growth with the coefficients of the lagged values of the two proxies used for infrastructure being both positive and significant.

4   METHODOLOGY AND ECONOMETRIC ANALYSIS

Accounting for the limitations identified above, the model specification for this section will concentrate on allowing for dynamic effects and non linearities that may be present in the association between aggregate output and infrastructure. An aggregate production function is augmented with both infrastructure and control variables. The control variables are the standard ones used in the literature and they enable us to test their respective significance in our context.[11]

Fedderke, et al (2005a) demonstrate that in order to avoid biased and inconsistent estimates in the presence of dynamic fixed effects and country specific effects, Pooled Mean Group Estimators (PMGE) can be used.[12] This is a dynamic heterogeneous panel estimation method that accounts for heterogeneity across countries included in the panel and also the possibilities of non linearities between some or all types of infrastructure and output. Accordingly, we can specify the following unrestricted error correction $ARDL(p,q)$ model;

$$\Delta y_{it} = \phi y_{i,t-1} + \beta^{'} x_{i,t-1} + \overset{p-1}{\underset{j=1}{\Sigma}} \lambda_{ij} \Delta y_{i,t-j} + \overset{q-1}{\underset{j=0}{\Sigma}} \delta \Delta x_{i,t-j} + \mu_i + \varepsilon_{it}, i = 1, \ldots N; t = 1, \ldots T \qquad (20)$$

where y_{it} is a scalar dependent variable, x_{it} is a k x 1 vector of weakly exogenous variables for group i, μ_i is fixed effects and $\varepsilon_{ij} \approx \left(0, \sigma_i^2\right)$, and assume $\phi_i < 0, \forall i$. Therefore, there exist a long run relationship between y_{it} and x_{it} of the form;

$$y_{it} = \theta_i^{'} x_{it} + \eta_{it}, i = 1, 2, \ldots, N, t = 1, 2 \ldots, T \qquad (21)$$

where $\theta_i = \beta_i^{'}/\phi_i$ is a k x 1 vector of long run coefficients, and η_{it} 's stationary with possibly non-zero means (including fixed effects). Therefore, we can rewrite (4.1) as;

$$\Delta y_{it} = \phi_i \eta_{i,t-1} + \overset{p-1}{\underset{j=1}{\Sigma}} \lambda_{ij} \Delta y_{i,t-j} + \overset{q-1}{\underset{j=0}{\Sigma}} \delta \Delta x_{i,t-j} + \mu_i + \varepsilon_{it} \qquad (22)$$

where $\eta_{i,t-1}$ is the error correction term from (4.1) and therefore ϕ is the error correction coefficient that measures the speed of adjustment to the long run equilibrium.

From this general formulation, the Pooled Mean Group (PMG) estimator by Pesaran, Shin and Smith (1999) allows the intercepts, short run coefficients and error variances to differ across groups. However, the long-run coefficients are assumed to be homogeneous. Hence $\theta_i = \theta, \forall i$. This common long-run coefficient and the group specific short-run coefficients are computed by pooled maximum likelihood (PML) estimation. Denoting the PML estimators as $\tilde{\phi}_i$, , $\tilde{\beta}_i, \tilde{\lambda}_{ij}, \tilde{\delta}_{ij}$ and $\tilde{\theta}$,the PMG estimators will be obtained as in the following;

$$\hat{\phi}_{PMG} = \frac{\Sigma_{i=1}^N \tilde{\phi}}{N}, \hat{\beta}_{PMG} = \frac{\Sigma_{i=1}^N \tilde{\beta}_i}{N}, \hat{\lambda}_{jPMG} = \frac{\Sigma_{i=1}^N \tilde{\lambda}_{ij}}{N}, \hat{\delta}_{jPMG} = \frac{\Sigma_{i=1}^N \tilde{\delta}_{ij}}{N}, \hat{\theta}_{PMG} = \tilde{\theta}$$

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The efficiency gains of this estimator over the Mean Group (MG) estimator proposed by Pesaran and Smith (1995), which allows for heterogeneity of all parameters, is based on the PMGE

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[11]Loayza et al (2003) provides a detailed exposition on the theoretical effects of these variables and their inclusion in growth regressions.

[12]Random Effects estimation also accounts for such effects to some extent, but is less efficient and also implies strong exogeneity assumptions.

assumption of long-run homogeneity of parameters. In addition, the heterogeneity of short-run parameters is retained. A Hausman test (h – test) statistic is used to test the difference between the MG and PMG long-run parameters. On the basis of this test, it is safe to assume long-run homogeneity and hence only results for the PMG estimator are reported. This ability of explicitly modelling the short-run dynamics and also recognising a long-run 'steady state' relationship is an important attribute for the use of this estimator in economic growth analysis where such dynamics are inherent.

Despite the PMG estimator's efficiency in the presence of homogeneity and consistency in the presence of heterogeneity, it is not a systems approach. This implies that it does not account for the possible endogeneity of some of the variables in the system. To account for this possibility requires the use of suitable instruments. The next sub section discusses the instrumentation process employed.

4.1   Variables and Data

The variables used in this paper are briefly described in this section.

4.1.1   Output and Capital Variables

GDPPC – Real GDP per capita from World development Indicators 2006. This is the variable used for the dependent variable to represent aggregate income per capita.

KPW – Physical Capital Stock per worker. Physical Capital stock was computed with the perpetual inventory method using investment series from the Pen World Tables 6.1.[13] The labour force used in the final computation was obtained from the World Bank's World Development Indicators. On the depreciation rate, while Nheru and Dhareshwar (1993) used 4%, Ndulu and O,Connell (2003) used 5% in a "Revised Collins/Bosworth Growth Accounting Decomposition" for African Countries. This paper uses a depreciation rate of 6% as in Hall and Jones (1999). This higher depreciation rate is used because SSA is renowned for inadequate maintenance on fixed assets and this is known to reduce their productive life spans.[14] As one of the endogenous variables of the aggregate production function, this variable is expected to have a positive relationship with per capita GDP.

EDU – Average years of schooling for population aged 15 years and over. The data for this variable is obtained from Barro and Lee (2001). This variable is used as a measure of human capital and hence expected to have a positive association with aggregate income.

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[13]The initial value of the capital stock is computed with the mostly used Harberger (1978) methodology which was also used by Nehru and Dhareshwar (1993) and many others. It starts with assuming a long run with the observation that if the capital output ratio is constant over a given period, then the rate of growth of capital over this period is equal to the rate of growth of output. This implies that $(K_t - K_{t-1})/K_{t-1} = g$, where g is output growth rate. Assuming capital to accumulate as in $K_t = (1-d)K_{t-1} + I$, where d is capital's depreciation rate and I is investment, then we can derive $(K_t - K_{t-1})/K_{t-1} = -D + I_t/K_{t-1}$ from which we have $K_{t-1} = I_t/(g+d)$. For the growth rate of output the average of the first three years corresponding to the average of the first three years of the investment series are used. As suggested by Harberger, this averaging will account for short runvariations in output growth and investment. The average also implies that the result is centred on the mid, hence the capital accumulation formula is applied backwards to obtain the initial capital value.

[14]Bu (2004) used firm level data from World Bank surveys to estimate depreciation rates of fixed assets of manufacturing industries from six developing countries and found that they are higher than those commonly used for industrial countries.

4.1.2 Economic Infrastructure indicators

The following types of economic infrastructure are used individually and also in combination to compute an infrastructure index.

TRDS – Total roads in kilometres per 1000 of the population. Total roads in kilometres obtained from World Bank database constructed by Canning (1998).

ELE – Electricity generation capacity in kilowatts per 1000 of the population also obtained from World Bank database constructed by Canning (1998).

TELS – Number of fixed line and mobile telephone subscribers per 1000 of the population from World Bank's World Development Indicators online.

4.1.3 Policy and Institutional indicators

The macroeconomic policy indicators of financial development, openness, inflation and the foreign exchange black market premium are used to construct the "Macro" policy index.

FIN – Money and quasi money (M2) as a ratio of GDP as an indicated of financial deepening with data obtained from WDI. This variable is one of the controls for country specific productivity motivations. It is also included with the rational that financial deepening facilitates better resource allocation in the economy and hence productivity encouraged (Levine, 2003; Collier and Gunning, 1999; Easterly et al, 1993; Easterly and Levine, 1997; Burnside and Dollar, 2000; Hausmann et al, 2005). This variable is therefore expected to be positively related to per capita GDP.

OPEN – Imports plus exports as a percentage of GDP. This is an openness variable that is included with the rational that the more open an economy is the more competitive it becomes and hence the more productivity is rewarded (Sachs et al, 1995; Sachs an Warner, 1997; Burnside and Dollar, 2000; Beck et al, 2000; Easterly and Levine, 2001, 2003; Bosworth and Collins, 2003; Fedderke and Bogetic, 2006).[15] In this study, this variable also controls for the external technological effects on productivity. A positive relationship is expected between openness and aggregate national income. Data for this variable is obtained from WDI online.

INFL – Following Fischer (1993), inflation can be regarded as a measure of domestic fiscal and monetary policy prudence. As an indicator of the domestic macroeconomic policy environment, lower and less volatile inflation is usually preferred. Inflation is therefore expected to be negatively related with output (Beck et al, 2000; Easterly and Levine, 2001, 2003; Ismihan et al, 2002; Sirimaneetham and Temple, 2006). This variable represents country specific fiscal and monetary policy interactions. Data is obtained from World Economic Outlook online

BMP – Parallel foreign exchange market premium as an indicator of domestic management of the external sector, obtained from Easterly's lost Decades ... (2001) macro time series dataset. A high premium is an indication of government intervention and mismanagement in the functioning of the foreign exchange market (Easterly et al, 1993; Easterly and Levine, 1997, 2001, 2003; Beck et al, 2000). The variable partly controls for country specific management of external technological productivity influences. This variable is therefore expected to be negatively related to per capita income.

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[15] Please note that some of these studies may have used a different measure of openness from the one used in this study. For example, Sachs et. al (2005) constructed openness dummy variables based on certain criteria. An analogous treatment for financial depth and exchange rate mismanagement is also possible in the literature to the extent that either of the two variables could be represented by indicators that are different from the ones used in this paper.

RGTS (Rights) – This is a governance variable constructed as a simple aggregation of Freedom House's Political Rights and Civil Rights scores. Both political rights and civil liberties are scored from 1 to 7 corresponding with best to worst in both variables. The G variable is intended to capture the institutional functioning of property rights and its components are obtained from Freedom House's database of democracy indicators online. From our empirical model specification, this variable is also controls for the country specific productivity incentives and motivations. This variable is therefore expected to be negatively related to GDP per capita – negativity in this case indicating that good governance in the form of enforcement and maintenance of political rights and civil liberties (Collier and Gunning, 1999; Bosworth and Collins, 2003; Hausmann et al, 2005; Fedderke et al, 2005) is good for higher income levels.

4.2   Non Parametric Empirical Analysis

The empirical analysis that follows employs aggregate annual data for a balanced panel of 19 Sub Saharan Africa (SSA) countries that spans the period 1980 to 1995 inclusive. This gives a total of 304 observations for each variable in the panel. The choice of the study period is based on the availability of data. Similarly, the countries in the panel are determined by the availability of data and the desire to construct a balanced panel. Consequently, the countries in the panel are; Benin, Cameroon, Central Africa Republic, Congo Democratic Republic, Congo Republic, The Gambia, Ghana, Kenya, Malawi, Mali, Mauritius, Niger, Rwanda, Senegal, Sierra Leone, Togo, Uganda, Zambia and Zimbabwe. South Africa is not included in the panel because of it's over whelming economic might as compared to all the other countries in SSA. For example, South Africa's GDP is more than the combined GDP of all the other countries in SSA. This makes this country very unique and therefore an outlier if included in the sample. The empirical analysis begins with a description of our data using the variables of interest for the study.

4.2.1   Descriptive Analysis of Key Variables in Panel

This section will mainly focus on the dependent variable and infrastructure variables so as to get an understanding of the behaviour and characteristics of the data. Thus we shall first look at the summary statistics and then proceed to look at the pair wise correlations between the dependent variable and the infrastructure variables. Table 1 contains the summary statistics of the infrastructure variables together with the dependent variable GDPPC for the panel as a whole. Amongst the infrastructure variables, table 1 shows that electricity generating capacity, in the bottom row of the table exhibits the largest variation with a standard deviation of 1.257 and a range of between 12.706 and 7.791 logarithmic units.

This wide variation in electricity generating capacity could be attributed to the fact that on one hand some countries in the panel having excess capacity as compared to domestic demand. On the other hand, some countries in the panel have domestic capacity that is not enough to cater for the domestic market and hence they use imported electricity to supplement the domestic capacity. For example, in Southern Africa, Zambia exports electricity, in West Africa, Ghana exports electricity, in East Africa, Uganda exports electricity, and in Central Africa, Democratic Republic of Congo exports electricity. All these electricity exporting countries as well as some of the countries importing this electricity are part of the panel of countries used in this study, hence the possibility for wide variation in the respective electricity generating per capita capacities.

On the contrary, table 1 also shows that the logarithm of per capita roads has the least variation of the infrastructure variables, with a standard deviation of 0.553 and a range between 9.352 and

7.036. This relatively small variation in roads is similarly exhibited by per capita GDP with a standard deviation of 0.526 and a range of between 8.969 and 6.187 logarithmic points. We proceed with correlation analysis before any preliminary remarks on the association of the variables could be made.

TABLE 1 HERE

4.2.2 Correlations Between Real GDP per capita and Infrastructure

Using all observations in the panel, table 2 below shows that the correlation coefficients between real GDP per capita and all the infrastructure variables are positive and significant at the 5% level. Accordingly to the magnitudes of the correlation coefficients, telephones are the most highly correlated with real GDP with a correlation coefficient of 0.60. This is followed by electricity generating capacity with a correlation coefficient of 0.56. This is an indication of an association between the infrastructure variables used in this study and real GDP per capita. Additionally, the infrastructure variables are also significantly correlated with each other. Per capita electricity generating capacity has significant correlation coefficients of 0.42 and 0.65 with per capita roads and per capita telephones respectively.

TABLE 2 HERE

These significant correlations between the infrastructure variables points to the possibility of multicollinearity in a regression in which all the infrastructure variables are simultaneously included as explanatory variables. Instead, the high correlation between the infrastructure variables could be used to justify the use of one of these variables as a representative variable for all the infrastructure variables. The other possibility, which is pursued in this paper, is that the high correlation between the infrastructure variables allows the construction of a composite infrastructure variable or index.

The analysis therefore proceeds with a two prong strategy. Firstly, the infrastructure variables will be considered individually and secondly, an infrastructure index that could be interpreted as a composite infrastructure good is constructed and separately treated as an additional infrastructure variable.

The infrastructure index is constructed using principal component factor analysis which produces the following index;

$$FAINF = 0.314 lntrds + 0.440 lntels + 0.508 lnegc.$$

This infrastructure index is found to have a pair wise correlation of 0.65 with the logarithm of real GDP per capita and it is significant at the 5% level. Therefore, in the section for estimation, the infrastructure index will be considered separately in addition to the individual infrastructure types which also enter the regressions in succession. But first we consider the correlation between our policy variables.

4.2.3 Macroeconomic Environment Control Variables

In the interest of parsimony, we follow the approach of Burnside and Dollar (2000) so that four of the control variables for macroeconomic policy (Trade, M2, Inflation and Black Market Premium) are used to construct an index that is referred to as Macro. These variables are all found to be significantly correlated with each other, hence the use of the index. Table 3 provides the correlation matrix of the variables.

TABLE 3 HERE

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While this index is intended to capture the overall quality of macroeconomic policy environment, constructing such an index also reduces measurement error associated with using one indicator as a proxy for policy.[16] Principal component factor analysis is used to construct the index as follows.

$$Macro = 0.377lnm2 + 0.371lntrade - 0.298lninfl - 0.325lnbmp$$

The macro index is found to have a correlation coefficient of 0.36 with real GDP per capita and it is significant at the 5% level. By construction, larger values of the index imply good policy and hence a positive coefficient is expected for this variable in our regressions.

On a similar note, the freedom house's political rights and civil liberties are also found to be significantly correlated with each other with a correlation coefficient of 0.88. Hence the two variables are aggregated into a single variable denoted as rights (rgts).[17] The construction of this variable is such that lower values are an indication of better political rights and civil liberties. This variable is included as a proxy for the institutions dealing with the protection of property rights. Therefore, this variable is expected to have a negative coefficient if indeed property rights do play a positive contribution to growth in aggregate output. The rights variable is found to have a negative correlation coefficient of 0.44 with real GDP per capita and this is significant at the 5% level.

4.3   Parametric Estimation Results and Analysis

For ease of comparison, table 4 presents the long run dynamic estimates of PMGE before and after instrumentation. Columns A1 through A4 report the estimates and model diagnostic statistics without instruments, while columns B1 through B4 reports similar information after instrumentation. Using and ARDL model as in equation (22) above, this estimator used the Akaike Information Criterion (AIC) to select the lag orders. The PMGE is preferred to the static estimators in the sense that this estimator has superior efficiency characteristics in the presence of homogeneity across groups and superior consistency properties in the presence of heterogeneity across groups. The estimates reported in Columns A1 through A4 of table 4 did not produce any statistically significant infrastructure variables. In addition, the signs of all the infrastructure variables are negative. This is counter intuitive for African countries and could be the result of endogeneity of infrastructure in our model. We therefore focus on interpreting results reported in columns B1 through B4 of table 4. Before this is done, we first present the process through which instruments are constructed for the infrastructure variables.

4.3.1   Instrumentation for Infrastructure

Following an approach pioneered by Fedderke and Bogetic (2006), instruments for stocks of infrastructure could be derived from constructing a demand for infrastructure function. Canning (1999), in a study of infrastructure's contribution to aggregate output using a world wide dataset of countries, indicated that the demand for infrastructure is driven by population density and urbanisation. This view is also held in Bogetic and Sanogo (2005) in trying to explain the pattern of urbanisation in the Cote d'Ivoire.

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[16]Indices also limits the influences of outlier observations and also helps in overcoming the difficulty of identifying separate effects of fiscal prudence, inflation control and exchange rate management in relatively small data sets when variables are highly correlated.

[17]The two variables are with values that range from 1 (indicating best) to 7 (indicating worst). Therefore, the aggregated rights variable ranges from 2 (best rights) to 14 (worst rights).

Following Fay (2001) as well as Fay and Yepes (2003), both on infrastructure demand in Latin American countries, the demand for infrastructure per capita could be estimated in a reduced form equation which can generally be written as follows.

$$\frac{I}{P} = F\left(\frac{Y}{P}, \frac{q_I}{w}, Y_{ag}, Y_{man}, A\right) \tag{23}$$

Where I is infrastructure, P is population, Y is aggregate income, $\frac{q_I}{w}$ is the price of infrastructure, and Y_{ag} and Y_{man} are the share of GDP from agriculture and manufacturing respectively, and A is for technology.[18] Roller and Wavermen (2001) used a similar formulation of the demand for telecommunications infrastructure in a simultaneous equation panel study with data from 21 OECD countries over a period of 20 years to determine the impact of infrastructure on economic growth. Their reduced form equation can generally be written as

$$TEL_{it} = h\left(\frac{GDP_{it}}{POP_{it}}, TELP_{it}\right) \tag{24}$$

Where TEL is the demand for telecommunications infrastructure and this is modelled to be a function of per capita GDP (GDP/POP) and the price of telephone services (TELP).[19] Intuitively, these studies on infrastructure demand used the basic micro economic foundation on demand for a good being dependent ob the price of the good , the income level of the consumers, and other factors that affect demand. The difference is on the way the infrastructure prices are accounted for in their respective models.[20]

Employing the above approach, we can construct an instrument in which the demand for infrastructure can be generally expressed as in the following reduced form function.

$$I_p = F\left(Y_p, P_i, VA_{ag}, VA_{ma}, Ub, Pd, A\right) \tag{25}$$

Where I_p is infrastructure demand per capita, Y_p is income per capita, P_i is the price of infrastructure, VA_{ag} is value added from the agricultural sector, VA_{ma} is value added from the manufacturing sector, Ub is urbanisation, Pd is population density, and A is technology. To overcome the problems of getting appropriate variables for infrastructure prices and country specific technology, we follow the Fay (2001) methodology and used static country fixed effects estimation to control for differences in both the prices of infrastructure and technology. Furthermore, the natural logarithm transformation is used to linearised the model and all the regressions included year dummies and a constant to further account for technological dependence on time. Consequently, the instruments were constructed with the following equations.

$$\begin{aligned} Trdinst \;\; &= 0.0246614 \quad {}^* \ln Gdppc - 0.0241752^* \ln VA_{ag} + 0.0114731^* \\ &\quad \ln VA_{ma} - 0.6705358^* \ln Pd + 0.2694915^* \ln Ub \end{aligned}$$

[18] This formulation was used in a study to predict the existing and future infrastructure needs of the Latin America and Caribbean region.

[19] In their empirical estimation, Roller and Waverman (2001) used telephone revenue from mainlines as a proxy for prices. Fay (2001) on the other hand employed fixed effects estimation to jointly control for the price of infrastructure and technology in their empirical implementation. Data limitations dictate that we follow the latter methodology to control for infrastructure price and technology in constructing our infrastructure instruments.

[20] While Fay (2001) and Fay and Yepes (2003) used fixed effects to account for country specific differences in prices and technology, Roller and Waverman (2001) used revenue from the telephones as a proxy for the price.

$$Telinst \quad = 0.196835 \quad {}^*lnGdppc - 0.1959319{}^*lnVA_{ag} - 0.097322$$
$${}^*lnVA_{ma} - 0.9116022{}^*lnPd - 0.4277121{}^*lnUb$$

$$Egcinst \quad = -0.1585318 \quad {}^*lnGdppc - 0.2441573{}^*lnVA_{ag} + 0.0177037$$
$${}^*lnVA_{ma} + 0.1110549{}^*lnPd - 0.5110642{}^*lnUb$$

$$Fainfinst \quad = 0.0363057 \quad {}^*lnGdppc - 0.1984108{}^*lnVA_{ag} - 0.0290405$$
$${}^*lnVA_{ma} - 0.7359361{}^*lnPd - 0.2412687{}^*lnUb$$

Where inst after the left hand side (LHS) variables denotes instrument, ln in front of the right hand side (RHS) variables denotes the natural logarithm,

Gdppc is per capita GDP at constant international dollars for income per capita, and all other variables are as defined above.[21] We re-estimated our infrastructure augmented production in which all the infrastructure variables are replaced by their respective instruments.

4.3.2 Parametric Estimation with Infrastructure Instruments

It is generally observed that using the hausman test statistic, long run homogeneity of our parameter estimates is only valid for some regressions before and after instrumentation depending on the significance level. In contrast, the error correction mechanism validates long run convergence, hence the existence of movements to a long run. The log likelihood ratio supports the equality of long run parameters. Put together, we have a situation in which the ECM points to the existence of a long run, with parameters that tend to be equal across countries (according to the LR statistic) so that we have long run convergence but not necessarily to homogeneous steady states. However, the short run dynamics through which long run convergence is achieved vary between countries, hence the significance of the ECM. It appears that while there is long run convergence of the countries, there are different types of steady states. This is along the lines of club convergence. More specific analyses along these lines will be made but first we take a look at the performance of our control variables and then proceed to our variables of interest - infrastructure.

In columns B2 and B3, physical capital's effect on aggregate output is positive and statistically significant. This variable's elasticity with respect to per capita output ranges from 0.242 to 0.247. These elasticities are below those obtained by Mankiw, Romer and Weil (1992) (MRW) as well as those obtained in Klenow and Rodriguez-Clara (1997), Hall and Jones (1999) and more recently by Canning and Bennathan (2000).

The corresponding coefficient estimates for the human capital variable are not conclusive in the sense that while one is positive and statistically significant (column B3), the other is with a counter intuitive sign but also statistically significant (column B2). On the contrary, POLS produces human capital coefficient estimates that are all positive and specifically statistically significant at 5% and

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[21]The coefficients of the variables used in the construction of the instruments are derived from the fixed effects regressions with year dummies and a constant included. All variables are in log transformation so that the equations are linearized.

10% levels in columns 1a and 1b respectively (See appendix). In particular, the human capital elasticity of output of 0.0885 in column 1b favourably compares with the 0.087 and 0.095 obtained by Canning (1999) for the full sample and developing countries respectively. Positive and significant contribution of both physical and human capital on aggregate output is consistent with the general expectations from the theoretical literature on growth.

The macro economic variable is consistently positive and significant regardless of the estimation method with an elasticity that hovers around 0.1. The exception is column B3 where macro is neither significant nor with a coefficient that is different from zero. This underscores the importance of a suitable macroeconomic environment as well as the complementarity of the component variables within this index. This corresponds to the findings in King and Rebelo (1990), Fischer (1993), Easterly (1993), Sachs, et el (1995), Sachs and Warner (1997), Hall and Jones (1999), Collier and Gunning (1999b) exclusively on Africa, Burnside and Dollar (2000), Easterly and Levine (2001, 2003), Ismihan et al (2002), Sirimaneetham and Temple (2006) and Hausmann, Pritchett and Rodrik (2005) amongst many others that good policy in the form of prudent management of monetary and fiscal policies to keep inflation under control, financial sector liberalization, exchange rate flexibility, and trade openness are an essential part of growth orientation of an economy.

Similarly, the coefficient estimates for the rights index is consistently negative regardless of the estimation method. Recall that negativity of this coefficient is expected, and implies that good political pluralism and upholding of civil liberties make a positive contribution to growth. In essence, these are elements of good governance which have also been shown to contribute positively to economic growth.[22]

TABLE 4 HERE

All the infrastructure variables now have a positive and significant effect on aggregate output with elasticities of 0.46, 1.34, 0.22, and 0.38 for roads, electricity generating capacity, telephones and the index respectively for columns B1 through B4. The elasticity of telephones with respect to aggregate output (0.22) is comparable to the 0.24 and 0.19 obtained by Uchimura and Gao (1993) for transport, water and communication in Taiwan and Korea respectively. In contrast, it is comparatively higher than the 0.16 obtained by Easterly and Rebelo (1993) for transport and communication in a multicountry study that includes developing countries, as well as the 0.139 obtained by Canning (1999)[23] for telephones in low income countries, and the 0.15 reported by Roller and Waverman (2001) for telephones using a panel of 21 OECD countries, but below the 0.41 obtained by Fedderke and Bogetic (2006) for South Africa.

The infrastructure index elasticity of 0.381 (column B4) is comparable to the 0.39 found by Aschauer (1989) and 0.34 found by Munnell (1990a) both for non military public capital for the United States, but higher than the 0.20 found by Mera (1973) for industrial infrastructure in regions of Japan as well as the 0.19 and 0.24 found by Uchimura and Gao (1993) for transportation, water and communication for Korea and Taiwan respectively.

In general, the results reported in table 2 as a whole should be interpreted with caution. In columns A1 through A4, all the coefficients estimates of the infrastructure variables are unexpectedly negative and significant. But, we can discount these counter intuitive results on the basis that there are other associated inconsistencies with the long-run homogeneity assumption that pro-

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[22] A good evaluation of the governance and growth experiences in SSA is provided in Ndulu and O'Connell (1999). The protection of property rights is also widely recognised as a responsibility of the state and hence an essential element of good governance. Kaufmann, et al (1999) and Gradstein (2005) provides in-depth analyses on the importance of governance for economic growth.

[23] Canning (1999:12) reported elasticities of 0.144, 0.139 and 0.257 for full sample, lower-income countries and higher-income countries respectively.

duces them. Using the 5% significance level as a benchmark, the h-test statistic is significant in column A2; effectively rejecting the long-run homogeneity assumption for the electricity generating capacity regression before instrumentation. In contrast, and again using the 5% significance level as benchmark, the h-test statistic is not significant in all of columns B1 through B4. This lends support to the long-run homogeneity assumption. Accounting for endogeneity of the infrastructure variables through the use of instruments may have contributed to these observations.

This argument will not hold if a 10% level of significance is considered. In this case, the h-test becomes significant for the roads and electricity regressions before instrumentation (columns A1 and A2) and also for electricity and telephones after instrumentation (columns B2 and B3). Thus we have an overlap in which the electricity regressions reject the long run homogeneity assumption both before and after the use of instruments for this infrastructure variable. This is further evidence that there are significant variations in the electricity generation capacity of the countries used in our sample due to the inclusion of both electricity importing and exporting countries in our panel. This was highlighted earlier in the analysis of the descriptive data. Instrumentation therefore mainly assisted in reversing the counter intuitive sign of the elasticity of electricity generation capacity with respect to aggregate income. Evidently, there are very high positive returns to investment in electricity generation as illustrated by an elasticity of 1.34 in column B2.

It can immediately be recognised that instrumentation for infrastructure does not only reverse the counter intuitive coefficients estimates signs for these variables, it also retains their statistical significance. However, the size of the infrastructure coefficients are relatively higher (with the exception of the 0.220 in column B3 for telephones) than those of comparable studies reported earlier.

In general error correction mechanism coefficients reported in table 4 are all between zero and minus one. This implies a rapid short-run transition adjustment to the long run. Thus, since individual countries adjust differently to positive infrastructure shocks in the short run, they all converge to different steady states in the long-run. As noted earlier, the hausman test rejects the legitimacy of the long run restrictions of the parameters for some of the regressions (depending on the level of significance considered) and especially for the electricity regressions if the hausman test is considered at 10%. Therefore, we should not lose sight of the existence of country specific differences because some of these peculiarities may be important determinants of these countries' growth paths.

The coefficients estimates obtained for infrastructure variables could only allow a general remark that accounting for the endogeneity of infrastructure in production reverses the counter intuitive negative impact that could be obtained even when there is a well acknowledged low quantity and quality for infrastructure stocks in existence as in SSA.

As a robustness check, we employ another dynamic panel data GMM estimation method that similarly uses an ARDL formulation together with a systems approach. Unlike the PMGE, this estimator uses appropriate lags of variables in levels as instruments for equations in first differences and conversely for equations in levels, all of which are combined into a system of equations with options to treat any of the variables in the system as endogenous or predetermined. This method is described in detail in a related paper that uses public capital expenditure figures as proxies for public capital.[24] We therefore only discuss the results of the estimation.

Table 5 present the short-run parameter estimates of SYS GMM with standard errors that are robust to the presence of heterogeneity and contemporaneous correlation. Both the Sargan test

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[24]Interested readers could also access a description of this method in Arellano and Bond (1991), Arellano and Bover (1995) with production function applications in Blundell and Bond (2000).

for the validity of the over-identifying restrictions and the test for the presence of second order auto correlation in the first differenced residuals lend support for the model formulation and hence validate the system estimates for statistical inference. In the model specifications, both physical capital per worker and the infrastructure variables were treated as endogenous and therefore they all enter the short-run model specification with a lag structure which is not necessarily uniform. In contrast, the variables for human capital, macroeconomic policy and rights environment enter as weakly exogenous because these are mainly control variables. Furthermore, all regressions included year dummies and constants which have been suppressed for ease of presentation.

The short-run dynamics in table 5 implies that infrastructure investment carries possibilities of both negative and positive effects on the economy. Additionally, either of these effects could be significant in the short term due to possible adjustment constraints. We could also not a difference in the lag structure of the regressions. Specifically, the roads infrastructure model in column I involves lagging both the capital labour variable and the roads variable twice before significant reasonable results could be obtained. This implies using lags of order three and earlier as instruments for this model. In contrast, the models for electricity generating capacity in column II and telephones in column III were able to produce intuitive results using only one lag of the capital labour ration and the respective infrastructure measures. Therefore, for these models, it was possible to use instruments starting from the second lag of the respective variables.

TABLE 5 HERE

The longer lag for the roads model as compared to the other infrastructure models could be an indication that the economy takes longer to adjust and realise the full potential of investment in roads than with investment in telephones and electricity generating capacity. Eventually, however, all the infrastructure parameter estimates end up with a positive net effect in the long-run, the magnitudes of which are reported in table 6 below.

TABLE 6 HERE

The p-values of the common factor restrictions tests all validate the significance of the long-run elasticities. This conforms to what was obtained in the PMG estimations with instrument (and h-test evaluated at the 5% level of significance) that despite heterogeneities in the short-run, there is a smooth adjustment into a long-run, though each country may have its own long-run.

The long-run coefficient estimates for the capita labour ratio ranges from 0.04 to 0.07. Though they are similarly positive, they are smaller in magnitude as compared to those obtained with the PMG estimator and other studies referred to earlier. On the contrary, the human capital variable is now consistently positive and significant with long run elasticity that ranges from 0.37 to 0.63. This is a complete reversal from the negative and significant coefficient that was mostly obtained for this variable from the PMG estimator. The SYS GMM estimator has therefore performed better than the PMG estimator in this regard. However, the magnitude of the long-run coefficient is much higher than those obtained in comparable studies.

The macroeconomic policy and rights indices continue to be consistently with the expected signs in support of their role in economic growth. In addition, we have also seen a general increase in the magnitude of the long-run coefficient estimates for both indices.

Unlike the control variables, the long-run coefficient estimates for the infrastructure variables are now reduced in magnitude and more plausible and comparable to similar studies especially for developing countries. There is also a noticeable pattern in the size of the long-run coefficients for the infrastructure variables. The roads infrastructure, with the longest short-run lag structure, has the highest long-run elasticity, followed by electricity generating capacity. Intuitively, investment projects for a percentage increase in roads will naturally involve more resources and time to complete

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as compared to a similar investment for a proportionate increase in electricity generating capacity or the number of telephones. Therefore, it is reasonable to expect a percentage increase in roads infrastructure to have a larger multiplier effect than a percentage increase in the other two types of infrastructure in this study.

5 CONCLUSION AND POLICY RECOMMENDATION

In conclusion, physical and human capital can both positively and significantly affect aggregate output in the sample of SSA studied. Irrespective of whether we use static or dynamic estimators, the importance of a stable and open macroeconomic policy environment for production has also been demonstrated. With the macroeconomic environment being an interaction of several policy dimensions, the performance of our four component policy index has also demonstrated the importance of policy in facilitating productivity, and hence the need for coordinated policy. On a similar note, a conducive economic environment is also complemented by a governance system that ensures the provision and protection of political and civil rights.

While infrastructure has been found to have a direct impact on aggregate output in the sample of SSA countries used in this study, the isolation of this positive impact is better carried out with individual types of infrastructure studied separately if predictions of future requirements are to be made. Otherwise, it has also been possible to demonstrate the positive and significant effect of infrastructure on aggregate output through the use of an infrastructure index. Furthermore, it has also been demonstrated that infrastructure needs to be treated as endogenous to the economic production process in order to be able to identify both the direction of impact and a plausible magnitude of the impact. Therefore, adequately predicting the future demand of infrastructure investment is better carried out in a systems approach that treats infrastructure as endogenous and hence part of the economic system.

It is further noted that the estimated long run elasticities of infrastructure with respective to aggregate output are relatively higher than those obtained in similar studies for developed countries but comparable to those for studies involving developing countries. This could be interpreted as a reflection of the relatively higher returns for infrastructure investment in the sample of SSA countries used in this study because some of these countries are comparatively worse off both in terms of quantity and quality of existing infrastructure.

Furthermore, it is also important to note that SSA countries in the panel used for this study are found to be heterogenous and hence there is a need to always control for this in panel studies or regional programmes. Therefore, despite there is a general shortage of infrastructure in these countries, attempts to remedy the situation should not be generic but targeted to respective individual countries. This is very important in forecasting future demand of infrastructure investment. Even a regional forecast needs to proceed with the individual country forecasts aggregated into regional.

This study has not found any evidence of over investment in the types of infrastructure considered. Instead, it has found that existing stocks of all the three types of infrastructure studied are below their optimal level. Therefore, public investment in all these types of infrastructure could improve the growth prospects of the countries in the sample.

With the above in mind, policy makers and public managers in SSA countries should nevertheless be mindful of the source of funding for investment in infrastructure. It is important that scarce resources are not diverted from maintenance of existing infrastructure stocks. Several options are suggested in the literature as detailed in Kessides (2004). Social planners and managers should

ensure that new infrastructure adds to the existing stock instead of replacing the old stock due to lack of appropriate maintenance.

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Table 1: Summary Statistics for Key Variables

Variable	Obs	Mean	Std. Dev.	Min	Max
Lngdppc	304	7.156123	.5259426	6.187	8.969
lntrds	304	7.976344	.5529728	7.036	9.352
lntels	304	1.208047	1.002062	-.472	4.960
lnegc	304	10.24355	1.257206	7.791	12.706

Note: All variables are in their natural logarithm transformation.

Table.2: Pair Wise Correlations between Real GDP per capita and per capita Infrastructure Variables.

	lngdppc	lntrds	lntels	lnegc
lngdppc	1.00			
lntrds	0.32*	1.00		
lntels	0.60*	0.10	1.00	
lnegc	0.56*	0.42*	0.65*	1.00

Note: A * implies significance at 5% level.

Table 3: Pair Wise Correlations Between Macroeconomic Policy Variables

	lnm2	lntrade	lninfl	lnbmp
lnm2	1.00			
lntrade	0.55*	1.00		
lninfl	-0.41*	-0.20*	1.0000	
lnbmp	-0.28*	-0.44*	0.31*	1.0000

Note: A * denotes significance at the 5% level. Inflation (infl) and Black market premium (bmp) enter as log(1+ infl) and log(1+bmp) respectively.

Table.4: Long Run Elasticities With Dynamic Panel Data Methods. Dependent Variable LnGDPPC.

	A1	A2	A3	A4	B1	B2	B3	B4
	PMGE	PMGE	PMGE	PMGE	PMGE - IV	PMGE - IV	PMGE - IV	PMGE - IV
LnKpw	0.335** (0.045) [7.502]	0.288** (0.045) [6.430]	0.230** (0.043) [5.297]	0.352** (0.035) [9.945]	0.250** (0.058) [4.322]	0.242** (0.047) [5.138]	0.247** (0.057) [4.332]	0.095** (0.038) [2.519]
LnEdu	-0.050 (0.047) [-1.067]	-0.168** (0.037) [-4.585]	-0.043 (0.040) [-1.096]	-0.117** (0.038) [-3.062]	-0.112* (0.058) [-1.931]	-0.369** (0.080) [-4.595]	0.116** (0.043) [2.700]	-0.306** (0.086) [-3.538]
LnTrds	-0.132* (0.070) [-1.873]				0.462** (0.147) [3.139]			
LnEgc		-0.059** (0.028) [-2.096]				1.337** (0.205) [6.515]		
LnTels			-0.140** (0.022) [-6.346]				0.220** (0.052) [4.239]	
Fainf				-0.209** (0.034) [-6.131]				0.381** (0.075) [5.050]
Macro	0.112** (0.008) [14.701]	0.101** (0.011) [8.841]	0.087** (0.007) [12.728]	0.090** (0.007) [12.806]	0.125** (0.010) [11.929]	0.067** (0.020) [3.287]	0.131** (0.010) [13.351]	0.096** (0.009) [11.034]
LnRgts	0.010 (0.017) [0.564]	-0.047** (0.018) [-2.580]	-0.049** (0.018) [-2.786]	-0.031** (0.016) [-1.982]	-0.038** (0.019) (-1.995)	-0.086** (0.023) [-3.734]	0.000 (0.018) [0.012]	-0.129** (0.026) [-4.875}
ECM	-0.686** (0.093) [-7.387]	-0.691** (0.093) [-7.416]	-0.587** (0.092) [-6.361]	-0.690** (0.101) [-6.853]	-0.650** (0.091) [-7.165]	-0.316** (0.112) [-2.821]	-0.249* (0.129) [-1.931]	-0.531** (0.176) [-3.008]
h-test	10.80* {0.06}	17.26** {0.00}	6.48 {0.26}	8.88 {0.11}	4.42 {0.49}	10.68* {0.06}	10.60* {0.06}	1.39 {0.93}
LR	621.628** {0.00}	695.9695** {0.00}	535.3039** {0.00}	619.8339** {0.00}	706.2442** {0.00}	732.9628** {0.00}	507.5631** {0.00}	496.2151** {0.00}
RLL	556.358	515.6444	573.0227	553.7331	548.5772	623.3339	625.5320	604.1122
ULL	867. 172	863.6292	840.6746	863.6500	901.6993	989.8153	879.3136	852.2197

Notes: PMGE denotes Pooled Mean Group Estimator and PMGE-IV implies PMGE with instruments; figures in round parenthesis are standard errors, those in square brackets are t-ratios, those in {} are associated p values of the statistics. ECM denotes the error correction mechanism, h-test denotes the Hausman test statistic for the null hypothesis of long run homogeneity, LR is the likelihood ratio statistic testing for equal long run parameters, RLL and ULL are the restricted and unrestricted log likelihood values used for the LR test statistic. A ** and * denotes significance at 5% and 10% levels respectively.

Table 5: System GMM Estimation Results. Dependent Variable LnGdppc.

	I	II	III	IV
$Gdppc_{i(t-1)}$	0.8684** (0.056) [0.00]	0.9601** (0.015) [0.00]	0.9659** (0.012) [0.00]	0.9607** (0.016) [0.00]
Kpw_{it}	3.2592** (0.878) [0.00]	0.4570** (0.097) [0.00]	0.4098** (0.104) [0.00]	0.4775** (0.111) [0.00]
$Kpw_{i(t-1)}$	-6.0190** (1.796) [0.00]	-0.4553** (0.096) [0.00]	-0.4074** (0.103) [0.00]	-0.4756** (0.110) [0.00]
$Kpw_{i(t-2)}$	2.7645** (0.929) [0.01]			
$Trds_{it}$	0.3782** (0.163) [0.03]			
$Trds_{i(t-1)}$	-0.6600** (0.212) [0.01]			
$Trds_{i(t-2)}$	0.3121** (0.113) [0.01]			
Egc_{it}		-0.0664** (0.025) [0.02]		
$Egc_{i(t-1)}$		0.0716** (0.026) [0.01]		
Tel_{it}			-0.0705* (0.040) [0.10]	
$Tel_{i(t-1)}$			0.0731* (0.043) [0.10]	
Fainf				-0.1191 ** (0.053) [0.04]
Fainf				0.1271** (0.058) [0.04]
Edu_{it}	0.0483** (0.019) [0.02]	0.0185** (0.008) [0.02]	0.0215** (0.008) [0.02]	0.0163* (0.009) [0.08]
$Macro_{it}$	0.0254** (0.006) [0.00]	0.0110** (0.004) [0.01]	0.0110** (0.005) [0.03]	0.0110** (0.004) [0.01]
$Rgts_{it}$	-0.0860** (0.027) [0.01]	-0.0374** (0.011) [0.00]	-0.0394** (0.012) [0.00]	-0.0370** (0.011) [0.00]
Sargan Overidentification test ; P-value	0.269	0.149	0.133	0.109
Arellano-Bond test for AR(2) in first differences; P-value	0.160	0.143	0.184	0.174

Notes: All variables are in their logarithm transformations. Figures in round parenthesis are standard errors and those in square brackets are p-values. A ** denotes significance at the 5% level while a * denotes significance at the 10% level.

Table 6: Long-run Per Capita Output Elasticities from SYS GMM Estimates.

	C1	C2	C3	C4
Kpw	0.04	0.04	0.07	0.05
Trds	0.23			
Egc		0.13		
Tels			0.08	
Fainf				0.20
Edu	0.37	0.46	0.63	0.42
Macro	0.19	0.28	0.32	0.28
Rgts	-0.65	-0.94	-1.16	-0.94
Com. fac. P-value	0.008	0.169	0.211	0.239

Note: Com. fac P-value is the P-value for the test of the common factor restrictions for the derivation of the long-run coefficients.