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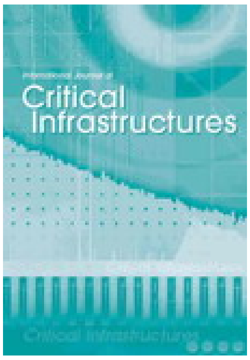

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Abstract: Investment in economically inclined infrastructure is pertinent to industrial sector growth in Sub-Sahara Africa (SSA), especially during this period of financial belt-tightening recovery due to the recent global pandemic. Findings suggest a dilapidated infrastructure spread across SSA, which has mired productivity growth, hence slow industrial sector growth. This study fills a vacuum in the literature by investigating the economic effects of infrastructure investment on industrial sector growth in SSA using disaggregated system-GMM approach. Diverse significant effects from various types of infrastructural tech on industrial growth across sub-regional countries were unravelled. Similarly, post estimations analysis via robust Arellano-Bond Autocorrelation and Hansen tests were adopted to establish the absence autocorrelation. The study uniquely disaggregated system GMM to provide valuable insights to policymakers. Hence, sub-regional countries should draft more policy support to prioritise economically motivated factor inputs such as information techs, access to energy, transport and water resources to expedite industrial sector growth.

Keyword: industrial sector growth; infrastructural investment; system generalised methods of moments; GMM.

JEL codes: C1 H4 L8.

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Biographical notes: Sunday Anderu Keji is an erudite scholar, who had impacted knowledge over the years. He had taught across different economic fields. Also, he had supervised different student's project in quantitative analysis. He holds an MSc in Economics at University of Hull, UK and currently running his PhD in Economics at University of KwuaZulu-Natal

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(UKZN), South Africa. He had contributed to the body of the economic literature across high indexed journals like SCOPUS, IBSS ISI, among others. Currently, he is working on focused specialised fields in economics such as human capital skills, infrastructural development and industrial sectors growth.

Josue Mbonigaba holds the position of Associate Professor in the School of Accounting, Economics and Finance at the University of KwaZulu-Natal. He specialises in development economics, particularly health economics research. His noteworthy contributions to extending knowledge in his field over the years can be grouped into four broad categories: health economics, foreign aid and development, environmental and water economics, human capital and productivity, and regional economic cooperation.

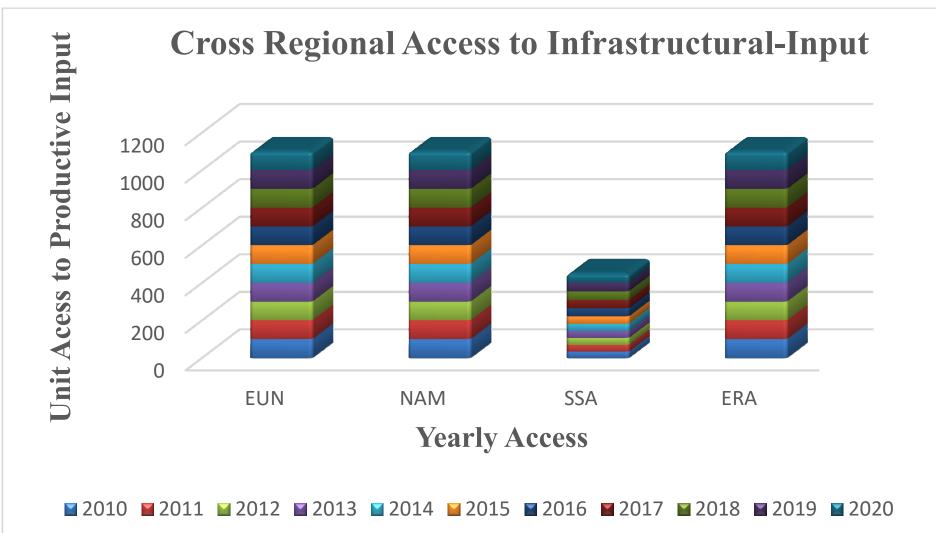
Gbenga Wilfred Akinola bagged his Doctor of Economics from the University of Kwazulu Natal in 2018. His current area of specialisation is development economics with special interest in health economics where he has authored many articles. He is currently an honorary Post-Doctoral Fellow in the University of Kwazulu Natal.

1 Introduction

African sub-region infrastructural investment is about $170 billion yearly, with the investment shortfall estimated at around $108 billion (African Development Bank, 2018). With this enormous investment gap, there is a crucial need to scale productivity via feasible infrastructure investment (Ngai and Samaniego, 2009; Abdurraheem and Naim, 2018; African Development Bank, 2018). Hence, the sub-region must unravel its potential in infrastructural-tech development for industrial sector growth. Particularly by investing in different infrastructure types with high economic returns to scale for industrial output growth. Lately, concerns have been about the poor spread and access to productive infrastructure with high productivity returns. It is expected that relevant infrastructural techs would minimise the cost of production for internationally competitive goods to be produced for industrial sector growth. Also, it will provide the basis for sustainable productivity growth. Hence, it is pertinent to address the massive gap in infrastructure development across the SSA region.

Notably, the increasing demand for modern infrastructure networks to aid the production of high-quality goods has necessitated industrial sector development in SSA. It is important to note that physical capital, in terms of infrastructure through the production process, is an imperative input for industrial advancement in the short and long run (Rebelo, 1991 and Mankiw, 1995). However, the lack of commitment by the authorities (stakeholders) in the realm of affairs has further promoted underinvestment in different infrastructural facilities, which might have caused slow industrial output growth in Sub-Saharan Africa (Iweriebor et al., 2015; Opoku Osei et al., 2018). This has led to increasing the cost of production and reducing value addition, particularly to finished goods in the sub-region, thereby reducing productivity growth in general. Investment in high returns on economic scale infrastructures such as electricity, ICT, railway, aviation facilities, road networks and housing, among others, are pertinent to expand productivity growth. However, stakeholders have not prioritised investment in those physical infrastructures that have the most effect on industrial sector growth as against the current marginal effect recorded on industrial output growth in SSA nations (Fedderke and Bogetić, 2006). Henceforth, the policy question is, for example, does high return to scale public infrastructure directly influence industrial sector growth? How does a stakeholder's decision affect infrastructural development to improve industrial sector growth across SSA? It is generally evident that Sub-Saharan Africa is endowed with a large deposit of natural resources to drive modern tech physical infrastructure. However, the right decisions and policies as to which area to channel and explore in terms of the rapid investment have repeatedly affected mass production, which in turn caused slow industrial sector growth. For instance, the current World Bank's bi-annual study reports from country focus disclosed how some countries in SSA invest poorly in public goods like infrastructure despite the immense resources to fare better (World Bank, 2018). Evidence from Figure 1, which cuts across various regions like Euro-Area (ERA), European Union (EUN), and North America Euro (NAM), have exposed that Sub-Saharan (SSA) lags behind other regions in terms of infrastructure spread toward productivity growth.

Figure 1 Configuration of inter-regional infrastructure (see online version for colours)



Source: Adapted from World Bank Development Index, 2022

Figure 1 reveals the comparative rank of the cross-region spread of infrastructure in the last decade. Figure 1 displayed that SSA's performance, in terms of factor inputs, like infrastructure for output growth, was low compared to other regions. Therefore, it is evident that nations in SSA lack the requisite infrastructure to drive industrial growth. Notably, most sub-regional governments in Sub-Saharan Africa have made little or no concerted effort to identify and correct gaps in infrastructural investments for industrial output growth. Ludé and Thérèse (2020) emphasised that the roles of governance in public infrastructure investment cannot be over-emphasised, which is an implication of this study. Similarly, Sultana et al. (2012), Emily and Muyengwa (2021), and Shahrivar et al. (2022) stressed that maintenance of critical infrastructures is pertinent for output growth. Infrastructural maintenance can be in the form of performance-based contracting.

This strategic approach can address most challenges facing infrastructural development across SSA countries. In the meantime, past studies revealed diverse conclusions and were unable to ascertain the long-run effect of infrastructure investment on industrial output growth. For instance, related studies by Bogetić and Fedderke (2006), Mendoza et al. (2014)Abdurraheem and Naim (2018), Keji and Efuntade (2020), Abdullahi and Asongu (2022) and Du et al. (2022) suggested that infrastructural techs development propels productivity growth. Whereas studies by Gukat and Ogboru (2017), Okumoko et al., (2018) and Bennett et al., (2015) posited that public investment in infrastructure has a negative and insignificant influence on output growth using autoregressive distributed lags, ordinary least square (OLS), among other likely biased estimates.

Consequently, short-run and long-run system GMM empirical approaches were employed in the study to control possible biased estimates, endogeneity and simultaneity problems that may likely arise, which makes this method unique and different from the past studies. The empirical modelling considered the time-factor long-run system GMM technique as one of the bases for infrastructure life-span, which informs investment decisions. The implication of unbiased estimates in the study is to answer the current problems of slow industrial sector growth in SSA through sector-based policy support that could attract viable infrastructural investment. On this note, it is pragmatic for the region to re-strategise by regaining its regional competitiveness of the 1960s among the committee of regions via massive investment in infrastructure for industrial sector growth (Akinlo, 2020; Danquah and Kwabena-Adade, 2020; Ludé and Thérèse, 2020). Therefore, a study of this nature is pertinent to draw the necessary attention of the stakeholders on the need to expedite industrial sector growth via massive investment in economically motivated infrastructure in SSA. Also, this study's outcome would answer the current policy debates.

Dilapidated infrastructure and unsuitable investment in infrastructure are hypothesised to be among several factors responsible for low industrial sector growth in SSA. On this note, it is crucial to study and measure the veracity of slow industrial output growth by addressing the poor spread of infrastructure investment across SSA countries. This study requires serious attention because it is of policy concern. Therefore, it is hypothesised that infrastructure investment does not significantly affect industrial sector growth in the SSA region. Because of this, both short-run and long-run system general method moments were employed as the estimating techniques, and the study's objective was to examine the impact of infrastructure investment on industrial sector growth in some selected SSA countries. Estimating whether a long-run link exists between different types of investment in infrastructure and industrial sector growth often requires using the long-system GMM procedure. It is imperative to examine both the short-term and long-term effects of various types of infrastructure on industrial output growth to ascertain which of the infrastructure yield high economic returns to productivity scale for a context-relevant policy that can address low industrial output growth in SSA. Also, it is noteworthy that most early studies have yet to employ complementary methods such as long-run and short-run system GMM to ascertain the stable impact of an investment in infrastructure on industrial output growth in SSA. Segregating the infrastructural effects via the long-term and short-term productivity growth using system GMM is part of the contributions of this study.

Consequently, the study is grouped into various sections; Section 1 explains the introduction, Section 2 covers the theoretical framework and the literature review, Section 3 discloses the methodology and the model building, Section 4 explains the empirical analysis and the discussion of the results, while Section 5 reveals the conclusions and the future research.

2 Literature review

2.1 Theoretical groundwork

The motive of the study is built on the evidence that investment in high economic returns to scale infrastructure causes increasing industrial output growth in SSA. This is because the neoclassical growth theory posited a direct relationship between technical progress, such as physical infrastructure, and output growth. Apt inquiry about this theoretical assumption in SSA is pertinent due to the mixed results from previous findings in line with this rationality. Notwithstanding, a tenet of the theory that explains the importance of viable investment in infrastructure to productivity growth is now reviewed thus.

Specific economic models showed capital accumulation, such as physical capital and infrastructure, as a source of output growth (Mankiw et al., 1992; Lucas, 1988; Magazzino et al., 2015; Corporate Finance Institute, 2021). Whereas some other economic theories posited physical capital, such as infrastructure, as a process of advancing social needs (Wagner, 1876; Keynes, 1930, as cited in Udo and Efiong, 2014 and Magazzino et al., 2015). The frontline models among its contemporaries are the neoclassical growth model from the version of the Cobb-Douglas function, Wagner's law (model), and the Keynesian model.

Wagner's Law of Public Investment on Social Welfare: This addresses the general needs of the citizenry via government outlay on public goods such as infrastructure as the sources of social needs. Adolph Wagner's 1876 echoed that it is fundamental for government to invest in public goods for general output growth (Buchanan, 1967; Kuckuck, 2012; Magazzino et al., 2015; Iqbal et al., 2018). The main fundamental is to enlarge industrial growth by expanding investment in public goods such as infrastructure. The government cannot upsurge industrial growth through broad spending but via targeted spending on factor-input promoting industrial growth.

2.2 The protagonists of neoclassical growth theory

This literature widely attests to the physical capital impact on output growth. The neoclassical model stresses that economic output is built on capital accumulation and technical advancement, all things being equal (Nicolaides, 1988). Neoclassicists posited that output growth could be attained via any of the two factors or other inputs, like an increase in a unit of capital-input and technology growth (i.e., a rise in quality of both labour and physical capital like infrastructure), as well as a rise in capital-investment (i.e., physical capital investment as an input), and technological progression (i.e., increasing in discoveries and innovations) (Solow, 1956; Nicolaides, 1988). That is, per-capita growth rate variances continue when the rate of technical advancement varies across countries (Ebong et al., 2016). Consequently, Solow and Swan (1956) improved the neoclassical framework via mathematical modelling to show the link between technological growth, physical capital, and economic output growth. Therefore, the Solow and Swan (1956) model explained the exogenous aspect of indicators comprising the capital inputs as a key element of industrial output growth, allowing us to attain our objectives in the study. The essential roles of capital accumulation as key factor input of output growth as modelled by Solow and Swan (1956) aligning with the version of the Cobb-Douglas function underpins this study.

In view of this, theoretical modelling for capital input, such as infrastructure, is assumed to directly influence output growth. However, empirical works in SSA seem to be mostly inconsistent with this theoretical assumption. Also, there is insufficient evidence to attest to this theoretical groundwork regarding the effect of infrastructural investment on industrial output growth via disaggregated system GMM. For instance, the contrary deductions from the studies like Bennett et al. (2015), Orji et al. (2017), and Okumoko et al. (2018) across the Sub-Saharan region have led the authors to enquire the pertinent roles of infrastructure investment on the industrial growth process, particularly in the case of SSA. Notwithstanding, the related empirical literature is reviewed next.

2.3 Related literature on infrastructure and output growth

Udo and Efiong (2014) adopted Wagner's model to contend that societal complexity makes the rise in government investment inevitable across numerous sectors to ease efficiency in productive output as the division of sectors arises, which necessitates social change for output growth sustainability. Government investment channelled to infrastructure facilities positively related to general output growth (Keji and Efuntade, 2020). Whereas Grossman's model in 1972 adopted health production as a factor of social-economic inputs through nutrition, income, employment, and education, which is made up of individual health stocks at the macroeconomic level, as the extra cause of industrial output growth.

However, Nurudeen and Usman (2010) adopted the Keynesian model to elucidate the dynamic role of aggregate public investment in any economy. Keynes's diverse means through different opinions concerning the link between government outlay on infrastructure and output growth. Firstly, the increasing infrastructural outlay is believed to bring economic advancement. Secondly, the increasing public spending on infrastructure can disrupt output growth due to crowding-out effects on essential fiscal investment. Udo and Efiong (2014) supported the first assertion by Keynes that public investment in infrastructure improves output growth. Conversely, the second assertion by Keynes is that persistent government investment through social spending can lead to higher taxes or borrowings to disrupt output growth, hence crowding-out effects. Therefore, Keynes's model might not perfectly align with different economic circumstances in various SSA economies. Still, it instead provides economists with many choices to clarify likely economic phenomena when there is interference in physical capital investment and output growth in the long term. Consequently, to unravel the specific objectives of this study, knowledge from the Keynesian framework provides us with many choices.

Bhattacharya and Bhattacharya (2018) studied the new Institutional Design for Infrastructure sustainability through feasible financial stability in the Pan-Asian region. The study suggested multicurrency Bonds for sustainable infrastructural investment in Asia. Kolawole (2020) studied the link between government spending and infrastructure advancement in Nigeria from 1981 to 2018 through ARDL and Granger-causality techniques. The study revealed a long-run cointegrating link between government expenditure and infrastructure in Nigeria. In a related study, Emily and Muyengwa (2021) examined the effect of maintenance on infrastructural facilities around municipalities in Limpopo Province, South Africa. The authors adopted qualitative and quantitative analysis through structural interviews to disclose that poor maintenance culture influences the performance of the infarct structure in Limpopo.

Shahrivar et al. (2022) examined the prioritisation of infrastructural maintenance through a comparative analysis of the Fuzzy theory in multi-decision making (MCDM). The study adopted MCDM methods to empirically compare maintenance strength in a fuzzy environment, which revealed diverse maintenance levels. Similarly, Tortorelli et al. (2022) studied the optimal configuration of critical infrastructures through decision backing. The authors adopted a decision support system to recommend possible configurations and protection for critical infrastructure.

Stoichev (2014) adopted L-strategy to protect critical infrastructures and individuals against terrorist attacks in a society. The study established several strategic methods for securing the EU's individuals and infrastructure.

Du et al. (2022) assessed how investment in different infrastructures affects China's economic output worth. The researchers resolved that investment in infrastructure supports the quality of economic output in China. Fedderke and Luiz (2005) analysed the link between economic output and infrastructure investment in South Africa via Pesaran, Shin, and Smith, 1996 and 2001, F-statistic tests to find the directions of relationships between infrastructure and the indicator for economic progress. They concluded that infrastructure investment significantly affects economic growth. Fedderke and Bogetić (2006) used pooled mean group (PMG) test of PSS 1999 to explore both the inverse and direct effects of public infrastructure on economic progress in South Africa. They explored contradiction analysis to disclose how public infrastructure crowds out private infrastructure in South Africa. Abdurraheem and Naim (2018) studied Gaps in types of infrastructural spending in SSA. The authors posited that the impact of Sukuk instruments for infrastructural funding is still at a minimal level. Hence there are wider gaps in the types of infrastructural funding in SSA. The study concluded that Sukuk funding of infrastructural gaps in the SSA region could eliminate the burden of debt across the countries, which was predominantly posed by the conventional source of a long-term project. Meanwhile, Ajayi (2007) concluded that industrial spatial patterns are subject to the applicability of industrial linkages in product authorisation, which was a major driving seat for industrial growth. The findings examined recent trends and spatial patterns of productive industry in Nigeria. Productivity flows were examined via artisans' setup and upwardly grew to large-scale production. Hence, the study suggested that productivity growth can be sustained in Nigeria through proactive industrial privatisation. Edun et al. (2013) examined the effects of infrastructural development on the Nigerian economy. The authors employed simple foreign investment of diversified equilibrium to conclude that infrastructural effects on economic output in Nigeria were at the lower state. Whereas Bennett et al. (2015) posited that industrial advancement has an insignificant impact on Nigerian economic output growth. OLS was adopted to investigate the influence of industrial development on economic growth between 1973 and 2013. Hence, the authors suggest that the government should put fair and plain level playing measures for rapid industrialisation in Nigeria. In another related study, Abdullahi and Asongu (2021) examined the lop-sided effect of infrastructural technology (i.e., access to the internet) on economic growth across forty-two Sub-Saharan countries between 2008 and 2018. The researchers adopted dynamic panel data analysis to conclude that access to internet access as a form of technology influenced economic growth across the 42-SSA countries.

Hence, this study intends to contribute to the literature from three major perspectives. Firstly, it tries to classify productive infrastructure from none productive infrastructure by narrowing down specific economic return to scale infrastructure that can expedite industrial sector growth in Sub-Saharan Africa. Secondly, this study tries to empirically contribute to the literature by adopting a system-generalised method of moment conditions to ascertain which specific infrastructures have a higher return to scale on industrial output through the past and the present periods. The dynamic nature of the system GMM is the best option to account for the time path effects of cost-effective infrastructure on industrial output. The method of analysis curbs omitted variable bias, endogeneity and simultaneity problems. Thirdly, this research disaggregated system GMM to account for short-run and long-run effects of infrastructural investment on industrial sector growth in SSA. It is another contribution to the mainstream empirical literature, as this would pave the way for short- and long-term policy support for industrial output growth in SSA. Notably, outcomes from this study might help the key investors identify which of the infrastructure needed to be prioritised for higher economic returns to scale for improved industrial sector growth in SSA. Also, findings from this study would provide necessary improvement to the current poor value-added output in SSA.

3 Methodology

The modified version of the Cobb-Douglas function shall be adopted to empirically investigate the impact of infrastructure investment on industrial output growth in SSA. Working closely with Arellano and Bover (1995), Adeleye et al. (2017), Bokana and Akinola (2017), Mbonigaba and Akinola (2019a), and Du et al. (2022), this study attempted to adopt short-run and long-run system GMM methods to curb measurement error, to address endogeneity and simultaneity problems, to check the specific impact of various types of infrastructure among the countries in SSA.

3.1 Model specification

The main objective is to assess how various types of infrastructure investment influence industrial output growth across SSA. At this point, the Cobb-Douglas form of the neoclassical framework is adopted to evaluate the effect of infrastructural advancement on output growth. It is, therefore, necessary to collapse the Cobb-Douglas function to ascertain the impact of infrastructure, specifically through technologically improved investment with a productive economic scale, which made up the novelty in the study.

$$Y = AK^{\alpha}L^{\beta} \tag{3.1}$$

Next, the model is log linearised for proper econometric analysis.

$$logY = logA + logK^{\alpha} + logL^{\beta} \tag{3.2}$$

$$LogY_{i,t} = logA + \alpha logK_{i,t} + \beta logL_{i,t} + u_{i,t} \tag{3.3}$$

Based on the stated objective, Y means the industrial output level. A, in equation (3.3), explains the amount of technical input to production. L is denoted as labour, while K denotes capital inputs.

Leveraging on the stated objective by identifying the economic effects of infrastructure development K as suggested by the Cobb-Douglas form of the neoclassical framework in equation (3.3) is pertinent. Hence, K and L are further disaggregated thus

$L_{i,t}$	effects of Labour inputs
$K_{i,t}$	Infrastructural effects
α and β	elasticity coefficient of industrial output with respect to physical infrastructure and labour in country i at time t.
$u_{i,t}$	stochastic error terms in country i at time t.

To disaggregate into:

$L_{i,t}$	(LBF)
$K_{i,t}$	(ICT ACE ACT AWP GCF FDI)
$Y_{i,t}$	(IDO)

where

$LBF_{i,t}$	Labour force in country i at time t.
$ICT_{i,t}$	Information technology/access to internet in country i at time t.
$ACE_{i,t}$	access to energy in country i at time t.
$ACT_{i,t}$	access to transportation in country i at time t.
$AWPi,t$	Access to water path in country i at time t.
$GCF_{i,t}$	Gross capital formation in country i at time t.
$FDI_{i,t}$	Foreign Direct Investment in country i at time t.
$IDO_{i,t}$	Industrial Output Growth in country i at time t.

Hence, the system generalised method of moments model is now incorporated into countries' specific effects for econometric analysis thus;

$$LogIDO_{it} = \Phi LogIDO_{it-1} + \beta_1 K_{it} + \gamma Z'_{it} + \eta i + \eta_t + u_{it} \tag{3.4}$$

where

Log IDO is the dependent variable that denotes industrial output, lag of IDO describes the past year's industrial output, K is disaggregated to capture all the independent variables of human capital skill development (such as ACE ICT ACT AWP), Z' is the vector of control factors (like LBF GCF FDI), whereas the η_i elucidates unnoticed cross country-specific impact while η_t signifies time trend in the individual country. i denotes several nations to be assessed, t implies the number of time series, $\boldsymbol{\Phi}$, $\boldsymbol{\beta}_1$, and $\boldsymbol{\gamma}$ coefficients for each control variable, and u explains the stochastic factors. The addition of the control variable is to determine maybe the dynamic effect of infrastructural investment on industrial output truly holds after considering the dynamic nature of the model employed in the study. Hence, the study adopted a dynamic model via sys-GMM to address measurement error, curb omitted variable bias, and tackle endogeneity problems that are likely to arise (Arellano and Bond, 1991; Arellano and Bover, 1995; Blundell and Bond, 1998; Adeleye et al., 2017). Also, the Hansen test is employed to test the overall validity of the instruments. The dynamic econometric model is specified thus

$$\begin{aligned} logIDO_{i,t} &= \Phi LogIDO_{it-1} + \beta logGCF_{i,t} + \alpha_1 logFDI_{i,t} \\ &+ \beta_1 logLBF_{i,t} + \beta_2 logACE_{i,t} + \beta_3 logICT_{i,t} \\ &+ \beta_4 logACT_{i,t} + \beta_5 AWP_{i,t} + u_{i,t} \end{aligned} \tag{3.5}$$

3.2 Justification for the estimating techniques

We are motivated to better understand what type of infrastructure network has higher economic returns to scale, as this would properly guide future investment decisions on infrastructural technology via a conducive work environment for value-added industrial output to improve the region's competitive advantage. That is, infrastructures were classified into various types. This is to ascertain which of the infrastructure yield better input-output returns to scale for industrial output growth in Sub-Saharan Africa. Disaggregated GMM is adopted to ascertain the degree of association-ship between each infrastructure and industrial output growth across SSA. This technique would address likely measurement errors, simultaneity and endogeneity problems in the cause of the empirical analysis of the economic effects of infrastructural investment on industrial productivity growth in SSA. Hence, low value-added output would be addressed. Also, the study adopted a dynamic model via system-GMM to measure likely change in the level of infrastructural indicators to address measurement error, curb omitted variable bias, to address possible endogeneity problems by disaggregating short-run system GMM from long-run system GMM analysis (Arellano and Bond, 1991; Arellano and Bover, 1995; Blundell and Bond, 1998; Adeleye et al., 2017: Mbonigaba and Akionola, 2019b). The study shall adopt the Hansen/Sargan test for validity and over-identifying of the instruments. Hence, to achieve our objective via this method, the following conditions must be fulfilled; thus, the number of cross-sections of countries must be higher than the time lags. The instrumental variables estimation is used. i.e., (IV) estimation. Instruments are classified as internal [gmmstyle ()] and external [ivstyle ()]. Z as an instrument must be exogenous to error term (u), that is, E (Z'u) = 0, and the Z instruments in number must be ≤ number of cross-section, N. Note: In line with the rule of thumb, the variable(s) that are in between [gmmstyle ()] and [ivstyle ()] are called internal and external instruments respectively.

4 Data statistics and apriori expectations

The infrastructure and industrial output indicators data were drawn from the world development indicators via World Bank national accounts data, OECD National Accounts data files and International Labour Organisation, ILOSTAT drawn from the World Development Indicators (2022). These data are extensively relevant; maybe it is because of their accessibility and computability in relative inter-regional empirical analysis. Although there are elements of limitations to the accessibility of some data via these databases, but they are still better forums to draw data for this study that concerns cross-country analysis (Adeleye et al., 2017). Data for industrial output growth is the dependent variable, while data for infrastructure, such as access to transportation, energy and water and information technology (ICT), are independent variables. Meanwhile, data for foreign direct investment (FDI), gross capital formation (GCF) and labour force are control factors which are inserted as internal and external instruments.

Notably, salient meanings of the justification for each variable have been explained in the previous section, while we disclose the summary statistic and a priori expectation thus.

Table 1 Descriptive statistics and apriori expectations

Variable	*Mean*	*Std. dev.*	*Min*	*Max*	*Apriori expectations*
IDO	25.53742	13.37973	4.555926	84.3492	N/A
GCF	9.896579	29.93144	–81.77223	507.9529	Positive
FDI	3.280891	7.73127	–26.63836	161.8237	Positive
ICT	2.273357	4.642566	0	37.64051	Positive
ACE	36.45954	24.50093	0.5338985	100	Positive
ACT	20.74003	15.87316	0.1257757	79.49361	Positive
AWP	43.46409	71.39404	0.4148473	761.1115	Positive
LBF	7163373	1.02e+07	94101	6.45e+07	Positive

Source: Author's Computation, 2023

Table 2 Correlation matrix

Variables	*IDO*	*GCF*	*FDI*	*ICT*	*ACE*	*ACT*	*AWP*	*LBF*
IDO	1.0000							
GCF	0.0831	1.0000						
FDI	0.1794	0.1487	1.0000					
ICT	0.0154	0.0259	0.0217	1.0000				
ACE	0.0767	0.0264	0.0168	0.6207	1.0000			
ACT	–0.1588	0.0984	0.1618	–0.0511	0.0706	1.0000		
AWP	0.4384	0.0866	–0.0996	–0.0058	0.2100	–0.0934	1.0000	
LBF	–0.0194	–0.0236	–0.0174	–0.2113	0.0327	0.3688	–0.1212	1.0000

Source: Author's computation, 2023

Table 1 shows a cursory assessment of the data that the variables for FDI, GCF and ICT recorded minimum statistics throughout the years under review, while data for access to water resources (AWP) pooled highest most maximum followed by FDI and GCF. Data for GCF and FDI possessed a wider range compared to data for ICT and AWP, which have a close range. However, data for access to water and GCF FDI recorded (761.1115, 507.953, and 161.824) high, respectively. In the meantime, measures of ICT and FDI are very close to the mean, with 2.227 and 3.28, with the least standard errors. The highest mean was recorded by the labour force, which implies the highest height (kurtosis curve), followed by access to water. Table 2 explains the possible association-ship between the dependent and independent variables based on the need to ascertain the theoretical rules such as apriori expectations. The overall outcomes of the series' revealed a negative and weak correlation among the estimators. Some of the series disclosed contrary apriori expectations, which further justify our arguments under the background problems, reflecting the present situation concerning SSA's poor industrial output growth. Industrial output exhibited a positive correlation with all the indicators except for access to transport and labour force. Within the seven regressors, data for labour force and access to transportation revealed a negative correlation with industrial output. This might be connected with the present situations of low productive skills coupled with poor mobility networks in SSA. While correlation coefficient among the independent variables is both positive and negative but generally weak, which means that the data are free from a possible collinear incidence.

4.1 Results and discussion

Having done the pre-estimation analysis such as correlation matrix test and summary statistics to estimate the data properties and level of association–ship among the series. This study thereby proceeds to investigate both short-run and long effects of infrastructure investment on industrial output in SSA via a dynamic model of system GMM. The first outcomes via the dynamic model are revealed in Table 3.

Table 3 Short-run dynamic panel-data estimation, two-step system GMM (Robust)

Number of instrument = 36 Group variable: c-id	*Number of observation = 267*	*Wald chi2(15) = 6522.03 Prob. > chi = 0.0000*	*Obs. per group: min = 3 max = 26*	*Time variable = Years Number of groups = 37 Avg. = 7.22*
Variables	Co-efficient	Standard error	Z-statistics	prob. value
Lag1IDO	0.6812117	0.0646195	10.54	0.000
GCF	–0.0201535	0.0280451	–0.72	0.472
FDI	0.2972407	0.0863838	3.44	0.001
ICT	–0.370619	0.1885871	–1.97	0.049
ACE	0.1318502	0.0627986	2.10	0.036
ACT	–0.0512796	0.0698672	–0.73	0.463
AWP	0.0305843	0.0155775	1.96	0.050
LBF	5.96e-08	7.70e-08	0.77	0.439
Cons.	513.0566	188.1797	2.73	0.006

Source: Author's computation, 2023

The cross-sections of the first row and columns in Table 3 revealed the nature of the empirical data and the general significance of the statistical methods adopted in the study. For example, the list of variables employed in the study was accounted for in the first column to describe the level relations between the dependent variable (industrial output) and the independent variables for types of infrastructural with respect to their coefficients, standard error, Z-statistics, and probability value was exposed. The robust option of standard error was adopted in the study to control the downward bias of the standard error coefficients in order to avoid the superfluous z-value. Hence, the study further disclosed the true impact of economic investment in infrastructure on industrial sector growth in SSA.

Notably, the lag of industrial output strongly predicts the lead of the industrial output. This implies that industrial output growth is likely path-dependent, which indicates that the current level of productivity has a strong effect in determining the future rate of industrial output in the corresponding year. Variable for ICT is negative and statistically significant with a p-value of (0.049, i.e., a 5% level of significance), while indicators for FDI, access to energy and access to water are positive and statistically significant to influence industrial output growth with a p-value of (0.001) (0.036), and (0.050) respectively. For instance, a 1% increase in ICT reduces about (0.371)% of output growth, which contradicts the expected economic theory (intuition). This is a serious implication for productivity growth. Hence, it is pertinent to unravel what might be responsible for this theoretical inconsistency in the case of SSA. Meanwhile, data for GCF, access to transportation and labour force are statistically insignificant. Remarkably, a 1% rise in gross investment brings about a (0.020)% fall in output growth. This negative impact negates the assumption of the extant literature, which exhibits a true infrastructural investment atmosphere in SSA. Meanwhile, the internationalisation of infrastructural investment via FDI improved industrial output growth by about (0.297). This implies that more investment through foreign counterparts could influence productivity growth in 40 SSA countries. On the contrary, a unit of labour's mental ability and effort toward productivity growth, which was a proxy for the labour force, was positive and insignificant. It is imperative to subject the results to post-estimation tests to establish the validity of our inferences. Hence, to ascertain the model's reliability via panel autocorrelation and Hasen/Sargan tests.

Table 4 Robust Arellano-bond autocorrelation test

Ho: no autocorrelation		
Arellano and Bond test for AR(1)	z = –1.55	Pr > z = 0.121
Arellano and Bond test for AR(2)	z = –1.00	Pr > z = 0.316

Source: Authors computation 2023

Table 5 Hansen test of over-identifying restrictions

Ho: Over-identifying restrictions are valid	
chi2(25)	= 21.78
Prob > chi2	= 0.648

Source: Authors computation 2023

The Autocorrelation tests for higher order and lower order autocorrelations and the Hansen/Sargan test of over-identifying restrictions results were reported in Tables 4 and 5. Roodman (2009) emphasised the need to ascertain the autocorrelation levels as stated by Arellano-Bond, which opined that an autocorrelation test should be done on the levels residuals as against the differenced levels, and this can only apply through system GMM. The autocorrelation outcomes revealed that our model is free from possible incidences of autocorrelation, as the presence of autocorrelation in lower order (bond) is being self-corrected up to the higher order (bond) of autocorrelation. Hence, the study relied on this outcome to proceed with the Hansen test of over-identifying restrictions. Hansen/Sargan test statistic conventional rule of thumb posits that the null hypothesis of 'the instruments as a group which are exogenous'. Hence, the farther the p-value from one, the better the Hansen statistics. Therefore, with the Hansen coefficient in Table 5, the Null hypothesis is rejected that group instruments are strictly not exogenous. Meaning that over-identifying restrictions are not valid. Hence, the GMM instruments employed in the study are free from adverse effects on the results. Consequently, our models in the study are reliable, consistent, and valid in identifying the effects of infrastructure investment on industrial sector growth in SSA.

4.2 This research has un-ravelled the short-run economic impact of infrastructural investment on industrial output growth in Sub-Sahara Africa

Panel data were drawn from forty small open economies of SSA countries between 1990 and 2021. The choice of this group of countries was guided by data accessibility. The choice of scope in the study is to allow both short and long-run specific effects evaluation of infrastructural investment on industrial output growth by individual indicators. Hence, the author contributes to the body of literature by providing evidence that improving infrastructure significantly impacts industrial output growth in SSA via short-run and long-run system GMM analysis.

By contributing to the extant empirical literature, it is important to establish the ranks of connection between infrastructure investment and industrial productivity advancement in the long run. This is one of the novels in the study, as most of the previous works mostly stopped at the mere short-run impact. The importance of long-run system GMM in the study is to reveal how investment in infrastructure has transformed productivity growth over the years because it takes time for an investment of this nature to grow and manifest in output growth. Hence, long-run GMM estimation is crucial for the study. Given this, the next step is to elucidate the long-run effect of infrastructure investment on industrial output growth in Sub-Saharan African economies. On this premise, this study attempts to estimate whether an investment in infrastructure with a higher economic scale has a long-run influence on industrial sector growth in SSA.

4.3 Significantly, the long-run investigation is to be carried out on the significant short-run indicators under the first system GMM model in Table 3

As this would further disclose the consistency of our findings, which would show the consistency of the regressors' effects from those significant estimates both in short-run and the long-run models (Arellano and Bond, 1991; Arellano and Bover, 1995; Blundell and Bond, 1998; Adeleye et al., 2017; Roodman, 2009). Remarkably, the key variables such as **FDI, ICT, ACE,** and **AWP** are statistically significant in the short dynamic model analysis and are the variables of interest in this section.

The long-term system GMM analysis relied on the following statistical computation and formula. That is, the long-run impact of infrastructure investment on industrial sector growth for the η^{th} parameter effects is estimated by

$$\beta_\eta / [1 - \Phi]$$

where β_η denotes the significant coefficient of the short-run system GMM estimate, Φ explains the short-run coefficient of the system GMM lag-dependent estimate. As stated above, using STATA syntax, the short-run coefficient estimate is divided by one minus the short-run lag coefficient to compute the long-run coefficient. *This is another contribution of the study to the empirical literature, as the study put transformation periods of infrastructure investment into consideration, which is very rare among mainstream economic studies*. Findings from Table 6 showed that all indicators of infrastructure development via investment exhibit long-run effects on industrial sector growth in SSA. The variables for infrastructures as a source of the former or conventional mean of economic to scale have both negative and positive effects on the industrial sector growth in SSA. Precisely, the internationalisation of infrastructural investment proxy as fdi statistically significant in the long run. Consequently, foreign collaborations would positively influence industrial productivity via FDI in the long run across the sub-region.

Additionally, variables such as investment in information techs, energy and water resources proxy as an investment in ICT, ace and awp are statistically significant in the long run. The indication is that investments in energy, information techs and water have long-run effects on industrial output. Statistical details of relevant statics reports on economic returns to scale, such as statistical coefficients, Z-statistics, probability value, and interval confidence level, were disclosed in Tables 6 and 7.

Table 6 Long run dynamic panel-data estimation, two-step system GMM (specific effects)

Statistics	*Coefficient*	*Std. err.*	*Z statistics*	*P>|z|*	*95% conf. interval*
FDI	0.932408	0.3538741	2.63	0.008	0.2388275 1.625989
ICT	–1.162587	0.6445644	–1.80	0.071	–2.42591 0.1007362
ACE	0.413598	0.2271999	1.82	0.069	–0.0317056 0.8589016
AWP	0.0959392	0.043034	2.23	0.026	0.0115941 0.1802844

Source: Author's computation 2023

4.4 *The cross-section view of the estimating coefficients in Table 7 disclosed the strength of the infrastructural effects on industrial sector growth in Sub-Sahara Africa*

For instance, an indicator for ICT has the highest economic returns to scale than other indicators, such as access to energy, water and FDI. This implies that investment in ICT would economically improve industrial output growth more than energy, water resources and FDI. Also, FDI would propel better investment in energy and water resources. Hence, it is pertinent for the investors in SSA to prioritise investment in certain sets of infrastructure that could yield higher returns to productivity scale for industrial sector growth in SSA. Based on the findings, the Sub-Saharan African region needs massive investment in technology-inclined infrastructures such as ICT alongside other infrastructure indicators like improved energy access and water resources. Also, indicators for transportation networks, such as access to transportation and local investment, such as GCF, are poorly spread across the region. Therefore, there is a need for both local and foreign investors to massively invest in modern infrastructure like road networks as one of the major inputs for industrial sector growth. The implication is that the sub-region's productive output would improve as the cost of production reduces due to efficient means of infrastructural connectivity. Sophisticated value-added goods are possible due to improved product quality across the region; hence local and infant industries are protected from external shocks attributed to the incessant importation of locally made industrial goods across the SSA.

Table 7 Contextualising of short-run and long-run economic effects via system GMM on infrastructure

Variables	*Order of returns to scale*	*Short-rung coefficient effects*	*Order of returns to scale*	*Long-run coefficient effects*
FDI	2	0.297	2	0.932
ICT	1	0.371	1	1.163
ACE	3	0.132	3	0.414
AWP	4	0.031	4	0.096

Source: Author's computation 2023

In summary, the emerging implications from this study provide the fundamental road map for policymakers on the need to prioritise infrastructural effects on the industrial sector growth in SSA, via rapid infrastructural investment across the SSA countries. Hence, accomplishing some sustainable development goals (SDGs), particularly the ninth SDG towards building resilient infrastructure, promote inclusive, sustainable industrialisation and foster innovation, among others, premising on the United Nations 2030 Agenda for Sustainable Development as pronounced in 2015.

5 Conclusions and future research

In quick response to the current slow level of industrial sector growth in Sub-Saharan Africa and due to the sparse literature on how the investment in economic returns to scale infrastructure affects industrial sector growth in SSA. Consequently, this research examined the economic effect of infrastructural investment on industrial output growth in SSA. The study used panel data drawn from 40 small open economies of SSA countries between 1990 and 2021. The data accessibility guided the choice of this group of countries, and the choice of scope in the study was to create room for the evaluation of both short and long-run specific effects of infrastructural investment on industrial output growth by individual indicators. Hence, the author contributes to the body of literature by disclosing evidence that improving infrastructure significantly impacts industrial output growth in SSA via short-run and long-run system GMM analysis. Also, the study has disclosed that the key indicators of infrastructure development, such as ICT, access to transportation networks, and GCF, negatively influence productivity growth, which further reveals the under-development state of infrastructural indexes in SSA. Other notable contributions of the study include contextualising different types of infrastructure to show the true states of infrastructural spread in SSA. From the estimated results, it was observed that the variable for transportation networks is not significant to influence industrial sector growth. This disclosed the dilapidated state of vital industrial input, such as access to transportation in SSA. At the same time, GCF and labour force exhibit insignificant negative effects on productivity growth. This might be connected to the current state of poor productive skills hence slow industrial output growth in SSA, characterised by poor curriculum design and intellectualism, and lack of political will. Hence necessary attention is needed in these areas to address the poor productivity growth in the region. The stakeholders need to make more serious efforts to reconfigure policy support to strive for local and foreign investment in infrastructure across the region by allowing productivity to strive rather than politics, as this would address current dares of poor value-added products in the region.

Although this study tries to fill certain gaps in the literature by examining the effects of infrastructural investment on industrial sector growth in SSA through disaggregated system-GMM approach. However, based on the recent development globally, which have much focus on continental infrastructural development, and as part of SDG towards building resilient infrastructure across different continents. Therefore, future research can focus on the other sub-regional countries from Africa continent, which might influence the emerging results from this study due to different country's productive structure. Also, there is still a limitation in data accessibility that prevented the inclusion of some SSA countries in our study. It is pertinent for the future researcher to be wary of this slight limitation.

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