Does Infrastructure Really Explain Economic Growth in Sub-Saharan Africa?

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Abstract

In the light of Africa's palpable deficit in public infrastructure, we use System GMM to estimate a model of economic growth augmented by an infrastructure variable, for a panel of 45 Sub-Saharan African countries, over the period 2000-2011. We find that it is the spending on infrastructure and increments in the access to infrastructure that influence economic growth and development in Sub-Saharan Africa. Interestingly, these significant associations, especially those of infrastructure spending, are more important for lesser developed economies of the region than for the relatively more developed economies, which uncommonly have better than near-zero access to infrastructure. In addition to these robust direct links between the target variables, we find importantly that infrastructure access, and quality, also relate to economic growth indirectly via export diversification (trade competitiveness), and cross-border capital flows and export diversification, respectively. Among other important policy derivatives of our findings, we emphasize that efforts aimed at reversing Africa's pervasive infrastructure deficit, in ways that enable economic growth and development, must be carefully nuanced.

Keywords: Infrastructure access; infrastructure stock and quality; economic growth; Sub-Saharan Africa; System GMM

JEL Classification: *H54, O11, O40, O55*

1 Introduction[1]

An AfDB/UNDP/OECD (2014) report called for a comprehensive strategy to promote sustainable inclusive growth in Africa. Specifically, the report called on countries to, among others, ensure political and macroeconomic stability, create favorable conditions for doing business, encourage the proper functioning of financial markets, and provide adequate human capital and infrastructure investment. Calls of this nature, coming from the African Development Bank

[1]Parts of the background draw from the work Odongo Kodongo did for African Capacity Building Foundation.

(AfDB), currently an important infrastructure financier in Africa, might be construed as self-serving and intended to safeguard the bank's key business segment. This paper is therefore an attempt to understand whether investment in public infrastructure does indeed play an important role in fostering economic growth in the Sub-Saharan Africa (SSA) region.

Public infrastructure (defined in this paper as physical installations such as highways and roads, airports, telecommunication facilities, water supply systems, electricity, waste treatment facilities and the like)[2] is believed to provide services that form a part of residents' consumption bundles and augments capital and labor as an input in the production process (Ayogu, 2007). Access to infrastructure provision promotes human development, and betters quality of life through improved productivity and sustainable economic growth (Sanchez-Robles, 1998; Egert, Kozluk, and Sutherland, 2009; Ajakaiye and Ncube, 2010). Specifically, public/economic infrastructure provisioning may enhance trade and commerce (Mbaku, 2013) and play an important role in alleviating poverty and inequality (Ndulu, 2006; World Bank, 2006). We especially view infrastructure deficit as an important binding constraint on some traditional antecedents of economic growth, in addition to the fact that it may also directly enable growth.

Despite its apparent importance, public infrastructure stocks of most African countries are believed to be way below the capacity required to support their required levels of production. By the end of the 2000s decade, annual infrastructure investment needs for Africa was estimated at USD 93 billion (15% of GDP), a third of which would be for operations and maintenance in various infrastructure sectors (Foster and Briceño-Garmendia, 2010; AfDB, 2011). It was also estimated that annual expenditure on infrastructure going forward would range from 9% to 13% of GDP (Sachs et al., 2004; ECA, 2005).

To put the region's infrastructure deficit to perspective, we present in Figure 1, a comparative evolution of infrastructure endowments for the world's developing regions over 2007-2013. The figure shows that the SSA region trails its peers on every key metric. For instance, fixed line telephone coverage has stagnated over time at below 0.5 lines per 1000 people compared to other regions of the developing world which have at least 1.5 lines per 1000 people. One may argue that the apparent low fixed line telephone reach has, to some extent, been mitigated by the expanding mobile telephone coverage. However, even on the mobile telephony score, as Figure 1 illustrates, SSA fares poorly relative to other regions. In fact, African Union (2014) estimates that internet penetration rate for SSA was only 6% in 2012, substantially lower than developing regions' average penetration rate 40%. If the region were to achieve universal rural access, for both voice service and limited broadband service based on WiMAX technology[3], it would need an investment of USD 1.7 billion a year. Overall, the estimated ICT sector annual investment need is USD 9 billion, including USD 2 billion for maintenance (Foster and Briceño-Garmendia, 2010).

[2] Various definitions of infrastructure can be found in Fourie, 2006.

[3] WiMax is a standardized wireless version of Ethernet intended primarily as an alternative to wire technologies (such as Cable Modems, DSL and T1/E1 links) to provide broadband access.

Power appears to be the worst affected infrastructure sector in SSA. In addition to the evidence in Figure 1, various accounts have documented the region's critical power shortage situation: over a five-year cycle (2008 to 2012) SSA's total primary energy consumption increased only by 0.9% from 10.23 QBtu to 10.32 QBtu and it's share of the world energy consumption was only 1.9%.[4] In most countries, a good proportion of power generation is from hydro-power, coal and gas plants, with the more expensive thermal generation (diesel turbines) often used to boost supply during low base load generation. To meet suppressed demand, provide additional capacity and support projected economic growth, installed electricity production capacity would have to grow more than 7 GW per year, requiring annual funding of USD 41 billion over 5 years, with USD 14 billion for operations and maintenance (Eberhard et al., 2011).

According to available estimates, SSA has ample water resources that are, however, underdeveloped, unsustainably managed and underutilized, with only 5% of agriculture under irrigation (African Union, 2014). UNICEF data[5] show that, as of 2012, SSA, with 64% access to improved drinking water, lags behind all regions and also falls below the least developed countries average of 66% (see Figure 2). To deal with this dismal performance, Africa Water Vision 2025 called for increased development of water resources by 10% in 2015 and 25% by 2025 to meet increased demand from agriculture, hydropower, tourism and transport. Annual funding gap in the sector was estimated at USD 11 billion (AfDB, 2011).

In the transport sector (not covered in Figure 1), SSA's road network comprises strategic trading corridors of not more than 10,000 km that carry about USD 200 billion of trade annually; road access rate is only 34% compared to 50% in other developing regions and transport costs are 100% higher in SSA than in other regions (African Union, 2014). The region has ambitions for an intra-regional road network (Trans-African Highway), which remains a pipedream due to poor maintenance on key segments. Such a network would require construction of 60,000-100,000 km of paved road (Foster and Briceño-Garmendia, 2010). The region's road density (204 km of road per 1,000 sq. km of land area) is substantially lower than the world average of 944 km and is less than 30% of the next-lowest region, South Asia.

As of 2011, only about 15% of SSA's roads were paved compared to 26% in Latin America and the Caribbean, 65% in East Asia and the Pacific, 76% in Middle East and North Africa, and 86% in developing Europe and Central Asia (computed using World Bank data). Railway infrastructure is not that much better: the spatial density, which compares track mileage with the size of a country, ranges from 1 to 6 for most countries (16 for South Africa); 13 countries have no operating railway at all (Bullock, 2009). A transport network

[4] "QBtu" refers to quadrillions of British Thermal Units. All World Bank data used in this paper were accessed from World Development Indicators on various dates between March and May 2015 on the website:
http://0-databank.worldbank.org.innopac.wits.ac.za/data/reports.aspx?source=world-development-indicators

[5] Accessed from http://data.unicef.org/water-sanitation/water on April 12, 2015.

with sufficient regional, national, urban, and rural road connectivity, accompanied by adequate rail, port, and airport infrastructure, requires spending of approximately USD 18 billion a year, half of which would be for maintenance only (Foster and Briceño-Garmendia, 2010).

SSA governments and their development partners are cognizant of the region's colossal infrastructure development need and huge funding gap. It is understood, however, that mobilization of investment funds for various public infrastructure sectors is made difficult by the region's financially weak public institutions that, collectively, have an aggregate annual revenue shortfall of approximately USD 8 billion (AfDB, 2011). Growth economists and policymakers are concerned that continued underinvestment in infrastructure might derail development efforts in various economic sectors and adversely impact regional economic growth. Although agreement exists on the need to improve SSA's infrastructure endowment if longer term impact on economic growth is to be realized, there appears not to be a clear understanding of the nature of the relationship between infrastructure and economic growth. Our postulation, however, is that infrastructure is to a large extent both an enabler of growth antecedents as well as, if not more so, a direct antecedent of growth in the SSA kind of environment.

We explore an initial mapping of the possible nature of the relationship between several infrastructure indicators and aggregate income, using energy consumption and number of telephone lines as two key infrastructure metrics. Figure 3 graphs a 12-year (2000–2011) relationship between energy consumption per capita and GDP per capita for several SSA countries. Energy consumption data is obtained from the USA Energy Information Administration (EIA) database; GDP per capita is from World Bank's WDIs. In general, it is reasonably evident in the figure that countries, such as Seychelles, with higher levels of infrastructure also have higher income levels; similarly, countries with low infrastructure levels also have low income levels. Subsequently, we stack the countries into a panel and run a pooled correlation – the coefficient of 0.66 indicates a potential positive relationship between energy consumption and income; however, the correlation coefficient between telephone lines and income is relatively low at 0.37. These two observations, combined, point to the possible impact infrastructure provision could have on economic growth in SSA.

The literature has proposed several plausible theoretical explanations of infrastructure's impacts on economic growth. One school of thought regards infrastructure as part of a country's physical stock of capital and therefore a factor of production (e.g. Aschauer, 1993; Gramlich, 1994). Proponents of this school argue that changes in the stock of infrastructure impact national output and directly induce economic growth. The second viewpoint is that infrastructure complements other factors of production: the argument here is that infrastructure may improve total factor productivity by lowering input costs or by expanding the production frontier or the set of profitable investment opportunities (e.g. Barro, 1990).[6]

[6] For instance, availability of safe Internet may increase speed of communication and

In the third school of thought, infrastructure is believed to stimulate the accumulation of factors of production. Advocates of this view argue that accumulation and productivity of a factor (e.g. labor) is incentivized by infrastructure (e.g. educational and health facilities and roads to access those facilities) (Fedderke and Garlick, 2008). In this sense, infrastructure indirectly affects economic growth. Furthermore, it has also been argued that infrastructure investment can affect economic growth by stimulating aggregate demand or by directing industrial policy toward a desired path[7].

Our postulation in this paper aligns with these latter views on the nature of relations between infrastructure and economic growth. Particularly, this view is more germane for a lesser developed region, such as SSA, where traditional antecedents of economic growth are either significantly inadequate or lacking. Therefore, an erroneous consideration of infrastructure as only directly related to growth may yield insignificant estimate or a weak reflection of infrastructure's effects on growth. As a result of this tendency, care must be taken in specifying appropriately the test of the relation of infrastructure to economic growth (i.e., both direct and, the more plausible, indirect effects).

Empirical tests of the effects of infrastructure on economic growth use various econometric specifications that depend on the underlying theoretical argument(s). In the Sub-Saharan Africa region, the preponderance of evidence from various studies of individual countries (e.g., Reinikka and Svensson, 1999; Fedderke et al., 2006; Estache and Vagliasindi, 2007) and panels (Estache et al., 2006; Calderón and Servén, 2010) point to the SSA's lost growth opportunities which they variously attribute to low infrastructure investment that has jeopardized the region's *international competitiveness*, *increased the cost of doing business, inhibited foreign direct investment* and derailed trade (emphasis ours). These explanations imply an indirect link between infrastructure development/access and economic growth through the highlighted variables. We test the indirect relationship empirically. Boopen (2006) likewise presents panel estimates of the output contribution of transport infrastructure using a similar dataset as Estache et al (2006) and Calderón and Servén (2010). Further, geographical impediments, such as landlocked nature of many SSA countries, which might potentially be redressed through adequate provision of transport and telecommunications infrastructure, puts the region at a disadvantage in attracting trade and investment (Acemoglu et al., 2002; Redding and Venables, 2004; and Cinyabuguma and Putterman, 2011).

South Africa has attracted more attention in this literature, partly reflecting the significantly better quality of its data relative to that of other countries in the region and early adoption of modern financing (Calitz and Fourie, 2010). Fedderke et al. (2006) use a detailed database on infrastructure investment and capital stocks, spanning as long as a 100 years, to test for the existence of

timeously open up profitable trade opportunities just like reliable electricity may reduce manufacturers' energy (electricity) costs.

[7]However, opponents of these arguments have pointed out that expanding aggregate demand without an accompanying change in productive capacity may cause long-term inflation and thus question its efficacy as a policy tool (e.g. Canning and Pedroni, 2004).

a long-run relation between different infrastructure measures and GDP. Their results suggest a bidirectional relation in most cases. Kularatne (2005) explores the effects of economic infrastructure investment (as well as social spending on health and education) on GDP. He also finds bidirectional effects, although the impact of infrastructure investment appears to occur indirectly through private investment. Dinkelman (2011) finds a significant impact of household electrification on employment in South Africa's rural labor markets.

Most of the Africa-focused studies have sought to understand the effects of infrastructure investment on economic development on a country-by-country basis. However, a majority of them focus on one element of infrastructure (e.g. telephone, roads) in disregard of the multidimensional nature of public infrastructure and commonly find that infrastructure stocks are positively related to economic *development* (measured as levels of income). In this study, we take a different approach: first, we examine both the direct and indirect relationships between economic infrastructure and economic *growth* for 45 countries in SSA as a group, using alternative measures of infrastructure that combine several of its dimensions. In contrast to the only known study in the literature that has examined the relationship between infrastructure stocks/quality and economic growth (Calderón and Servén, 2010), our study explores the more plausible indirect effect of infrastructure on economic growth in addition to the direct effect which has been almost the exclusive focus of past related studies.

Further, Calderón and Servén (2010) deal with the issue of cyclicality by using 5-year rolling averages of infrastructure variables. Our view is that this approach causes smoothing in the infrastructure data and, in cases of missing data (an unavoidable problem for African countries for which data are always scarce), distorts observations by repeating one year's values for several years. To deal with this important concern, we use non-averaged annual data to address this apparent data distortion. Furthermore, their study does not examine the possible linkage between infrastructure spending and economic growth; neither does it examine the relationship between incremental infrastructure stocks/quality and economic growth. Our study attempts to fill these gaps. Importantly, in an unprecedented analysis, we explore potential channels, alluded to by previous studies as highlighted in our foregoing literature review, through which economic infrastructure might impact economic growth in the SSA region; we believe that the nuanced relationship is more plausible in the African context.

To mention briefly, we document, contrary to the extant literature, that rather than the sheer stock and/or quality of infrastructure being relevant for economic growth in the SSA region, that is so legendarily bereft of basic infrastructure, it is the spending on infrastructure and increments in access to infrastructure that influence growth. Interestingly, these significant associations, especially those of infrastructure spending, are more important for lesser developed economies in the region than for the relatively more developed economies, which uncommonly have better than near-zero infrastructure levels. In addition to these robust direct links between the target variables, we find importantly that infrastructure access, and quality, also relate to economic growth indirectly via export diversification (trade competitiveness), and cross-border capital flows

and export diversification, respectively. This finding supports our postulation that analysis of the infrastructure—growth nexus ought to be a bit more nuanced than simply examining only their direct association. Among factors that have been documented in the literature as relevant growth factors, we found human capital and institutions to feature consistently significantly in most of our model estimations.

2 Empirical design

2.1 *Determinants of economic growth*

Neo-classical models of economic growth predict that countries with lower initial income levels relative to their long-run steady-state position should grow faster – i.e., the convergence hypothesis. This prediction derives from diminishing returns to capital: economies with lower capital per capita relative to their steady state tend to have higher rates of return on capital (Barro, 1996). The theoretical argument is that poorer countries lack in some critical exogenous factors, which, once supplied, cause exceptionally high returns on capital during the catch-up period (Roberts and Fagernäs, 2004); and they can draw from international capital markets to supplement domestic savings (Rodrik, 2014). These predictions have been confirmed by some studies (e.g. Ghura and Hadjimichael, 1996) which also found that male secondary and higher education, life expectancy, fertility rates, the terms of trade and external competitiveness, and democracy and the rule of law, all have significantly positive impacts on per capita GDP growth and investment expenditure; and that inflation and government consumption (excluding expenditure on education and health) have significantly negative effects.

In another strand of the literature, economists have tried to explain the role of accumulation of factors of production (especially capital) to economic growth. Easterly and Levine (2001) have observed that the accumulation of factors of production, including human capital, tends to be persistent and progressive through time, while economic growth seems irregular over time and similarities in the accumulation of factors among countries have not been matched by convergence in the countries' growth rates. In contrast to this observation, some researchers argue that growth can be explained by changes in total factor productivity; in fact, several studies find that a host of policy variables (e.g., openness, government expenditure, macroeconomic stability, control of corruption, bureaucratic effectiveness, and mitigation of expropriation risk), which might improve the efficiency of factor-utilization, significantly explain economic growth (Ghura and Hadjimichael, 1996).

Other variables that have been found to have a significant effect on growth include natural resource endowment, distance from external markets (Redding and Venables, 2004), transport costs, climate, disease incidence (Sachs and Malaney, 2002) and institutional quality, proxied by a composite index of the rule of law and property rights (Rodrik et al., 2002). Rodrik (2003) argues that initiat-

ing growth does not necessitate a set of growth-inducing policies and institutions; rather, a government's favorable attitude to the private sector and the elimination of impediments to enterprise, the creation of domestic policies and institutionalization of respect for property rights and contracts, sound monetary and fiscal management, and market-oriented incentives are important for determining sustainable growth. However, Rodrik (2014), analysing the recent high growth in African economies, argues that although institutional quality can generate greater economic stability and prevent deep crises from arising out of past mismanagement, institutional quality may not, on its own, be deemed a driver of economic growth.

Financial development has also received a great deal of attention in the economic growth literature. For instance, Calderon and Liu (2003), using Geweke decomposition test on pooled data of several developing and industrialized countries, find that financial development generally leads economic growth, with stronger effect observed for developing countries than industrialized ones. Importantly, their findings suggest that financial deepening works through rapid capital accumulation and productivity growth to influence economic growth; the influence through productivity growth being the stronger of the two. Similarly, Hassan et al. (2011) find a positive relationship between financial development and economic growth in developing countries; they conclude that a well-functioning financial system is a necessary but not sufficient condition to reach steady economic growth path in developing countries. In Africa, Nyamongo et al. (2012) find that Diaspora remittances are not only an important source of economic growth but also appear to complement financial development in enabling it.

In an important recent critique of the economic growth literature, Mthanti (2015) argues that institutional variables are partially shaped by local context and culture which makes it difficult to predict their temporal evolution; he proposes aggregate entrepreneurship orientation, a mélange of aggregate risk taking, innovation and proactive-ness, as an important economic growth determinant. Additional critique is that variables such as institutional quality, infrastructure investment and financial development might as well be explained by economic development dynamics, making them endogenous to the growth process (Glaeser, et al., 2004; Lee and Kim, 2009; and Rodrik, 2014).

2.2 *Econometric specification*

Generally, theoretical economic growth thinking begins with the Solow model, which explains aggregate income by aggregate capital and labor. And because capital exhibits diminishing marginal returns, long-run growth is explained by population growth and technological progress, both of which are exogenous. This general model, which has been revised to include several variables, notably government spending (infrastructure), human capital, protection of property rights and market distortions (see Barro, 1996), has been criticized on several grounds including its failure to explain technological progress and cross-country income differences. These deficiencies have motivated the development, and

burgeoning empirical applications, of endogenous growth models. Barro (1990), one of the earliest contributors to theoretic endogenous growth modeling, argues that the government's contribution to current production is driven by its *flow* of productive (infrastructure) expenditure, which can prevent diminishing private-sector capital returns, raise the marginal product of private-sector capital, and these in turn raise the rate of output growth. This motivates our study's focus on *incremental* infrastructure investment/development.

Thus, to understand the effect of infrastructure development/investment on economic growth in SSA, we formulate, in the spirit of Barro (1990), an endogenous economic growth model of the form:

$$y_{it} = \alpha y_{i,t-1} + \beta' X_{it} + \varepsilon_{it}, \tag{E2}$$

where the disturbance term $\varepsilon_{it} = \eta_i + \epsilon_{it}$, such that η_i are individual fixed effects and ϵ_{it} are the idiosyncratic shocks. y is the natural log of GDP per capita; X is the vector of growth determinants as discussed in Section 2.1. Subtracting $y_{i,t-1}$ from equation (2) yields the following growth equation:

$$\Delta y_{it} = \delta y_{i,t-1} + \beta' X_{it} + \varepsilon_{it} \tag{E3}$$

where Δ is the difference operator and $\delta = \alpha - 1$. We augment equation (2) with an infrastructure variable, z, as follows:

$$\Delta y_{it} = \delta y_{i,t-1} + \beta' X_{it} + \gamma z_{it} + \varepsilon_{it} \tag{E4}$$

The variable, z,includes infrastructure development indices AIDI and AIQI (defined in Section 3.1 as African Infrastructure Development Index and African Infrastructure Quality Index) and infrastructure investment variable, namely, public sector gross fixed capital formation, separately entering the equation (4). Because the lagged dependent variable is endogenous to the stochastic individual fixed effects (η_i), the disturbances (ε_{it}), are serially correlated (see e.g., Bond, 2002). Therefore, estimating equation (4) in its current form would bias the estimated coefficients. A common way of dealing with individual fixed effects (η_i) is to transform equation (4) by differencing it once (Holtz-Eakin et al., 1988). However, this procedure is inappropriate for unbalanced panels (as in this study) in which one missing variable may generate several missing differenced variables in the transformed data.

The forward orthogonal deviations transformation procedure (Arellano and Bover, 1995) performs better in such situations because it subtracts the average of all future available observations of a variable from levels of that variable.[8] Because lagged values of untransformed endogenous variables do not enter the transformation mechanism, they can be used as valid instruments, to control for endogeneity. This is the basis of the system generalized method of moments

[8] An important advantage of this transformation is that, because the rows of the transformation matrix are orthogonal to each other, the transformed data maintain the properties of the original data. For instance, if the original data were identically and independently distributed (iid), the transformed data will be iid as well (see Roodman, 2006).

(GMM) for dynamic panel data models (Blundell and Bond, 1998), which we use to estimate equation (4). In our estimation, we include time dummies to control for the potential effect of 2007/8 financial crisis on economic growth in Africa. We test equation (4) on a panel of 45 SSA countries, using annual data for the period 2000 through 2011.[9] Our data come from World Bank's African Development Indicators.

3 Data and measurement

3.1 *Measuring infrastructure*

Although many studies have found a positive long-run relationship between infrastructure and economic growth, interpretation of these results is always complicated by infrastructure measurement issues. According to Calderon and Servèn (2010), measuring infrastructure as a single variable, either in physical or monetary unit fails to capture the multi-dimensional nature and heterogeneity of infrastructure across time periods and countries, and does not properly distinguish between quality/productivity and bulk of infrastructure. Additionally, simultaneity can be a serious econometric problem in infrastructure-growth studies because countries with faster growing output may spend more on infrastructure while infrastructure provision may also positively mediate the relationship between aggregate input and output, and hence foster output growth. Indeed, Kumo (2012), using South African data, confirms strong bidirectional causality between infrastructure investment and economic growth.

These flagged issues inform our variable measurement and choice of econometric procedures. That is, we try to respond to the criticism about the use of single variable measures by applying an index of various infrastructure measures. The African Infrastructure Development Index (AIDI), developed by AfDB (2013), is a weighted average of nine indicators of infrastructure covering four key components: electricity, transport, information and communications technology (ICT), and water and sanitation. Although the index emphasizes measures of infrastructure "bulk", it also captures some aspects of infrastructure "quality". For instance, bulk of transport infrastructure is captured through *total road network in km* (per square km of exploitable land area) while transport infrastructure quality is addressed through *total paved roads* (km per 10,000 inhabitants).

Water and sanitation is covered only through quality measures: *improved water source* and *improved sanitation facilities* (both as percentage of population with access) while electricity and ICT are only represented through bulk measures. The methodology used to develop AIDI is discussed in detail in AfDB (2013b). We interpret the AIDI index as *infrastructure access*[10] and use

[9] Serious attempts at involving the private sector in infrastructure financing started with market reforms in the mid-1990s. This investigation seeks to capture the relationships of interest post reforms.

[10] We thank the reviewer of an earlier version of this paper for suggesting this interpretation.

it as our core measure of infrastructure development in the SSA region.[11] To our knowledge, this would be the first time the AIDI index is used in a study relating infrastructure development to economic growth.

Table 1 shows the basic relationship between AIDI and real GDP in local currency units for SSA countries over the 2000 – 2011 decade. In the cross-sectional units, the two variables exhibit very strong correlation (in some cases, negative) in levels (1 & 3). With such high levels of association, it is no surprise that studies examining the role of infrastructure in explaining economic development in Africa have recorded high levels of statistical significance of the infrastructure coefficient. We believe that some of such results can be ascribed to coincidence of statistical association. Because of the negative correlations in a few countries, the pooled (panel) correlation is only 0.015 (see bottom right of the table). The table shows that infrastructure access (levels) seem to have a poor relationship with economic growth (1 & 4), with a substantial number of countries reporting low and/or negative correlations.

Finally, we see that growth in infrastructure access seems to have some reasonable relationship with growth in real GDP in several countries, albeit with a negative sign in some cases (2 & 4). Because of its fairly close relationship to economic growth at this basic testing level, we conjecture that incremental infrastructural investment/development is more relevant to economic growth in SSA than current levels of available infrastructure. Accordingly, we use the change in infrastructure access $[In(AIDI_t) - In(AIDI_{t-1})]$ as our dominant infrastructure proxy. However, for comparability with existing studies (e.g. Calderon and Serven, 2010; and Fedderke et al, 2006), we estimate some equations with levels of infrastructure as an alternative measure.

Third, because our infrastructure access measure, the AIDI index described above, puts more emphasis on infrastructure stock than it puts on infrastructure quality, we develop a synthetic index of infrastructure quality as an alternative measure of infrastructure development. Our *African Infrastructure Quality Index* ($AIQI$) is constructed from six variables: telecommunications (secure internet per million people and telephone faults per 100 mainlines), power (percent of transmission and distribution losses in electricity production), transport (share of paved roads in total roads) water (percent of population with access to improved water source) and sanitation (percent of population with access to improved sanitation). We normalize each variable using the formula $d_i = (A_i - m_i)/(M_i - m_i)$ where A_i is the actual value of variable i, m_i is the lower limit (empirical minimum) for variable i. This procedure ensures that observed values retain their rank in the normalized series. We restate two variables – electric power transmission and distribution losses (kWh) and telephone faults (per 100 mainlines) – by subtracting the normalized values from unity to ensure that higher values for each normalized variable represents higher quality

[11] AfDB's (2013b) measure contains index values for the period between 2000 and 2010 only. To estimate the 2011 index values, we work with the values for 2009 and 2010 and the 2009-2011 average obtained from the AfDB website: http://www.afdb.org/en/documents/document/2009-2011-country-africa-infrastructure-development-index-aidi-47372/

infrastructure.

To ensure consistency between our infrastructure quality variable and the infrastructure access variable (AIDI), we calculate the weight of variable i using the method used in AfDB (2013b)[12] as: $w_i = \sigma_{Tot}/\sigma_i$, such that $1/\sigma_{Tot} = \Sigma_i 1/\sigma_i$. We start by applying this procedure to compute the dimension index for telecommunications, which is represented by two variables. The resulting telecommunications dimension is then treated as a distinct variable for purposes of constructing our synthetic quality index. With the resulting weights, we use the following linear transformation to construct the synthetic African Infrastructure Quality Index (AIQI):

$$AIQI = \Sigma_i w_w x_i \tag{E1}$$

The resulting index compares favorably with AfDB's (2013b) Africa Infrastructure Development Index (AIDI) as well as with its component variables as shown in Table 2. A word of caution in the interpretation of the negative correlation coefficients is necessary: the two variables in their original forms imply poor quality infrastructure; in our index construction (as already explained), they are transformed so that large values imply good quality infrastructure. The transformed series correctly correlate negatively with the original unstandardized series (as reported in Table 2).

Due to the multiplicity of infrastructure services (and the accompanying complexity in measurement), many studies (e.g., Barro, 1990; 1991) use monetary values of investment in public assets to proxy infrastructure. Again, for ease of comparison with such studies, we also use the (log of) World Bank's public sector gross fixed capital formation, as an additional proxy more specifically representing infrastructure investment. This variable is defined as outlays of expenditures to increase the stock of fixed assets and is, therefore, a flow, akin to the percentage change in the infrastructure access defined above.

3.2 *Description of variables*

The control variables included in our estimations include the following. First is human capital, measured as the United Nations Development Program (UNDP) human development index reported in World Bank's World Development Indicators. Human capital is important because it enables a country's pool of labor resources to acquire hard skills (e.g. ability to operate machines) and soft skills (e.g., for teamwork and effective communication) which can potentially improve the productivity of capital. UNDP's human development index is composed of life expectancy, national income, and average and expected years of schooling.

Second, from Section 2.2, it is clear that financial development is considered important for economic growth especially in low-income countries (e.g. Hassan et al., 2011; Menya et al., 2014). Commonly used proxies of financial development include the ratio of broad money supply (M2) to GDP which indicates

[12] The reasoning behind using standard deviations as the weighting basis is to adjust for volatility in the original series and thereby reduce volatility in the index ranking of countries.

the size of financial intermediation (Calderon & Liu, 2003; Hassan et al., 2011) and the ratio of credit to the private sector to GDP which represents the actual resources that are channeled to the private economy (Hassan et al., 2011; Menya et al., 2014). We use both measures interchangeably. Third, we control for terms of trade shocks, defined, following Calderon and Serven (2010), as log differences in terms of trade indices; terms of trade shocks can promote economic growth in the long run by impacting on savings/investment rate and capital accumulation (Chowdhury, 2015).

Other control variables that have been used by previous studies (e.g., Barro, 1990; Nyamongo et al., 2012) which are also included here include governance (proxied, in turns, by control of corruption and rule of law), government consumption as a percentage of GDP, inflation (measured as GDP deflator) and exchange rates (local currency units per unit of the USA dollar). As a measure of price stability, inflation is expected to adversely affect consumer demand and adversely affect economic growth.

Notably, an additional set of variables – i.e., trade competitiveness, cost of doing business and foreign direct investment (cross-border capital flow) – are presented separately because they speak to a key innovation of our study. We postulate that infrastructure, importantly, also impacts economic growth via indirect channels, especially given the very low levels of infrastructure endowment in SSA countries. So the little infrastructure endowment available likely strengthens and/or enables growth antecedents. The economics of how these growth antecedents works with infrastructure to impact growth are fully explored in section 4.4 where the analysis of the indirect relations is developed further and tested.

Descriptive statistics of the variables are presented in Table 3. The maximum values of the AIDI infrastructure index is fairly high – an examination shows that these values relate to the higher income economies of Seychelles (range: 47.43 to 87.00) and South Africa (46.07 to 77.91), whose infrastructure are relatively more advanced than that of the rest of the region. The general observation is that richer countries in the region seem to have better infrastructure endowments than poorer countries. We interpret this observation to mean that infrastructure development is endogenous to economic growth and accordingly treat the variables as such in our estimations.

Further, we run our empirical tests initially with all forty five countries in the panel and then run additional tests excluding all economies defined by the World Bank[13] as upper middle income and high income: Botswana, Equatorial Guinea, Gabon, Mauritius, Namibia and South Africa. However, the median infrastructure development index of 12.85 out of a possible 100, confirms Africa's much-discussed poor infrastructure endowment. As expected, the infrastructure quality index (AIQI) is even poorer, with a maximum of 16.61 and a median of only 5.82.

On the average, terms of trade in Africa have improved over the 2000-2011

[13] Upper middle income countries were defined, as of July 2011, as countries with GNI per capita of USD 3,976 or higher. See World Bank's website: http://chartsbin.com/view/2438 (accessed April 7, 2016).

period as shown by the positive mean and median of the shock variable, which suggests a general weak but ascending favorable balance of trade position. The medium credit to the private sector and broad money supply stand at 18.33% and 22.44%, respectively, relative to GDP, both of which speak to the low financial depth in the Sub-Saharan Africa region. The distribution of the credit to the private sector is very broad (standard deviation of 3932%) with the minimum and a maximum values being, respectively, –34.19% and 46,875%. A closer look at the data shows that the high values belong invariably to Mozambique, a fast growing economy in the African region whose growth seems to be largely anchored on an expansionary monetary policy, public spending, and foreign direct investment (FDI) flows.[14]

Government spending to GDP also varies widely, a sign that economies in the region operate different macroeconomic management policies. The implication of these observations is that there is need to control for cross-sectional heterogeneity in our estimation, which justifies the fixed effects procedure applied through the system GMM, discussed in Section 2.2. Institutional quality, represented by control of corruption and rule of law, appears weak, with both the means and medians recording negative results. A final observation is in respect of missing variables. Data is scarce on several of our variables for the SSA region. Although this is largely taken care of by the forward orthogonal deviations transformation in the system GMM, we nonetheless repeat the estimations excluding all countries with more than four missing observations for any of the variables. That gives us a smaller sample of 31 countries.

4 Empirical results

4.1 *Infrastructure access, infrastructure quality and growth in public fixed capital formation*

We estimate the model in equation (4) using a panel of all 45 countries in our sample. We use the Arellano and Bond (1991) instrument set in the first test (Table 4) and then, given the instrument proliferation observation of Roodman (2009), we restrict the instrument set to between 2 and 5 lags of the dependent variable (Table 5). In all estimations, we instrument infrastructure development and investment by population growth. The population variable is transformed in the same way as the explanatory variables. The appropriateness of population growth as an instrument is rooted in theory and supported by several empirical analyses that have reported a strong relationship between population growth and density and both national income and infrastructure. In their theoretical model, Becker et al. (1999) argue that the net relation between increasing population and per capita incomes depends on whether inducements to human capital and expansion of knowledge enabled by larger populations are stronger

[14] This is according to a recent AfDB/OECD/UNDP report, available at: http://www.africaneconomicoutlook.org/fileadmin/uploads/aeo/2015/CN_data/CN_Long_EN/Mozambique_GB_2015.pdf (accessed April 7, 2016).

than the traditionally acclaimed diminishing returns to land and other natural resources.

In an empirical analysis with data of developing economies, Simon and Gobin (1980) find a positive relationship between population density and economic growth and conclude that over the long term, population growth has a positive effect on per capita income. Similarly, Weinhold and Reis (2001) show a strong positive contemporaneous relationship between infrastructure and urban population as well as provide evidence supporting the hypothesis that *growing* urban populations lead to more infrastructure development (in the Granger-causality sense). Further, Esfahani and Ramírez (2003) find a strong positive association between returns to net infrastructure investment and population density. In our analysis, we also use population density as an instrument and find qualitatively similar results.[15] We include time dummies in all equations.

Results, reported in Table 4, show a weak relationship, which is sometimes negative, between the target variable – infrastructure indexes – and economic growth. Alongside this weak relationship, human (capital) development index, financial development, terms of trade, exchange rate, and control of corruption, which had been documented as important in previous economic growth studies, also register statistically significant relations to economic growth. However, as we have flagged in the foregoing discussion, these relationships may be spurious; and indeed when we remove potential instrument proliferation (Table 5), none of the infrastructure variables remains significantly related to economic growth. Accordingly, we base our discussion on the empirically better set of results presented in Table 5.

Apart from showing a strengthened convergence, with higher coefficients of lagged GDP per capita than those reported in Table 4, all three measures of the infrastructure metric (Africa infrastructure index, infrastructure quality index and public sector GFCF) are statistically insignificant in relation to economic growth. This outcome suggests that the level of access infrastructure or its quality, as were then available in African countries, did not affect economic growth. Recall, going by our preliminary analysis in section 3.1 (and Table 1), and our postulation about SSA's level of infrastructure endowments, that infrastructure increments and consideration of channels that transmit the effects of infrastructure to economic activity are our important areas of focus. We will turn to these areas shortly. First, we explore briefly how the control variables impact economic growth in Africa, especially for potential useful policy guides, and highlight the possible channels, among antecedents of growth, through which infrastructure impacts economic growth (see Table A1 in the Appendix).

In support of findings by Ghura and Hadjimichael (1996), Easterly and Levine (2001), Pritchett (2004) and others, human capital is highly statistically relevant and economically important to economic growth in Africa (with an average coefficient of about 7.000 in economic growth per a unit change in human capital). Similarly, the coefficient of the control of corruption variable supports Rodrick's (2002, 2003) and, Lee and Kim's (2009) finding of how

[15] These are not presented in the paper but are available with the authors upon request.

institutions matter for both developing and developed economies in driving economic growth. Not only do these two help in eliciting incremental returns from Africa's limited capital stock, they also, especially institutions, minimize the distortionary effects their absence would have on markets.

Though a preponderance of studies about finance—growth nexus finds a positive relationship (Calderon and Liu, 2003; Hassan et al., 2007; Ojah and Kodongo, 2015), on occasions the positive relation has not been straightforward, suggesting the likelihood of a nonlinear relationship. A recent study by Aizenman et al. (2015) has evidently confirmed this likelihood with data from developing Asia and Latin America. They documented the kind of negative relations between financial deepening and economic growth, which we report in Table 5. Therefore, it appears, using the ratio of M2 to GDP as a proxy of financial depth, that African countries have not attained a threshold level of financial development that would support incremental level of economic activity.

;lternatively, it could be that the implied increased level of money supply subsumes the effect of inflation on economic activity instead of representing financial intermediation. In fact, the more reflective proxy, of credit supply to the private sector, has no statistically significant effect on economic growth (perhaps because a good proportion of credit supplied, especially to individual borrowers, which is largely in the form of unsecured personal loans, could be financing consumption, rather than investment activities). Unlike in developing East Asia, which has a significant endowment of process technology and thus export a great deal, as an economic growth strategy, relative currency value depreciation in Africa yields a significant negative relation to economic growth. Though African countries export a significant amount of its natural resources (which yields favorable terms of trade during commodities' price spikes), the burden of importation with highly weaker currencies more than negatively overwhelm the terms of trade effect (Muhanji and Ojah, 2011 & 2016).

Given the insignificant effect of infrastructure access or quality on economic growth in Africa (per our result of Table 5), we explore suspected areas that sensibly reflect the link between our variables of interest. These areas have also been theoretically hypothesized as relevant (see Section 1). Before that, however, we attempt, in Sections 4.2 and 4.3, to establish the robustness of the foregoing findings.

4.2 *Infrastructure access/quality and economic growth in low-income Sub-Saharan African countries*

Let us first consider the likely effects of the heterogeneity of African economies. It is possible that mixing richer countries with a relatively superior infrastructure endowment with poorer countries with near-zero endowments may distort the relationship between infrastructure and economic growth in the panel. Consequently, in this section, we remove seven countries classified by the World Bank

as upper middle income or high income countries.[16] We rerun our tests on 38 poorer countries in the SSA region. Because of space constraints, we use only money supply as the financial depth variable and control of corruption as the proxy for institutional quality.

Results of the rerun test are reported in Table 6. Panel A uses the full set of instruments; panel B uses the restricted set. Once more, we discuss the estimates of the more technically developed 'restricted instrument set' (Panel B of Table 6). These results largely resemble those in Table 5 (and our interpretation there suffices here), except for an important difference regarding GFCF (public sector): expectedly, convergence is robustly strong for the set of lesser developed countries; secondly, variables we would deem basic drivers of economic growth (i.e., human capital and institutions) remain significant and positively related to economic growth.

Interestingly, however, none other variable is significantly important, in contrast to Table 5 which documented negative effects of money supply and currency depreciation. Most interestingly and in confirmation of our suspicion that sample heterogeneity may have affected the results in Table 5, infrastructure, in the form of gross fixed capital formation (GFCF), is found to enter significantly positively the model of the lesser developed countries sample. That is, increases in the capital base of lesser developed economies are relevant for growth than increases in capital base of the relatively more advanced economies, which perhaps have already hit the threshold of requisite infrastructure stock (Reinikka and Svensson, 1999; Estache et al., 2006; and Kumo, 2012).

4.3 *Improved infrastructure access and infrastructure quality*

Because current flow of money into infrastructure development may *indirectly* contribute to economic growth by increasing consumption through higher labor employment and attendant increased income, we test whether the observed effect of public spending on fixed capital assets on growth can also be observed in the change in access and quality of infrastructure that the spending creates. We use log differences in infrastructure access and quality indices for this purpose. Results are in reported in Table 7.

Focusing on the restricted instruments set, the results show that improved access to infrastructure is important for economic growth, and thus buttress the finding in Table 6. Infrastructure quality improvement, though not statistically significant, are positive and larger when the relatively more advanced African economies are included in the sample (coefficient of 0.678 of Eq. 4 in Panel A) than when they are excluded (coefficient of -0.070 of corresponding Eq. 4 in Panel B). This overall non-effect of infrastructure quality is not entirely surprising considering the poor quality and low infrastructure endowment in the continent. On the other hand, any improvement (i.e., small addition) in

[16] We use the World Bank's classification as of January 2011, obtained from their website: http://librarians.acm.org/sites/default/files/Jan%202011%20World%20bank%20list%20of%20Economies.PDF

infrastructure *access* goes a long way in alleviating their 'legendary shortage' and thus reflects in economic growth. Finally, note that both convergence and human capital remain robust and are stronger statistically and economically for lesser developed economies than for the sample that includes more advanced African economies, an outcome that aligns, broadly, to findings by Lee and Kim (2009).

4.4 *Mediating effect(s) of pertinent growth antecedents*

As we argued in Section 1, it is very likely in the SSA context that infrastructure might indirectly impact economic growth by improving total factor productivity. This is possible, according to economists, such as Barro (1990) and others, if infrastructure provisioning acts by lowering input costs or expanding the production frontier or the set of profitable investment opportunities. For instance, availability of safe internet may increase the speed of communication and timeously open up profitable trade opportunities. To illustrate this point in a more practical sense, consider the Sub-Saharan African region, where the electric power grid is often unstable due to insufficient generation, and transmission and distribution inefficiencies, forcing manufacturers to operate expensive standby thermal power generators. In such situations, the provision of, and access to, reliable electricity would obviate the need for emergency thermal generation thereby reducing manufacturers' energy costs and overall cost of doing business. The resultant reduced business cost should improve countries' trade competitiveness, improve their attractiveness as investment destinations, and increase economic output.

The literature is rich with suggestions that public infrastructure significantly affects countries' attractiveness as an investment destination and trade competitiveness. For example, Kumar (2001), using a synthetic infrastructure index capturing transport infrastructure, telecommunications infrastructure, information infrastructure, and energy availability for 66 countries over the 1982-94 period, finds that infrastructure availability contributes to a country's attractiveness for foreign direct investment and promotes export-orientation of production of multinational enterprises. Similarly, Obwona (2001) argues that poor infrastructure facilities, especially in transport, communications and information technologies, are major impediments to investment in lower income countries. Many studies have also found a role for trade competitiveness, foreign direct investment flows, and cost of doing business in explaining economic growth (see e.g. Li and Liu, 2005). Given these findings in the literature, it is not irrational to argue that infrastructure can indirectly inform economic growth by acting via growth antecedents.

In this section, therefore, we attempt to understand whether infrastructure availability and quality may act through the mediating effects of some of these variables to impact economic growth. We examine here cost of doing business, trade competitiveness, and foreign direct investment (cross-border capital flows) all of which have featured prominently in the literature. We proxy cost of business by the cost of starting a business, reported in World Bank's Ease

of Doing Business Indicators[17]; trade competitiveness is proxied by export diversification indices reported by UNCTAD; and foreign direct investment is the aggregate inward and outward FDI flows as a proportion of GDP, also reported by UNCTAD.

First, as a prelude to testing one of our key postulations, we conduct a preliminary analysis of how growth antecedents – of trade competitiveness, cost of doing business and cross-border capital flow – relate to economic growth / development, and how infrastructure relate to these growth antecedents, respectively. The results, reported in Table A1 in the appendix, provide additional justification, to theoretical and anecdotal motivations in the preceding paragraphs of this section, of why these variables are likely channels by which infrastructure indirectly impacts growth.

Tables 8 (for infrastructure access) and 9 (for infrastructure quality) report our regression results, with Panel A reporting results of models using level of infrastructure access/quality and Panel B reporting results of models using increments in infrastructure access/quality. As in previous estimations of our baseline model, convergence remain relevant, human capital and institutions remain largely positive though not all statistically significant, financial development remains negatively related to growth; and most importantly, improvements in infrastructure access remains robustly related to economic growth (Table 8). Moreover, the view from extant literature that availability of infrastructure could affect economic growth via other drivers of economic growth is given credence in our documented result (Panel A). More specifically, a unit of the combination of infrastructure access and export diversification (i.e., trade competitiveness) yields an average of 1.614 units increase in economic growth in SSA.

This additional finding (i.e., indirect effects of infrastructure access), plausibly suggests that even for economies of SSA which rely largely on harvesting their natural resources for export earnings (without value addition by way of processing/manufacturing) and, thus economic growth enhancement, they need and accordingly value basic public infrastructure availability such as electricity, roads and ports. Further, note that interaction terms of the other two intermediating variables considered – i.e., cost of doing business and cross-border capital flows (net foreign direct investments (FDI)) – have no statistically significant effect in the models in Table 8.

The results in Table 9, though essentially similar to those of Table 8, reveal a few interesting and noteworthy findings. These results are based on analysis of intermediating variables through which infrastructure quality could work to affect economic growth (results in Panel A of Table 9 uses quality of available public infrastructure while results in Panel B uses increments in the quality of available public infrastructure). Focusing on the interaction term variables, a

[17] The ease of doing business is captured by an index known as Distance to Frontier (DTF) that covers several aspects of "doing business" including starting a business, getting electricity, dealing with construction permits, paying taxes etc. The comprehensive index is available for many African countries only from 2010. Thus, we use the "cost of starting a business" data which are available for a much longer period (from 2004).

unit of combination of infrastructure quality and export diversification on one hand, and a unit of combination of infrastructure quality and cross-border capital flows on the other hand, yield average units increases of 4.594 and 0.452 of economic growth, respectively (Panel A). The combined effects of the same intermediating variables and increments in quality of available public infrastructure yield the corresponding average units increases of economic growth of 5.985 and 0.406, respectively (Panel B).

Judging by the magnitude of the coefficients reported above, it is clear that these indirect effects are both statistically and economically important. Further, the intermediating effects through trade competitiveness are more economically important than those through cross-border capital (4.594 and 5.985 versus 0.452 and 0.406). The lesson here is that quality of available infrastructure appears more impactful on economic growth by leveraging the effects of trade competitiveness, which has been documented as a significant driver of economic growth across many countries, including Africa countries (Muhanji and Ojah, 2011), than the impact likely to be experienced by leveraging cross-border capital flows. Yet again, the intermediating effects of "cost of doing business" are statistically unimportant in these models reported in both Table 8 and Table 9.

Consistent with the effects of control variables in Table 8, convergence remains relevant in Table 9, human capital and institutions remain largely positive, financial development remains negatively related to growth; and interestingly, quality of institutions are more statistically relevant when quality of available infrastructure are considered compared to when access to infrastructure are considered (Table 9). Again, as has been consistent in all other previous estimations, both the level of and increment of quality of available infrastructure themselves remained unimportant in these latest set of model estimates.

5 Additional tests

5.1 *Do missing observations matter?*

Critics may argue that missing data (even though well-handled econometrically in previous estimations) may have an effect on our findings. We rerun our tests, excluding countries for which at least four time periods of data for any variable are missing. The following countries are removed by this rule: Benin, Burundi, Cape Verde, Djibouti, Eritrea, Ghana, Niger, Nigeria, Rwanda, Seychelles, Tanzania, and Zimbabwe. We also exclude Equatorial Guinea (high income) and South Africa (relatively more advanced infrastructure) from the sample. This leaves a sub-sample of 31 countries. All remaining variables have two or less missing observations, except human development index which had 4 missing observations for all countries. Besides the expected weakening of some variable coefficients, due largely to smaller sample size, the result in Tables 5 and 7 are essentially upheld in the rerun tests reported in Table 10.

5.2 *Pure infrastructure stock index*

Our analyses, thus far, have used the infrastructure access index (AIDI) developed by African Development Bank and our own infrastructure quality index (AIQI). Although the AIDI index includes aspects of quality and aspects of stock as pointed out before, we find it necessary to include, as further robustness check, a separate analysis of the stock of infrastructure. In this section, we document that the relationship between stocks of infrastructure and economic growth is similar to that between quality of infrastructure and economic growth. For consistency, our 'pure' stock of infrastructure index, labeled AISI, is developed using the same methodology as the other two indexes that we have used. The pure infrastructure stock index, is constructed using electricity production (kWh); road density (km of road per 100 square km of land area); telephone lines (per 100 people); and international internet bandwidth (bits per second per person) all obtained from World Development Indicators database, for 2000–2011.

Table 11 presents results. Like infrastructure quality, the stock of infrastructure appears not to inform economic growth in the Sub-Saharan African region, both in levels and in annual improvement. The implication of this result is that provision of infrastructure is not important if it is not significant as to reach most economic agents in order to foster widespread involvement in economic activity. This is critical in Sub-Saharan Africa where the provision of infrastructure is sometimes concentrated in urban areas where only a minority of the populace resides, leaving the bulk of the population with minimal access to infrastructure and hence excluded from the mainstream of their countries' economy. This result does not seem to speak directly to the role the extant literature (e.g. Calderón and Servén, 2010; Fedderke et al., 2006) has given physical infrastructure in informing economic growth in the region. This is a major aspect of our contribution to the literature – research effort needs to clearly delineate the aspects of infrastructure that are relevant to economic growth in order for it to inform policy in a more productive manner.

5.3 *Infrastructure and economic development*

In Table 1, we saw that levels of infrastructure development are more highly correlated with levels of income than they are correlated with economic growth. Hence, in this section, we seek to establish whether a significant relationship exists between infrastructure variables (levels and increment/growth) and economic development (income levels). We proxy economic development by GDP per capita.

The pertinent results are reported in Table 12. The same baseline model specification deployed in the economic growth estimation is adopted in the determination of the extent, if any, to which public infrastructure relates to economic development. Unsurprisingly, the results of the economic development model estimation are largely similar to those of economic growth, particularly per the findings reported in Tables 6, 7 and 10. The results in Table 12 show

that increments in infrastructure stock are important for economic development (coefficient of 0.127 at the 5% significance level). Similarly, increments in infrastructure quality, though not statistically significant, are positively related to economic development. Further, as in the case of the economic growth model estimation, human capital and institutions largely have significantly positive coefficients; financial development is statistically negatively related to economic development. However, at variance with the economic growth model result, inflation (which can be argued to reflect relative excess aggregate demand) statistically and positively relate to economic development.

6 Concluding remarks

Given the well-known public infrastructure deficit in Sub-Saharan African (SSA) countries, its speculated constraint on economic growth and development, and the many programs (especially at the regional level) that have been put forth in attempts to address these, we set out in this paper to explore the true nature of the relation between economic/public infrastructure and economic growth in more comprehensive ways than have hitherto been done. We mapped, at both the aggregate as well as individual infrastructure scopes, the evolution of public infrastructure in SSA; and confirmed the extent to which the region substantially lags behind most other regions of the developing world in public infrastructure endowments. The preliminary outcome of this detailed mapping amply made a compelling case for further investigation of the relation between infrastructure and economic growth and development in SSA.

We, therefore, set out to provide what in our view is a much more comprehensive analysis of the infrastructure—growth nexus to date. Taking a research methodology tack that would be most useful at informing and guiding cross-country regional effort at reversing public infrastructure deficit for the purpose of enabling economic growth; we constructed two multi-dimensional indexes reflective of the access to and quality of public infrastructure endowments in SSA countries. More specifically, we examined: (1) the effects of infrastructure access and quality on economic growth and development, respectively; (2) the effects of increments in infrastructure access and quality on economic growth; and (3) the intermediating effects of these infrastructure measures on 'most pertinent' drivers of economic growth; with these baseline model tests followed by a series of relevant robustness checks.

Our results show that rather than the sheer stock/access to or quality of infrastructure being relevant for economic growth in an environment characterized by low basic infrastructure endowments, such as Sub-Saharan Africa, it is the spending on infrastructure and increments in the access to infrastructure that influence growth in the region. Interestingly, these significant associations, especially those of infrastructure spending, are more important for lesser developed economies of the region than for the relatively more developed economies of the region, which uncommonly have better than near-zero stock of infrastructure. In addition to these robust direct links between the target variables, we find

that infrastructure access also relates strongly to economic growth indirectly via export diversification (trade competitiveness); and infrastructure quality also indirectly influences economic growth via cross-border capital flows and export diversification, both of which are fairly established drivers of economic growth.

Among factors that have been documented in the literature as relevant growth antecedents, which served as control variables in our model specifications, we found human capital and institutions to have featured consistently and mostly significantly positively in the majority of our model estimation results. Conversely and with lesser statistically significant coefficients, financial development featured negatively in many of the same model estimations.

The overarching policy upshot of our findings is that efforts aimed at having the reversal of Africa's pervasive infrastructure deficit enable economic growth and development, must be carefully nuanced. Priority should be placed on reversing the palpable deficit in many of the region's basic infrastructure endowments that are essential for fostering efficient production activities, which in turn enables economic growth. Our results suggest that current endowments are insufficient to meaningfully impact macroeconomic economic activity. Therefore, emphasis on quality of current infrastructure stock appears not to be that critical; unless, of course, it is in regards of a SSA country like South Africa which uncharacteristically possesses infrastructure endowment level that has reached or surpassed an implied threshold level necessary for enabling incremental aggregate economic activity.

This last observation flags an important area for a follow-up research on the topic of our study. It would be useful to ascertain whether or not a threshold level of infrastructure endowment is necessary before infrastructure could fulfill its touted huge promise of enabling economic growth and/or development. This quest is even much more relevant given the near-zero level of endowment of almost all forms of public infrastructure of SSA, relative to other regions, which we documented in the background to our analysis (section 1). Similarly, in the light of existing findings of country-specific studies which suggest that certain individual infrastructure, such as electricity and ICT, have significant effects on the economy, it would be a worthwhile exercise to ascertain whether some public infrastructure are more important than others, particularly in the SSA kind of environment. This quest will certainly be achievable as better quality individual infrastructure data become available.

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Table 1: Correlations between infrastructure indexes (AIDI) and real GDP in Sub-Saharan Africa

	Correlation between				Correlation between				Correlation between				Correlation between		
Country	1&3	1&4	2&4	Country	1&3	1&4	2&4	Country	1&3	1&4	2&4	Country	1&3	1&4	2&4
Angola	.94	-.11	.44	Cote d'Ivoire	-.61	.10	.20	Liberia	.59	-.04	-.05	Seychelles	.82	.44	.23
Benin	.84	-.33	.03	Djibouti	.95	.64	.74	Madagascar	.14	-.13	.26	Sierra Leone	.84	.01	.10
Botswana	.92	-.19	.31	Eq. Guinea	.64	-.43	-.35	Malawi	.91	.55	.33	South Africa	.77	-.14	.13
Burkina Faso	.81	-.04	.20	Eritrea	-.85	.07	-.17	Mali	.91	-.34	-.84	Swaziland	.94	-.37	-.50
Burundi	.47	.09	.03	Ethiopia	.97	.34	-.56	Mauritania	.89	.06	.16	Tanzania	.94	-.19	-.10
Cameroon	.92	-.54	-.44	Gabon	.63	.58	.28	Mauritius	.99	.03	.20	Togo	.50	.66	.08
Cape Verde	.96	-.02	.38	Gambia	.51	-.04	.21	Mozambique	.96	.06	.50	Uganda	.92	.10	-.02
Cen. Afr. Rep.	-.26	.57	.07	Ghana	.98	.74	.38	Namibia	.92	.14	.54	Zambia	.99	.56	.66
Chad	.73	-.32	-.47	Guinea	.83	-.39	-.15	Niger	.79	.16	.20	Zimbabwe	-.25	.80	.52
Comoros	-.90	-.22	.23	Guinea-Bissau	.37	.16	.17	Nigeria	.93	.22	-.01				
Congo, DR.	.97	.56	.48	Kenya	.86	.24	.05	Rwanda	.94	.07	.08				
Congo, Rep.	.95	.18	.54	Lesotho	.99	.39	.28	Senegal	.88	-.25	-.05	Panel	0.015	0.018	0.078

1 is African Infrastructure Development Index (AIDI) – proxy for infrastructure development
2 is growth in infrastructure (annual percentage change in AIDI)
3 is real GDP per capita (logs)
4 is growth in real GDP per capita (annual percentage)

Data Sources: World Development Indicators (real GDP) and African Development Bank (Infrastructure Index)

Table 2: Correlations between infrastructure quality indices and infrastructure variables

	Correlation with AIQI
Secure internet per million people	0.2353
Telephone faults per 100 mainlines	–0.0985
Percentage of transmission and distribution losses in electricity production	–0.0738
Share of paved roads in total roads	0.7034
Percent of population with access to improved water source	0.5383
Percentage of population with access to improved sanitation	0.4540
Africa Infrastructure Development Index – AIDI (AfDB, 2013)	0.4724

Table 3: Summary statistics

	Mean	Median	SD	Min.	Max.	#Obs.
GDP per capita growth	2.07	2.03	5.41	–41.17	45.91	538
Africa infrastructure index (AIDI)	16.20	12.85	13.72	0.37	87.00	540
Africa infrastructure quality index (AIQI)	5.93	5.82	3.15	0.15	16.61	540
GFCF (public sector) (% of GDP)	17.90	9.55	27.22	0.25	227.47	481
Human development index	0.44	0.43	0.12	0.23	0.80	343
Credit to private sector (% of GDP)	599	18.33	3932	–34.19	46875	423
Money supply (M2) (% of GDP)	30.00	22.44	24.42	2.83	148.71	521
Terms of trade shocks	0.02	0.01	0.12	–0.98	0.52	537
Inflation (GDP deflator)	15.34	6.69	114.53	–29.55	2630	540
Exchange rate (LCU units per USD)	5.06	6.10	2.28	–3.11	22.63	536
Government consumption (% of GDP)	408	15.28	2474	0.00	23461	449
Control of corruption	–0.58	–0.68	0.58	–1.71	1.25	495
Rule of law	–0.69	–0.70	0.63	–2.12	1.06	495

SD is standard deviation; Min and Max denote minimum and maximum; #Obs. is number of observations

Table 4: Estimation results with full instrument set

	Eq. 1a	Eq. 2a	Eq. 3a	Eq. 4a	Eq. 1q	Eq. 2q	Eq. 3q	Eq. 4q	Eq. 1i	Eq. 2i	Eq. 3i	Eq. 4i
Lagged GDP per capita	-3.818***	-4.190***	-3.860***	-4.290***	-3.601***	-4.936***	-3.957***	-5.086***	-4.760***	-3.959***	-4.546***	-4.000***
	(0.790)	(0.376)	(0.809)	(3.782)	(1.202)	(0.724)	(0.976)	(0.824)	(0.756)	(0.672)	(0.840)	(0.786)
Africa infrastructure index	-3.332	-5.377***	-4.079	-5.117**								
	(5.785)	(2.434)	(5.312)	(2.385)								
Infrastructure quality index					-0.164	-3.108***	-0.559	-1.483				
					(2.302)	(0.850)	(2.183)	(1.431)				
GFCF (public sector)									0.036*	0.060***	0.033	0.060***
									(0.021)	(0.017)	(0.022)	(0.020)
Human development index	7.261***	5.050**	7.760***	5.286***	5.751	3.596**	7.423***	5.059***	7.137***	2.288	7.095***	2.789
	(2.703)	(1.065)	(2.237)	(9.536)	(4.143)	(1.656)	(2.321)	(1.366)	(1.470)	(2.187)	(1.502)	(1.889)
Credit to private sector	-0.434		-0.601		-2.420		-2.716		1.809		1.962	
	(2.508)		(2.323)		(2.617)		(2.230)		(2.359)		(2.610)	
Money supply (M2)		-5.497***		-5.438***		-6.847***		-8.035***		-3.840**		-4.697**
		(1.434)		(1.310)		(2.226)		(2.408)		(1.578)		(2.067)
Terms of trade shocks	1.011	-0.721***	1.125	-1.116	0.091	-1.761	1.216	-1.607	5.390***	6.228*	5.533**	7.323
	(2.438)	(2.724)	(2.424)	(2.851)	(3.796)	(4.506)	(2.782)	(5.186)	(2.007)	(3.562)	(2.381)	(4.909)
Inflation	0.627	0.439	0.652	0.426	0.956*	0.781*	1.027*	0.556	0.218	-0.335	0.375	-0.458
	(0.500)	(0.293)	(0.477)	(0.427)	(0.543)	(0.402)	(0.521)	(0.525)	(0.360)	(0.601)	(0.372)	(0.647)
Exchange rate	-7.032***	-3.616	-6.781**	-3.036	-7.671	1.451	-6.355**	5.995	-9.578***	-0.903	-8.520***	0.827
	(2.422)	(3.970)	(2.740)	(4.049)	(2.758)	(7.320)	(2.802)	(10.72)	(2.223)	(7.298)	(2.613)	(8.070)
Government consumption	1.276	1.509	1.401	1.596	1.491	0.862	1.899	1.122	0.872	0.750	1.470	0.342
	(1.951)	(1.522)	(2.059)	(1.800)	(2.194)	(2.083)	(2.325)	(2.356)	(1.858)	(2.220)	(1.676)	(2.159)
Control of corruption	1.325	2.078*			2.721	7.987***			2.274**	3.661*		
	(1.508)	(1.253)			(3.412)	(2.960)			(1.124)	(2.084)		
Rule of law			0.635	1.677			2.049	5.275*			2.093	3.230
			(1.987)	(1.885)			(3.806)	(2.974)			(1.698)	(2.418)
p-value of Sargan test	0.487	0.414	0.472	0.400	0.429	0.635	0.392	0.538	0.495	0.633	0.501	0.615

Robust standard errors are in parentheses. "a" stands for infrastructure "access"; "q" represents "quality" of infrastructure and "i" represents infrastructure "spending". ***, **, and * represent statistical significance at 1%, 5% and 10% respectively.

Table 5: Estimation results with restricted instrument set

	Eq. 1a	Eq. 2a	Eq. 3a	Eq. 4a	Eq. 1q	Eq. 2q	Eq. 3q	Eq. 4q	Eq. 1i	Eq. 2i	Eq. 3i	Eq. 4i
Lagged GDP per capita	-4.825***	-4.662***	-4.887	-4.861***	-4.921***	-5.266***	-4.904***	-5.332***	-5.728**	-3.518***	-6.088***	-3.811***
	(0.832)	(0.905)	(5.980)	(0.617)	(8.522)	(1.094)	(0.776)	(7.393)	(1.040)	(0.562)	(1.198)	(0.692)
Africa infrastructure index	-3.514	-4.333	7.204	-4.323								
	(3.868)	(3.910)	(25.89)	(2.914)								
Infrastructure quality index					-0.600	-0.739	-0.363	-0.355				
					(1.227)	(1.379)	(1.091)	(1.215)				
GFCF (public sector)									0.061	0.045	0.059	0.031
									(0.040)	(0.027)	(0.045)	(0.030)
Human development index	9.560***	2.519	17.86	5.597**	8.804***	2.778	9.066***	5.835**	6.374***	-2.085	7.245***	-1.258
	(2.553)	(3.045)	(12.63)	(2.171)	(2.301)	(3.530)	(1.967)	(2.745)	(2.283)	(2.203)	(2.557)	(2.035)
Credit to private sector	-0.805		-6.728		-0.723		-0.866		0.748		0.205	
	(2.390)		(9.529)		(2.341)		(2.284)		(2.991)		(3.400)	
Money supply (M2)		-3.848***		-3.395***		-2.952**		-2.995**		-2.556***		-2.749***
		(1.234)		(1.030)		(1.313)		(1.246)		(0.787)		(1.000)
Terms of trade shocks	3.765	0.407	-3.599	0.828	4.402	0.363	4.450	0.363	3.734	1.571	3.873	1.143
	(2.441)	(2.546)	(6.285)	(2.294)	(2.838)	(3.543)	(2.737)	(2.763)	(2.354)	(1.677)	(2.963)	(1.931)
Inflation	-0.205	0.591	1.032	-0.059	-0.223	0.618	-0.228	0.128	-1.203	1.052*	-1.193	0.860
	(0.612)	(0.538)	(1.320)	(0.440)	(0.664)	(0.599)	(0.601)	(0.561)	(0.801)	(0.567)	(0.952)	(0.527)
Exchange rate	-7.996***	3.657	-1.428	-1.115	-8.780***	3.876	-8.756***	-0.863	-9.577**	0.739	-9.957**	5.486
	(2.850)	(8.827)	(2.080)	(6.588)	(2.878)	(10.858)	(2.671)	(9.227)	(4.560)	(1.075)	(4.940)	(11.67)
Government consumption	0.330	-0.797	6.900	-0.858	0.233	-0.399	-0.088	-1.339	0.058	-3.218	-0.188	-4.489
	(1.795)	(2.797)	(1.032)	(1.793)	(1.740)	(3.075)	(1.441)	(2.184)	(3.250)	(2.790)	(3.195)	(2.799)
Control of corruption	-0.569	5.248*			0.741	7.395*			3.725*	4.516**		
	(2.041)	(2.700)			(1.707)	(3.830)			(2.244)	(1.930)		
Rule of law			-7.265	1.379			1.783	3.989			3.998	2.108
			(8.060)	(2.089)			(2.315)	(2.760)			(3.049)	(1.918)
J-statistic p-value	0.280	0.472	0.240	0.356	0.301	0.358	0.325		0.723	0.550	0.681	0.503

Robust standard errors are in parentheses. "a" stands for infrastructure "access"; "q" represents "quality" of infrastructure and "i" represents infrastructure "spending". ***, **, and * represent statistical significance at 1%, 5% and 10% respectively.

Table 6: Estimation results for low-income Sub-Saharan African countries

	Panel A (full instruments set)			Panel B (restricted instruments set)		
	Eq. 1	Eq. 2	Eq. 3	Eq. 1	Eq. 2	Eq. 3
Lagged GDP per capita	-4.385*** (0.672)	-4.166*** (0.960)	-3.820*** (0.943)	-5.840*** (0.869)	-5.781*** (1.000)	-4.751*** (0.569)
Africa infrastructure index	-8.415 (5.591)			-3.419 (2.835)		
Infrastructure quality index		-3.706 (2.307)			-0.999 (1.356)	
GFCF (public sector)			0.049** (0.024)			0.074** (0.035)
Human development index	8.310*** (1.436)	6.721** (2.641)	3.547* (1.934)	8.194*** (2.459)	7.110*** (2.156)	-1.312 (1.495)
Money supply (M2)	-0.515 (4.978)	-4.784 (3.877)	-3.251 (4.753)	-1.224 (1.284)	-0.979 (1.926)	-1.128 (1.778)
Terms of trade shocks	2.033 (5.014)	-2.585 (5.465)	4.955 (4.527)	3.407 (2.452)	3.520 (3.436)	2.904 (2.331)
Inflation	0.284 (0.558)	1.187** (0.585)	0.310 (0.750)	0.750 (0.476)	0.329 (0.445)	0.461 (0.349)
Exchange rate	-6.359 (6.430)	-1.996 (1.246)	-3.345 (7.174)	-7.405 (8.810)	-5.928 (9.631)	1.113 (6.514)
Government consumption	1.750 (1.890)	3.432 (2.116)	2.634 (2.114)	1.322 (2.482)	1.681 (2.355)	0.987 (2.285)
Control of corruption	-2.014 (2.933)	-1.938 (2.151)	1.714 (2.087)	4.911 (3.268)	5.911 (4.316)	8.204*** (2.567)
J-statistic p-value	0.252	0.479	0.348	0.611	0.466	0.756

Robust standard errors are in parentheses. ***, **, and * represent statistical significance at 1%, 5% and 10% respectively.

Table 7: Growth in public infrastructure assets and assets quality

	Panel A (all countries)				Panel B (excluding richer countries)			
	Full GMM instruments set		Restricted instruments set		Full GMM instruments set		Restricted instruments set	
	Eq. 1	Eq. 2	Eq. 3	Eq. 4	Eq. 1	Eq. 2	Eq. 3	Eq. 4
Lagged GDP per capita	-3.679***	-4.777***	-4.434***	-4.958***	-4.202***	-4.947***	-4.928***	-5.325***
	(0.436)	(1.165)	(0.647)	(1.132)	(0.659)	(1.331)	(0.886)	(0.774)
D(Africa infrastructure index)	1.523***		2.261***		1.364		2.219***	
	(0.474)		(0.648)		(0.889)		(0.786)	
D(Infrastructure quality index)		-2.613**		0.678		-4.188		-0.070
		(1.278)		(1.466)		(2.796)		(1.058)
Human development index	4.159***	3.799	5.954**	1.657	8.318***	9.394*	7.323***	8.755***
	(1.038)	(2.545)	(2.919)	(4.074)	(1.388)	(4.876)	(1.790)	(1.824)
Money supply (M2)	-5.983***	-7.154***	-0.795	-2.369*	-0.686	-3.126	1.478	-0.700
	(1.807)	(2.458)	(1.085)	(1.419)	(3.430)	(4.608)	(1.364)	(1.574)
Terms of trade shocks	-1.156***	-1.249	0.091	0.614	4.680	-4.817	4.530*	4.818*
	(3.303)	(4.654)	(2.591)	(2.803)	(4.870)	(7.642)	(2.571)	(2.569)
Inflation	-0.137	0.425	-0.167	0.824	0.417	1.529	0.166	0.258
	(0.452)	(0.407)	(0.596)	(0.819)	(0.435)	(1.025)	(0.384)	(0.331)
Exchange rate	2.569	0.380	-6.457	5.459	-7.101	-2.404	-1.014	-9.223
	(4.965)	(9.892)	(1.057)	(1.203)	(8.084)	(1.608)	(1.149)	(9.989)
Government consumption	1.103	1.272	-2.134	-0.146	1.959	5.046	-0.364	0.058
	(1.562)	(3.063)	(2.404)	(3.350)	(1.736)	(3.549)	(2.473)	(1.482)
Control of corruption	3.132**	7.361***	1.680	7.142**	-0.542	0.299	3.601	3.892
	(1.443)	(2.491)	(2.534)	(3.212)	(2.136)	(2.992)	(3.031)	(3.070)
J-statistic p-value	0.664	0.706	0.668	0.356	0.154	0.441	0.584	0.454

Robust standard errors are in parentheses. ***, **, and * represent statistical significance at 1%, 5% and 10% respectively.

Table 8: Effect of mediating variables – infrastructure access

	Panel A (Levels of Infrastructure)				Panel B (% change in infrastructure access)			
	Eq. 1	Eq. 2	Eq. 3	Eq. 4	Eq. 1	Eq. 2	Eq. 3	Eq. 4
Lagged GDP per capita	-3.623**	-4.348***	-0.750	-3.887***	-4.463***	-4.614***	-6.891***	-2.757***
	(1.412)	(0.903)	(0.107)	(0.970)	(0.972)	(0.765)	(1.946)	(1.047)
Africa infrastructure index	-1.960	-2.109***	-1.341	-9.008	2.412**	2.305***	2.227*	3.273***
	(6.397)	(0.653)	(6.338)	(5.101)	(0.994)	(0.664)	(1.217)	(1.029)
Infrastructure quality index								
Human development index	2.869	4.722	9.457	3.235	4.986	5.434	1.191**	7.158**
	(2.929)	(3.207)	(0.310)	(5.089)	(3.584)	(3.572)	(0.564)	(3.168)
Money supply (M2)	-1.314	-3.663**	-4.364	-3.459**	-0.011	-1.087	-2.550	0.409
	(1.132)	(1.559)	(1.990)	(1.700)	(0.910)	(1.172)	(3.815)	(1.039)
Terms of trade shocks	5.074**	-0.467	-8.147	0.037	4.099	-0.518	-8.293	2.614
	(2.606)	(2.851)	(4.886)	(3.128)	(2.896)	(2.679)	(7.258)	(2.920)
Inflation	0.180	1.000*	0.205	0.580	-0.358	-0.191	-0.603	-0.084
	(0.874)	(0.545)	(0.523)	(0.831)	(0.617)	(0.658)	(0.941)	(0.735)
Exchange rate	3.393	0.116	-1.295	1.026	-0.575	-0.527	-2.439	-0.686
	(10.959)	(0.970)	(1.261)	(1.086)	(1.268)	(1.109)	(2.094)	(1.194)
Government consumption	-0.416	-0.190	-1.424	-1.375	-1.024	-2.171	-3.529	-2.302
	(3.080)	(2.306)	(4.659)	(3.284)	(2.383)	(2.705)	(4.464)	(3.227)
Control of corruption	7.044	4.803	-1.994	4.656	4.255	2.392	-1.092	4.967
	(4.553)	(3.564)	(3.681)	(4.703)	(3.891)	(2.907)	(5.778)	(4.970)
AIDI ×Doing business cost	-0.397			0.168	-0.668			0.070
	(0.418)			(0.242)	(0.488)			(0.213)
AIDI ×Export diversification		1.614***		1.673**		-1.368		8.938
		(0.515)		(0.840)		(3.576)		(7.800)
AIDI ×Net FDI flows			-0.053	0.033			0.037	0.114
			(0.071)	(0.065)			(0.104)	(0.079)
J-statistic p-value	0.30	0.65	0.15	0.34	0.39	0.61	0.26	0.54

Robust standard errors are in parentheses. ***, **, and * represent statistical significance at 1%, 5% and 10% respectively.

Table 9: Effect of mediating variables – infrastructure quality

	Panel A (Levels of Infrastructure quality)				Panel B (% change in infrastructure quality)			
	Eq. 1	Eq. 2	Eq. 3	Eq. 4	Eq. 1	Eq. 2	Eq. 3	Eq. 4
Lagged GDP per capita	-4.846***	-4.710***	-4.521***	-3.834***	-4.783***	-4.566***	-4.352***	-3.915***
	(1.111)	(1.023)	(1.084)	(0.928)	(1.508)	(1.067)	(1.278)	(1.441)
Africa infrastructure index								
Infrastructure quality index	-0.776	-0.360	-0.046	-0.229	1.542	0.546	1.034	1.914
	(1.746)	(1.401)	(1.293)	(1.666)	(2.163)	(1.388)	(1.321)	(3.006)
Human development index	1.998	4.559	4.821	4.112	2.093	3.498	3.053	3.855
	(3.706)	(3.436)	(3.082)	(3.679)	(5.008)	(3.896)	(3.448)	(5.380)
Money supply (M2)	-3.304**	-2.913**	-1.971	-2.507*	-2.417	-2.341	-1.392	-1.465
	(1.557)	(1.500)	(1.527)	(1.400)	(2.201)	(1.507)	(1.594)	(2.626)
Terms of trade shocks	0.256	1.034	1.389	0.541	0.944	1.299	1.364	1.867
	(3.604)	(3.872)	(3.342)	(3.320)	(3.564)	(2.677)	(3.219)	(5.266)
Inflation	0.284	0.429	0.974	0.024	1.456	0.585	1.234*	1.172
	(1.019)	(0.583)	(0.617)	(0.908)	(1.661)	(0.649)	(0.713)	(.673)
Exchange rate	0.595	0.779	0.341	0.463	1.014	0.990	0.771	1.575
	(1.286)	(1.088)	(1.071)	(1.300)	(1.503)	(1.030)	(1.043)	(1.930)
Government consumption	0.084	0.509	1.236	0.134	1.440	0.504	1.428	2.751
	(2.998)	(2.335)	(2.524)	(3.010)	(4.707)	(2.611)	(3.179)	(5.009)
Control of corruption	6.997	7.144*	8.621**	7.562	0.863	6.684*	9.700**	1.051
	(4.378)	(4.182)	(3.703)	(4.749)	(0.470)	(3.498)	(3.720)	(0.667)
AIQI ×Doing business cost	0.435			1.051	-0.795			-0.342
	(1.237)			(1.049)	(1.773)			(1.975)
AIQI ×Export diversification		6.043*		3.145		5.864**		6.097
		(3.088)		(3.631)		(2.780)		(5.204)
AIQI ×Net FDI flows			0.451**	0.452*			0.453**	0.358
			(0.209)	(0.266)			(0.209)	(0.374)
J-statistic p-value	0.52	0.49	0.34	0.50	0.36	0.39	0.28	0.30

Robust standard errors are in parentheses. ***, **, and * represent statistical significance at 1%, 5% and 10% respectively.

Table 10: Robustness to missing observations

	Levels of infrastructure indices		% change in infrastructure indices	
	Eq. 1	Eq. 2	Eq. 1	Eq. 2
Lagged GDP per capita	-7.279 (4.724)	-5.903** (2.962)	-3.436*** (0.833)	-3.283*** (0.587)
Africa infrastructure index	1.813 (3.871)		2.607*** (0.742)	
Infrastructure quality index		-2.504 (3.973)		-0.109 (0.765)
Human development index	1.685 (1.163)	1.891* (0.991)	-1.809 (2.183)	-3.132 (26.60)
Money supply (M2)	-1.306* (0.748)	-1.017 (0.867)	-0.752 (1.254)	-2.573*** (0.884)
Terms of trade shocks	-2.283* (1.266)	-2.503 (1.625)	1.620 (2.368)	2.533 (1.777)
Inflation	0.303 (1.884)	0.481 (1.719)	0.285 (0.593)	0.485 (0.572)
Exchange rate	-2.341 (107.2)	-4.517 (15.04)	1.546 (3.253)	8.491 (21.81)
Government consumption	3.029 (8.263)	-2.331 (7.535)	-2.549 (4.888)	-3.848 (2.756)
Control of corruption	-0.012 (15.12)	-0.182 (9.370)	4.825* (2.510)	2.620 (1.883)
J-statistic p-value	0.747	0.637	0.663	0.182

Robust standard errors are in parentheses. ***, and * represent statistical significance at 1%, and 10% respectively.

Table 11: Pure infrastructure stock and economic growth

	Level of infrastructure stock		Growth in infrastructure stock
	Full instrument set	Restricted instrument set	
Lagged GDP per capita	-3.698*** (0.558)	-3.492*** (0.729)	-4.386*** (-0.689)
Infrastructure stock index	0.188 (0.215)	-0.166 (0.328)	-0.089 (-0.430)
Human development index	4.270* (0.225)	2.760 (4.109)	5.502* (0.165)
Money supply (M2)	-4.002*** (1.272)	-3.450*** (1.073)	-3.287*** (-3.205)
Terms of trade shocks	2.746 (2.883)	2.661 (2.827)	1.258 (0.664)
Inflation	-0.125 (0.513)	-0.436 (0.394)	-0.775* (-1.752)
Exchange rate	0.631 (4.384)	4.165 (5.343)	8.571 (1.438)
Government consumption	0.685 (1.784)	0.706 (1.896)	-1.054 (-0.837)
Control of corruption	6.132 (4.391)	3.433 (3.485)	1.281 (0.354)
J-statistic p-value	0.61	0.55	0.49

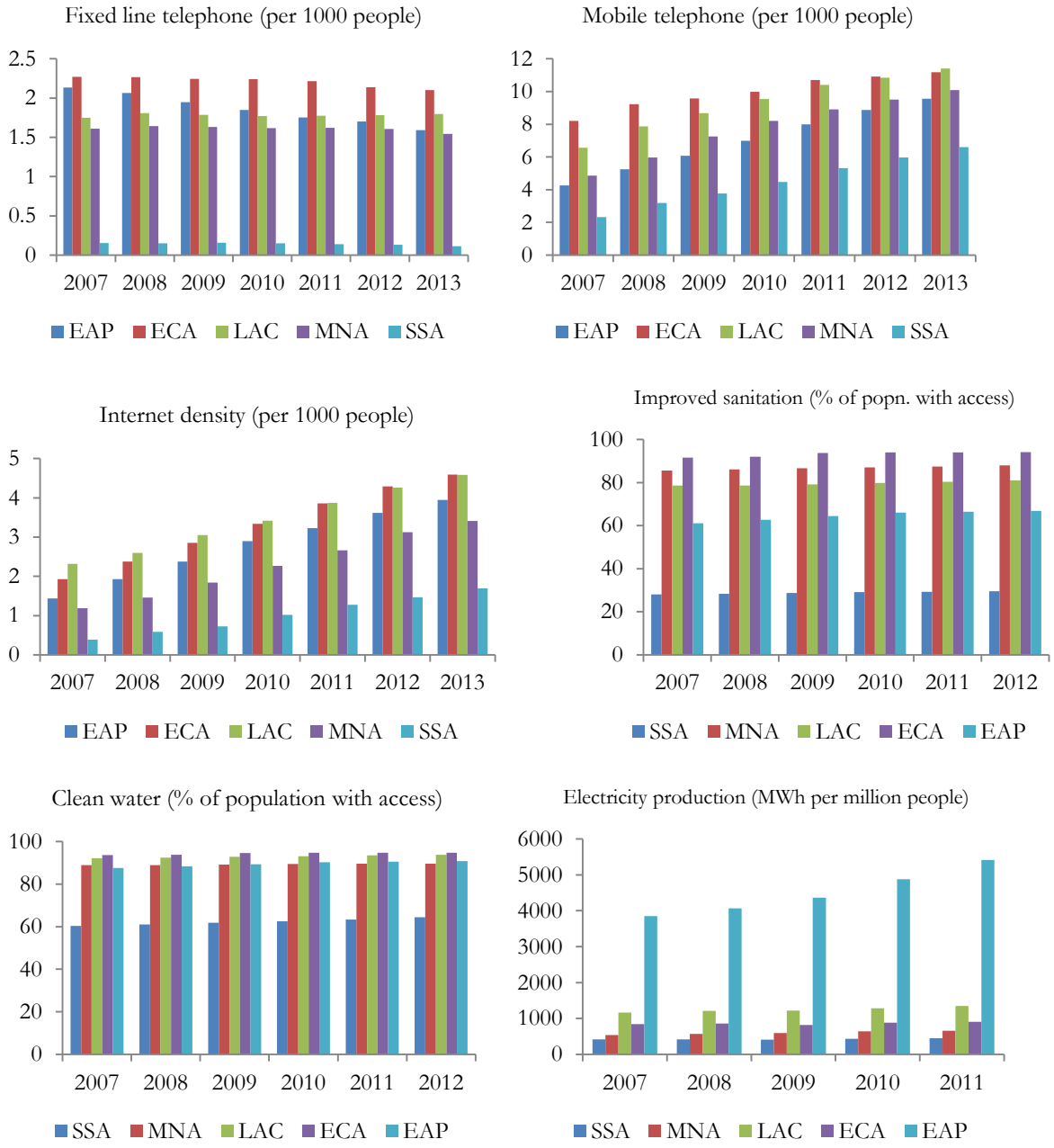
Robust standard errors are in parentheses. ***, and * represent statistical significance at 1%, and 10% respectively

Table 12: Infrastructure development and economic development

	Infrastructure level			% change in infrastructure		
	Eq. 1	Eq. 2	Eq. 3	Eq. 1	Eq. 2	Eq. 3
Lagged GDP per capita	0.446***	0.401***	0.560***	0.460***	0.400***	0.467***
	(0.091)	(0.102)	(0.078)	(0.118)	(0.096)	(0.072)
Africa infrastructure index	-0.031			0.127*		
	(0.050)			(0.069)		
Infrastructure quality index		0.002			0.003	
		(0.013)			(0.011)	
Infrastructure stock index			0.003			0.001
			(0.003)			(0.003)
Human development index	0.491	0.578*	0.357	0.558	0.532	0.691**
	(0.315)	(0.313)	(0.340)	(0.402)	(0.323)	(0.319)
Money supply (M2)	-0.038***	-0.024*	-0.029***	-0.029**	-0.025*	-0.032***
	(0.010)	(0.014)	(0.009)	(0.015)	(0.014)	(0.009)
Terms of trade shocks	-0.006	0.003	0.021	-0.017	-0.001	0.001
	(0.023)	(0.029)	(0.024)	(0.022)	(0.028)	(0.024)
Inflation	0.008**	0.011**	-0.000	0.004	0.011*	-0.003
	(0.004)	(0.005)	(0.005)	(0.005)	(0.006)	(0.005)
Exchange rate	-0.068	-0.022	-0.045	-0.072	-0.036	0.073
	(0.075)	(0.092)	(0.056)	(0.123)	(0.098)	(0.058)
Government consumption	0.019	0.024	0.026	0.015	0.022	0.011
	(0.020)	(0.021)	(0.027)	(0.025)	(0.022)	(0.016)
Control of corruption	0.054*	0.060*	0.067	0.037	0.060	0.035
	(0.032)	(0.036)	(0.040)	(0.032)	(0.037)	(0.036)
J-statistic p-value	0.43	0.56	0.35	0.59	0.47	0.45

Robust standard errors are in parentheses. ***, **, and * represent statistical significance at 1%, 5% and 10% respectively.

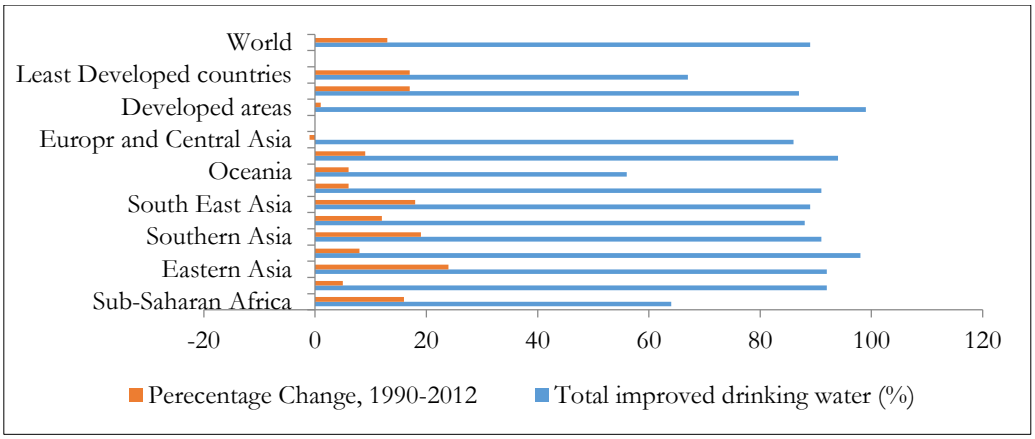
Figure 1: Trends in SSA infrastructure deficit



The figure covers the following developing regions: SSA – Sub-Saharan Africa; MNA – Middle East & North Africa; LAC – Latin America & Caribbean; ECA – Developing Europe & Central Asia; EAP – East Asia & Pacific.

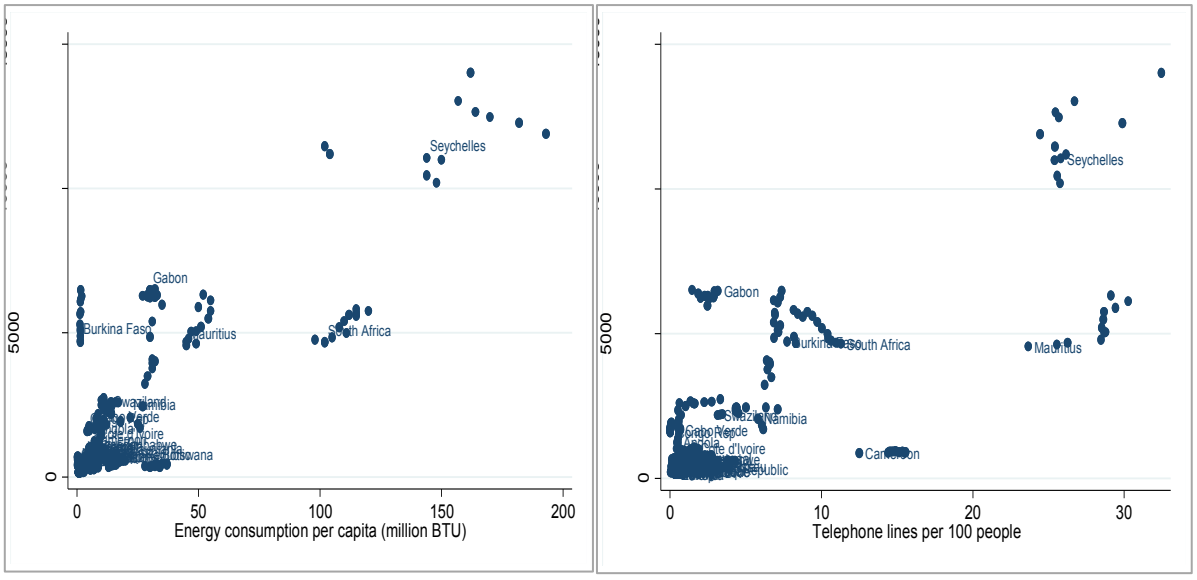
***Source*:** Authors' construction using World Bank's World Development Indicators data

Figure 2: Access to improved water by region



Source: Authors' construction using WHO/UNICEF data

Figure 3: Energy consumption, telephone lines and nominal GDP per capita in SSA



Source: Authors' construction. GDP and telephone lines data are from WDI; energy data are from the USA Energy Information Administration (EIA)

APPENDIX

1. List of countries

The countries are: Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo DR, Congo Republic, Cote d'Ivoire, Djibouti, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Seychelles, Sierra Leone, South Africa, Swaziland, Tanzania, Togo, Uganda, Zambia, and Zimbabwe.

2. Preliminary investigation of mediating variables

Table A1: Preliminary relations between infrastructure and potential intermediating variables

Do these variables explain economic growth?		Do these variables explain economic development?	
Doing business cost	-0.150	Doing business cost	0.190**
	(0.184)		(0.090)
Export diversification	5.965*	Export diversification	-0.577
	(3.338)		(0.639)
Net FDI inflows	0.050**	Net FDI inflows	-0.021***
	(0.025)		(0.008)

Does infrastructure explain these variables?					
	Infrastructure level			Change in infrastructure	
	Access	Quality		Access	Quality
Doing business cost	-1.130***	-2.149***	Doing business cost	0.324	1.466**
	(0.077)	(0.326)		(0.801)	(0.568)
Export diversification	-0.018***	0.019	Export diversification	0.018	0.037
	(0.004)	(0.016)		(0.053)	(0.029)
Net FDI inflows	-1.413	-9.617***	Net FDI inflows	2.761	1.901
	(0.915)	(3.315		(11.017)	(4.689)

We run panel OLS regressions with one explanatory variable and a constant in each case. The table reports the coefficient estimates of the explanatory variable with their standard errors in parentheses. ***, **, and * denote significance at 1%, 5% and 10% levels respectively.