



A Pathway for Infrastructure Progress in Sub-Saharan African Countries: Physical and Social Capital Perspectives

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Abstract

The basic functions and human activities of modern society would be significantly more difficult in the absence of critical infrastructure, given its economic importance. This study, therefore, investigates the drivers of infrastructure development in Sub-Saharan Africa. The estimations were conducted using static panel estimation methodologies on a panel of 43 selected SSA nations from 2000 to 2022. The infrastructure development was built using principal component analysis to generate a composite infrastructure index that includes six indicators. The study further breaks this into physical and social infrastructure indices and examines the differential effects of explanatory variables on them. The empirical results show that improvement in financial development, per capita GDP, governance, population density, and urbanization improve infrastructure development, physical and social infrastructure. Total government capital expenditure positively influences both infrastructure development and physical infrastructure, and a high literacy rate improves social infrastructure. From the theoretical implications of infrastructure development that are still in a formative state, evidence from the present study shows that infrastructure development responds positively to GDP (output level). This provides some useful insights into the validity of the adopted theory (accelerator theory of investment) as a theoretical foundation for infrastructure development. It is therefore recommended that SSA countries ensure that necessary policies are put in place to boost their per capita GDP, level of domestic financial development, and institutional quality to promote the development of infrastructure, among others.

Keywords: economic infrastructure, infrastructure development, principal component analysis, social infrastructure, panel regression.

JEL Classification: C23, C43, C51, H54.



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Introduction

Access to a well-functioning and efficient infrastructure is a necessary component for improving people's well-being and productivity. The significance of infrastructure to human survival cannot be over-emphasized. Infrastructure, both in terms of quantity and quality, is a critical component of growth and development in all countries, particularly in emerging and developing nations. Infrastructure improvements can help to support aggregate demand during the construction phase and, in the long run, by increasing the productive capacity of other inputs (Cerra et al., 2017). Infrastructure services, in general, are critical to the existence and maintenance of high living standards in modern society. The basic functions of modern society are highly reliant on infrastructure, and human activities would have been more difficult in the absence of critical services such as high-quality education, health facilities, transportation systems, high-speed telecommunications services, and proper sanitation facilities (Yates, 2014).

Despite its economic importance, infrastructure improvement is a worldwide challenge that is a critical component of the 2030 Development Agenda and a precondition for accomplishing the Sustainable Development Goals - SDGs (Agenda, 2015). Research and studies have provided compelling evidence indicating a significant disparity between the demand for enhanced or new infrastructure and the scheduled implementation of such infrastructure projects. Nevertheless, the main reasons for the infrastructure gap, as well as the measures to close it, are extremely complex (Foster and Briceno-Garmendia, 2010). The global infrastructure investment shortage is enormous, and it is not an issue limited to a few regions; practically every country in the entire world requires infrastructural development (Love et al., 2014), but this is more pronounced in most of the developing countries, most especially Sub-Saharan Africa (SSA).

Evidence has shown that no region in the world requires a more urgent transformation in its infrastructure development than the SSA region (Foster and Briceno-Garmendia, 2010). At present, SSA countries lack sufficient and long-term infrastructure to support increased economic growth (Saghir, 2017). The accelerated pace of globalization has led to a growing demand for infrastructure, while the economies in SSA have struggled to meet the rising needs due to inadequate supply. As a result, the region has a massive infrastructure gap that requires vast financial resources to close (AfDB, 2022). Furthermore, despite the advances made in the telecommunications industry, almost all parts of the infrastructure in SSA are in deplorable conditions due to insufficient funding, poor maintenance culture, and economic mismanagement. In terms of competitiveness,

SSA as a whole lags behind the rest of the world. This is mostly due to a significant lack of infrastructural services in terms of quality, quantity, and accessibility (Calderon et al., 2018). As a result, the region urgently needs to address the aforementioned infrastructure deficit problems. To address this, there has been a renewed focus on infrastructure determinants, as this would enable stakeholders to be properly informed on the drivers of infrastructure development.

As a result, some empirical studies have examined the influence of factors such as economic growth, institutional framework, government capital expenditure, among others (Akanbi, 2012; Cerra et al., 2017; Chan et al., 2022; Noah, 2021; Oluseye, 2024) on infrastructure. Despite this, there are still gaps in the literature that can be filled. This study supports previous studies on infrastructure development by evaluating the drivers of infrastructure development both at the aggregate and component levels. The study uses a composite infrastructure index that includes six indicators (energy, transportation, telecommunications, health, education, and water) to measure infrastructure development. The study further breaks this into social and physical infrastructure and examines the differential effects of explanatory variables on the components (social and physical infrastructure) and aggregate (infrastructure development). All these are largely missing in the previous studies on the subject matter. The subsequent sections of this study encompass a comprehensive examination of relevant literature in Section Two, an elucidation of the chosen methodology in Section Three, the presentation of empirical results in Section Four, and finally, Section Five draws the study to a close by providing policy recommendations.

Literature Review

The term "infrastructure" comes from the military's utilization of underlying structures during World War II (Srinivasu et al., 2013), even though there is no universally accepted definition of infrastructure (Snieška and Šimkūnaitė, 2009). Fourie (2006) classifies the definitions of infrastructure in the literature into two basic approaches: mainstream and alternative approaches. The mainstream focuses on infrastructure's technical, economic, and institutional features, while the alternative focuses on specific infrastructure functions. The alternative approach is also known as the 'functional approach', and it views infrastructure as the basic facilities that allow primary, secondary, and tertiary productive activities to function (Hirschman, 1958).

Infrastructure can be categorized into two main components: physical and social infrastructure. Physical or economic infrastructure is defined as

infrastructure that promotes economic activity, such as roads, highways, railroads, airports, sea ports, electricity, and telecommunications. Social infrastructure, on the other hand, is defined as activities that have both direct and indirect impacts on people's welfare, such as infrastructure that promotes the population's health, education, and cultural standards (Snieška and Šimkūnaitė, 2009). As a result of the above definitions, infrastructure can therefore be referred to as the facilities that support both economic and social activities in society, such as electricity, transportation, telecommunications, health, education, water, and sanitation, among others. Whereas infrastructure development refers to the construction and improvement of foundational services intending to improve economic growth and quality of life (Noah, 2021).

Theoretical Review

Although there are theories and schools of thought on the subject, this study is unaware of any received theory on infrastructure development that deals with the supply side of infrastructure (infrastructure supply model), given the fact that there are theories on infrastructure demand models, such as the theory of demand and consumption theory based on previous studies (Amusa et al., 2016; Kwakwa, 2017). Infrastructure development can be considered an investment because it is a component of actual investment, and investment theories are more applicable to the current study.

Purchasing existing shares, stocks, bonds, and securities on the stock market is sometimes referred to as an investment. However, these are not actual investments because they are just the transfer of existing assets. As a result, this is called financial investment as considered by some of the major investment theories, such as Keynes' Marginal Efficiency of Capital, Tinbergen's Internal Funds theory, and the Tobin Q theory. As a result, infrastructure investment comprises the development of roads, buildings, dams, and trains, among other things (Jhingan, 2005). The most appropriate investment theory in this study is the Accelerator Theory or Simple Accelerator Principle of Investment because it treats an investment as capital or real investment, which is more relevant to this study than other investment theories that treat the investment as a financial or business fixed investment. This posits that the capital-output ratio remains relatively stable and incorporates a feedback mechanism from current output to investment. This indicates that the capital stock in any given period is directly proportional to the level of output.

Empirical Review

Infrastructure, its importance for economic growth, finance, and the funding gap, as well as studies on private participation in infrastructure, have all been thoroughly examined (Li et al., 2023; Rehman et al., 2023), while others have considered the impact of various infrastructure on poverty reduction and industrialization (Araghi et al., 2018; Fagbemi et al., 2022; Nkemgha et al., 2023; Saadaoui Mallek et al., 2024; Setyadi et al., 2023; Wiratama et al., 2023), but only a few have explored the drivers of infrastructure development itself. Among the early studies that looked into this are those conducted by Randolph et al. (1996), and Canning and Pedroni (1999). An assessment of these studies shows that they all focused on infrastructure investment rather than the indicators that reflect the existence or stock of infrastructure.

In regard to infrastructure financing, studies such as Araya et al. (2013), Ba et al. (2010), Lu and Wilson (2024) have examined the various means of private investment in infrastructure. While there is limited literature available on infrastructure development and the factors driving it, especially in the context of SSA, there has been minimal research conducted on the factors influencing individual indicators or specific components of infrastructure. Among the most recent studies in this field are the ones by De (2010), Gillanders (2014), and Onyeji et al. (2012) which have either investigated the determinants of one of the infrastructure indicators or a component in developing countries.

In addition, the determinants of physical infrastructure that would unlock the productive potential of SSA were empirically studied in a study undertaken by Akanbi (2012), using two-stage least squares (TSLS), on a panel dataset consisting of 21 selected nations in SSA from 2000 to 2010. The findings from the analysis indicated that government capital expenditure, real GDP, inflation, and external balance significantly influence the development of physical infrastructure in SSA. Gopalan and Rajan (2016) contributed to the growing interest in sector-specific aid effectiveness literature by conducting an empirical analysis for a large panel of 139 countries from all regions, to assess the effectiveness of aid disbursements in improving access to water supply and sanitation facilities from 2002 to 2012, using generalized method of moments (GMM) and system-GMM. The empirical results obtained from the study demonstrated a significant and positive correlation between aid disbursements and the percentage of the population with enhanced access to water supply and sanitation facilities (WSS).

Cerra et al. (2017) looked into the factors that influence infrastructure and financing by employing a dynamic panel consisting of 110 nations, using the least

square dummy variable, least square dummy variable corrected, GMM, and SGMM spanning from 1990 to 2013. It was found that greater financial market depth and higher degrees of trade and financial openness were associated with increased levels of domestic infrastructure finance across countries. In a study conducted by Steckel et al. (2017) to identify potential factors influencing access rates to major infrastructure services, utilizing a panel data set consisting of 154 countries from 1990 to 2010. The study employed descriptive statistics as well as an inferential technique (fractional logit) model, to analyse trends and global patterns in access to these infrastructure services. The findings indicated that both GDP and population density play significant roles as drivers of infrastructure services; however, GDP exhibited greater robustness and influence in the analysis.

Between 1990 and 2015, Eicher et al. (2018) explored the factors influencing social infrastructure in 69 countries. They employed a comprehensive dataset that directly extracted information on political institutions from countries' constitutions. The findings of the study highlighted the significance of executive constraints and electoral system structure as critical determinants for the development of high-quality social infrastructure. Gomez et al. (2019) investigated the impact of particular socioeconomic characteristics on access to improved water sources in low-, low-middle-, and high-middle-income countries' rural areas using a linear fixed effects regression model. The study discovered that several factors, including gross national income, female primary school completion rate, agriculture, rural population growth, and governance indicators such as political stability, corruption control, government effectiveness, and regulatory quality, are associated with water access. In addition Oseni et al. (2022) reported that fiscal vulnerability influences transport infrastructure.

Finally, Noah (2021) examines the state of infrastructure development in SSA by considering 43 nations from 2000 to 2018 using descriptive statistics, stylized facts, and correlation analysis for the analysis of the data. The study's findings indicated notable improvements in infrastructural development within SSA during the study period, although the progress was relatively lower compared to other regions globally. The majority of these improvements were observed in the physical infrastructure domain, particularly within the telecommunication sector. There were also some advancements in health and water infrastructure, although to a lesser extent.

Research Novelty

Considering the studies reviewed above on the determinants of infrastructure, the majority of the earlier studies on the determinants of infrastructure development in SSA focused less on empirical research, and the ones that did only employed infrastructure spending or expenditure as a proxy for infrastructure development. Due to inefficiencies and the prevalence of corruption in SSA, measuring infrastructure development by infrastructure spending or investment may be incorrect. Those who addressed measurement issues only looked at a single indicator or a component (physical or social infrastructure) as a measure of infrastructure development, but not both in the same study, because single infrastructure indicators or components cannot fully represent or capture infrastructure development in its totality, which may lead to incorrect inferences. Apart from this, another important variable that has not been taken into account in the earlier studies is the literacy level. This study goes further to test it as a possible determinant of infrastructure development in SSA. In addition, to the best of the researchers' knowledge, most earlier studies were not based on a widely acknowledged theoretical approach. This study sets out to bridge these gaps by using the simple accelerator theory of investment as the theoretical foundation for the estimated models of infrastructure development and its components. These are the gaps that are currently being addressed to contribute to existing infrastructure knowledge.

Methods and Materials

Even though no single or tailor-made theory to explain infrastructure behaviour has been received or widely accepted because infrastructural development is a type of real investment, it can be handled as an investment, and as a result, investment theory is considered to be an adequate theoretical foundation for this research.

This study adopts the fundamental principles of the accelerator theory of investment as its theoretical foundation, following an evaluation of various investment theories. The aim is to establish an empirical relationship between infrastructural development and its determining factors in SSA. The accelerator theory is a straightforward model that incorporates feedback from current production to investment and is based on the assumption that the capital-output ratio remains relatively constant. In other words, the capital stock in a given period is directly proportional to the level of output. That is:

$$K_t = \sigma Y_t \tag{1}$$

In Equation 1, the total capital stock (K) is determined by the level of output (Y), where σ represents the proportion of output allocated to capital stock, and t represents the time. As a result, the accelerator theory of investment places a greater focus on infrastructural development and output level. This means that the level of output has a significant impact on infrastructure development. Apart from theoretical evidence, GDP is widely utilized as a proxy of output level in infrastructure studies (Akanbi, 2012; Steckel et al., 2017).

Model Specification

The primary and particular objectives of this study are to investigate the drivers of infrastructure development and its components (physical and social infrastructure) in SSA and to ascertain if these factors have the same or different effects on aggregate infrastructure and its components based on *a priori* economic theory propositions. Following the theoretical and empirical justifications, the models specified for estimation to explore the drivers of infrastructure development and its components in SSA are stated as follows:

$$INF_{it} = \beta_0 + \beta_1 GDP_{it} + \beta_2 GCE_{it} + \beta_3 DFD_{it} + \beta_4 GOV_{it} + \beta_5 POP_{it} + \beta_6 URB_{it} + \beta_7 LIT_{it} + u_{it} \quad (2)$$

$$PHY_{it} = \alpha_0 + \alpha_1 GDP_{it} + \alpha_2 GCE_{it} + \alpha_3 DFD_{it} + \alpha_4 GOV_{it} + \alpha_5 POP_{it} + \alpha_6 URB_{it} + \alpha_7 LIT_{it} + \varepsilon_{it} \quad (3)$$

$$SOC_{it} = \psi_0 + \psi_1 GDP_{it} + \psi_2 GCE_{it} + \psi_3 DFD_{it} + \psi_4 GOV_{it} + \psi_5 POP_{it} + \psi_6 URB_{it} + \psi_7 LIT_{it} + \eta_{it} \quad (4)$$

where INF represents the composite index of infrastructure, serving as a proxy for infrastructure development, PHY corresponds to the composite index of physical infrastructure, serving as a proxy for the development of physical infrastructure, SOC denotes the composite index of social infrastructure, serving as a proxy for the development of social infrastructure, GDP signifies the per capita GDP, measuring the level of output, GCE stands for total government capital expenditure, GOV represents the governance index, DFD represents the level of domestic financial development, POP represents population density, URB is urbanization and LIT is literacy level, u , ε , and η are the error terms, β_0 , α_0 , and ψ_0 are the intercepts, $\beta_1 - \beta_7$, $\alpha_1 - \alpha_7$ and $\psi_1 - \psi_7$ are the slope coefficients, t is time and i is country. Considering the models discussed above, the inequality notations for the *a priori* expectations of each parameter in the model suggest a positive

relationship. The basis for their inequality signs is premised on the conclusions of the previous related studies.

Based on Equation 2, GDP stands out as a significant determinant of infrastructure development, as indicated by the positive relationship between infrastructure development and output levels. GDP serves as a standard measure for the economy's income and demand levels. Increased economic activities create opportunities for infrastructure development (Gillanders, 2014). Governments in developing nations commonly finance infrastructure through the allocation of domestic public funds to capital expenditure in their budgets. Hence, directing the government budget towards increased capital expenditure is anticipated to substantially enhance both the infrastructure capacity and its expansion (Akanbi, 2012).

Infrastructure development is intricately tied to good governance, which establishes the socioeconomic conditions conducive to such progress. Furthermore, good governance significantly influences country risk, thereby impacting investor sentiments (De, 2010). Financial sector development within a nation is also presumed to have a positive impact on infrastructure development by facilitating the mobilization of funds necessary for the sector's growth (Ba et al., 2010). The population increase is posited to drive the demand for more infrastructure, suggesting a partly demand-driven nature of infrastructure development (Gopalan and Rajan, 2016).

Rapid urbanization poses challenges in providing infrastructure capable of meeting the stress induced by urban growth. Established cities must continually build, sustain, and fortify extensive infrastructure to cater to societal needs (Cerra et al., 2017). The literacy level within a society emerges as a crucial determinant of infrastructure development due to its impact on the demand for basic amenities. In addition to being an indicator of educational achievement, literacy also promotes societal advancement. A populace that is educated participates actively in development, creating the environment required for efficient and long-lasting infrastructure development.

Methods of Analysis

Data analysis techniques include descriptive, simple correlation, and panel data regression. Descriptive statistics provide key summary measures such as mean, maximum, minimum, and standard deviation values. Panel estimation techniques, which include panel ordinary least squares, fixed effects, and random effects (depending on the results of pre and post-estimation), as well as panel-corrected

standard error estimation, are used to estimate the equations (depending on the outcomes of other diagnostic tests). If the pooling assumption is accurate, the panel OLS technique of estimation can be used; otherwise, depending on the behavior or features of the error terms, the fixed or random effect approach can be used (Asteriou and Hall, 2016).

Data Coverage, Measurement, and Sources

For this study, annual data from a total of forty-three SSA countries were collected from various secondary sources, covering the period from 2000 to 2022. The selection of countries and the time frame was based on data availability. Although there were a few missing data points in the dataset, these gaps were addressed through techniques such as projection, moving average interpolation for filling missing data between two known points, and linear trend extrapolation using the least squares approach to estimate missing values based on existing data points. The data on infrastructure indicators and other variables are sourced from some well-known international organizations (World Bank, World Health Organization, United Nations Educational, Scientific, and Cultural Organization, and International Telecommunication Union) that archive countries' raw facts on social and economic indicators.

Mechanics of the Principal Components Analysis (PCA)

In contrast to prior studies that have focused on a specific indicator or component, such as physical infrastructure (transportation, energy, and telecommunications) or social infrastructure (health, education, and water), this study evaluates a wide range of infrastructure indicators. Given the potential correlation among infrastructure indicators, the principal component analysis (PCA) was employed to construct a comprehensive infrastructure index. The PCA approach enabled the derivation of a principal index that combined both physical components (such as energy, transportation, and telecommunications) and social components (including health, education, and water) of infrastructure. By utilizing PCA, a unified index was created to represent energy, transport, telecommunication, education, health, and water infrastructure.

The composite index is created using PCA for both the aggregate infrastructure development and its components. PCA is a mathematical method that reduces a set of possibly linked variables into a smaller set of uncorrelated variables. Maximizing the first principal component's explanatory power is the major goal; the remaining variability is best captured by the remaining

components. Eigenvalues are produced for every component in the first PCA step, and the principal component with the greatest eigenvalue is chosen to create a composite index that represents the total variance of the six core infrastructure indicators. In practice, the necessary weights are the first eigenvector obtained from the data. Subsequently, every weight is multiplied by its respective indicator and combined to create the composite infrastructure development index. That is, the linear combination of the different indicators yields this composite index as follows:

$$INF = \sigma_1 eny + \sigma_2 tlm + \sigma_3 tsp + \sigma_4 hlt + \sigma_5 edn + \sigma_6 wtr \quad (5)$$

where $\sigma_1, \sigma_2, \sigma_3, \sigma_4, \sigma_5$ and σ_6 are the eigenvectors (weights) from the PCA result in Table 1 (with the numerical values of 0.4635, 0.3984, 0.4536, -0.2572, 0.4089 and 0.4328 for $\sigma_1, \sigma_2, \sigma_3, \sigma_4, \sigma_5$ and σ_6 respectively), and *eny* is energy, *tlm* is for telecommunication, *tsp* is transport, *hlt* is health, *edn* is education and *wtr* is water. The resulting values of the generated weights (eigenvectors) for each underlying infrastructural variable by applying the PCA method are given in Table 1.

Table 1. The Eigenvectors of the Original Values

Composite Index Variables	Indicators	Weight
INF	eny	0.463
	tsp	0.398
	tlm	0.454
	edn	-0.257
	hlt	0.409
	wtr	0.433
PHY	eny	0.580
	tsp	0.538
	tlm	0.612
SOC	edn	-0.433
	hlt	0.626
	wtr	0.649

Source: Research finding.

Empirical Results and Discussion

Descriptive Analysis

The summary statistics of the panel series used in this study are presented in Table 2. The values of the mean, median, maximum, minimum, and standard deviation are presented in the third to seventh columns respectively. The values of the composite infrastructure index (INF), index of physical (PHY), and social (SOC)

components of the infrastructure are presented in Rows 1 to 3 respectively, while their drivers (per capita GDP - GDP, total government capital expenditure - GCE, domestic financial development indicator - DFD, governance - GOV, population density - POP, urbanization - URB, literacy rate - LIT) are presented in Rows 4 to 11 respectively.

Table 2. The Descriptive Statistics

Variables	Mean	Median	Maximum	Minimum	Standard Deviation
INF	266	166	2155	-4.761	311
PHY	327	199	2840	8.149	407
SOC	31.456	28.861	107	-48.397	21.908
GDP	2036	904	14385	195	2636
GCE	4.853	3.282	29.773	0.094	4.538
DFD	21.348	20.980	52.703	0.687	10.493
GOV	-1.484	-1.572	2.144	-4.701	1.461
POP	98.157	56.511	623	2.18	123.0
URB	38.333	37.966	89.37	8.246	15.817
LIT	60.574	62.964	95.868	10.802	20.007

Source: Research finding.

Correlation Analysis

Table 3 shows the coefficients of correlation between every pair of the variables (INF, PHY, SOC, GDP, GCE, DFD, GOV, POP, URB, and LIT) with their respective p-values below the correlation coefficients. The significance of the correlation coefficients is indicated by the p-values. If the p-value of a correlation coefficient does not exceed 5%, it is statistically significant, and hence a relationship between the pair of variables is assumed to exist in the study.

The results reveal that a significant number of variables exhibit correlation and statistical significance, as evidenced by their respective p-values, which are presented alongside the correlation coefficients in Table 3. However, none of the correlation coefficients among the regressors surpass 0.8, suggesting that the models are unlikely to suffer from severe multicollinearity (Asteriou and Hall, 2016). Consequently, it can be inferred that all models estimated using the variables included in the study are devoid of severe multicollinearity.

Table 3. Correlation Matrix

Variable	INF	PHY	SOC	GDP	GCE	DFD	GOV	POP	URB	LIT
INF	1.000 -									
PHY	0.999 (0.000)	1.000 -								
SOC	0.646 (0.000)	0.618 (0.000)	1.000 -							
GDP	0.800 (0.000)	0.790 (0.000)	0.706 (0.000)	1.000 -						
GCE	0.013 (0.698)	0.017 (0.624)	-0.074 (0.034)	0.099 (0.004)	1.000 -					
DFD	0.413 (0.000)	0.408 (0.000)	0.359 (0.000)	0.340 (0.000)	0.061 (0.083)	1.000 -				
GOV	0.576 (0.000)	0.569 (0.000)	0.511 (0.000)	0.542 (0.000)	-0.106 (0.002)	0.358 (0.000)	1.000 -			
POP	0.395 (0.000)	0.394 (0.000)	0.288 (0.000)	0.157 (0.000)	-0.061 (0.079)	0.127 (0.000)	0.203 (0.000)	1.000 -		
URB	0.418 (0.000)	0.405 (0.000)	0.512 (0.000)	0.588 (0.000)	0.229 (0.000)	0.258 (0.000)	0.243 (0.000)	-0.226 (0.000)	1.000 -	
LIT	0.532 (0.000)	0.522 (0.000)	0.527 (0.000)	0.617 (0.000)	0.104 (0.003)	0.294 (0.000)	0.419 (0.000)	0.192 (0.000)	0.334 (0.000)	1.000 -

Source: Research finding.

Panel Unit Root Tests

Table 4. Panel Unit Roots Test Results

Series	Stationary	HT	ADF-Fisher	LLC	Breitung	IPS	Hadri
INF	Level	1.051 (1.000)	5.224 (1.000)	5.038 (1.000)	18.551 (1.000)	21.960 (1.000)	69.220 (0.000)
	First Diff.	0.030 (0.000)***	268.169 (0.000)***	-5.985 (0.000)***	-4.557 (0.000)***	-6.426 (0.000)***	14.816 (0.000)
PHY	Level	1.052 (1.000)	4.394 (1.000)	4.933 (1.000)	18.711 (1.000)	22.648 (1.000)	69.190 (0.000)
	First Diff.	0.034 (0.000)***	262.827 (0.000)***	-6.011 (0.000)***	-4.217 (0.000)***	-6.231 (0.000)***	14.946 (0.000)
SOC	Level	0.986 (1.000)	113.939 (0.236)	-0.099 (0.461)	10.209 (1.000)	10.821 (1.000)	57.437 (0.000)
	First Diff.	0.667 (0.000)***	219.585 (0.000)***	-3.569 (0.000)***	-3.345 (0.000)***	-4.080 (0.000)***	29.144 (0.000)
GDP	Level	0.998 (1.000)	51.791 (0.999)	0.671 (0.749)	11.927 (1.000)	9.052 (1.000)	67.197 (0.000)
	First Diff.	0.162 (0.000)***	404.881 (0.000)***	-7.921 (0.000)***	-8.509 (0.000)***	-9.264 (0.000)***	5.185 (0.000)
GCE	Level	0.8 69 (0.788)	32.448 (1.000)	4.943 (1.000)	10.673 (1.000)	12.518 (1.000)	50.196 (0.000)
	First Diff.	-0.069 (0.000)***	587.069 (0.000)***	-9.337 (0.000)***	-11.042 (0.000)***	-10.611 (0.000)***	-0.048 (0.519)
DFD	Level	0.932 (0.999)	104.987 (0.080)*	-0.460 (0.923)	3.483 (1.000)	5.596 (1.000)	51.546 (0.000)
	First Diff.	0.141 (0.000)***	456.932 (0.000)***	-7.461 (0.000)***	-8.365 (0.000)***	-10.226 (0.000)***	5.138 (0.000)
GOV	Level	0.778 (0.479)	134.661 (0.000)***	-4.126 (0.000)***	0.271 (0.607)	-1.801 (0.036)**	35.591 (0.000)
	First Diff.	0.045 (0.000)***	586.309 (0.000)***	-14.034 (0.000)***	-12.724 (0.000)***	-12.747 (0.000)***	-0.550 (0.709)
POP	Level	1.028 (1.000)	96.993 (0.196)	-0.301 (0.381)	23.333 (1.000)	37.322 (1.000)	71.628 (0.000)
	First Diff.	0.534	189.398	-12.393	14.845	5.075	37.820

		(0.000)***	(0.000)***	(0.000)***	(1.000)	(1.000)	(1.000)
URB	Level	1.003 (1.000)	326.658 (0.000)	12.295 (0.000)	21.954 (1.000)	24.550 (1.000)	71.682 (0.000)
	First Diff.	0.731 (0.000)***	351.743 (0.000)***	-2.658 (0.050)**	10.566 (1.000)	8.609 (1.000)	30.345 (0.592)
LIT	Level	0.972 (1.000)	193.623 (0.999)	0.107 (0.543)	12.379 (1.000)	10.984 (1.000)	51.695 (0.000)
	First Diff.	0.694 (0.000)***	253.585 (0.000)***	-9.382 (0.000)***	-2.219 (0.013)**	-1.820 (0.000)***	28.115 (0.000)

Source: Research finding.

Note: Harris-Tzavalis (HT), ADF – Fisher, Im-Pesaran-Shin (IPS), Levin-Lin-Chu (LLC), and Breitung (Null: Panels contain unit roots), while Hadri (Null: All panels are stationary). Values in the parentheses () are the p-values of the test statistic.

Table 4 presents the results of the unit root tests for the panel series, employing various tests such as Harris-Tzavalis (HT), ADF-Fischer, Im-Pesaran-Shin (IPS), Levin-Lin-Chu (LLC), Breitung, and Hadri. The tests were conducted at both levels and first differences for each variable. The null hypothesis in these panel unit root tests (excluding Hadri) posits that the panels contain unit roots. The empirical findings of the stationarity tests indicate that most of the series are non-stationary at the levels due to the acceptance of null hypotheses. This implies that nearly all panel series possess unit roots at various levels. However, all panel series exhibit stationarity when estimated at the first difference.

Panel Cointegration Results Analysis

The results of cointegration tests for the aggregate, physical, and social infrastructure are presented in Table 5. The Kao-Engle-Granger technique was employed as the appropriate cointegration test for single-equation panel cointegration.

Table 5. Kao-Engle-Granger Panel Cointegration Results

Model	t-Statistic	p-value	Conclusion (H ₀)
Aggregate Infrastructure (INF)	4.643	0.000	Reject
Physical Infrastructure (PHY)	4.375	0.000	Reject
Social Infrastructure (SOC)	6.116	0.000	Reject

Source: Research finding.

Note: H₀: No cointegration.

The empirical findings in Table 5 indicate that the t-statistic is statistically significant for all three equations. This is supported by their respective p-values at 0.05, leading to the rejection of the null hypothesis. Consequently, it can be inferred that there are long-run correlations among the non-stationary series in the three models. This implies that the parameters of the models can be estimated using long-run regression techniques. Under these circumstances, the techniques considered most appropriate for the analysis in this study are the panel OLS, FEM, or REM methods. The final choice among these three estimation methods depends on the outcomes of the pre-estimation tests as well as the post-estimation tests.

Panel Regression Analysis

Following the objectives of this study, the estimates of the drivers of infrastructure development, physical and social infrastructure are presented in Table 6. These estimates were obtained by applying panel OLS, fixed effects model (FEM),

random effects model (REM), and panel-corrected standard errors (PCSE) to each equation. Subsequently, appropriate estimates were selected based on various pre- and post-estimation tests.

The empirical results of panel OLS, FEM, REM, and PCSE estimations for infrastructure development, physical and social infrastructure in SSA are shown in Table 6. To select the most suitable modeling technique and validate the findings, diagnostic tests were performed to assess the overall performance of the three models. The diagnostic tests include the F-test for deciding between the panel OLS and FEM methods; the LM test for deciding the appropriate method between the REM and OLS techniques; and the Hausman test for deciding the appropriate method between REM and FEM. Based on the results of these diagnostic tests, FEM estimates were chosen over REM and POLS for the three models.

Additionally, Table 6 displays the outcomes of diagnostic tests conducted for the fixed effect model of infrastructure development, physical and social infrastructure. The validity of the FEM estimates is contingent upon the results of diagnostic tests examining multicollinearity, heteroscedasticity, serial correlation or autocorrelation, and cross-section dependence. The VIF result reveals that the VIF value is fairly low for all variables, which implies that the models are devoid of a major multicollinearity problem. This backs up the findings of the correlation analysis.

Table 6. Panel Regression Results for the Infrastructure Development, Physical and Social Infrastructure – INF, PHY and SOC

	Infrastructure Development Model				Physical Infrastructure Model				Social Infrastructure Model			
	OLS	FEM	REM	PCSE	OLS	FEM	REM	PCSE	OLS	FEM	REM	PCSE
GDPPC	0.073*** [21.26] (0.000)	0.179*** [32.95] (0.000)	0.145*** {24.96} (0.000)	0.075*** [18.44] (0.000)	0.096*** [20.64] (0.000)	0.243*** [33.57] (0.000)	0.197*** {25.10} (0.000)	0.098*** [18.04] (0.000)	0.002*** [9.73] (0.000)	-0.002*** [-2.77] (0.006)	0.001* {1.76} (0.078)	0.003*** [20.84] (0.000)
GCE	-0.004** [-2.09] (0.037)	-0.005*** [-3.19] (0.001)	0.002 {1.24} (0.213)	4.075** [2.28] (0.022)	-0.004* [-1.67] (0.096)	-0.007*** [-3.19] (0.001)	0.003 {1.32} (0.185)	5.558** [2.30] (0.022)	-0.001*** [-7.67] (0.000)	-0.001 [-0.58] (0.563)	-0.001*** {-3.06} (0.002)	-0.001*** [-10.50] (0.000)
DFD	0.844*** [5.56] (0.000)	-0.197* [-1.78] (0.076)	-0.331*** {-2.51} (0.012)	0.868*** [5.78] (0.000)	1.106*** [5.38] (0.000)	-0.256* [-1.73] (0.085)	-0.442** {-2.50} (0.012)	1.142*** [5.77] (0.000)	0.037*** [2.83] (0.005)	-0.014 [-0.88] (0.380)	0.003 {0.18} (0.856)	0.037*** [4.59] (0.000)
GOV	27.370*** [5.74] (0.000)	-30.481*** [-4.80] (0.000)	-45.190*** {-6.55} (0.000)	28.569*** [7.65] (0.000)	35.457*** [5.50] (0.000)	-39.516*** [-4.67] (0.000)	-60.170*** {-6.48} (0.000)	36.553*** [7.31] (0.000)	1.611*** [3.98] (0.000)	-1.755** [-1.97] (0.049)	0.024 {0.18} (0.856)	1.611*** [8.01] (0.000)
POP	0.685*** [13.71] (0.000)	0.876*** [6.07] (0.000)	1.252*** {10.07} (0.000)	0.709*** [18.44] (0.000)	0.884*** [13.09] (0.000)	1.227*** [6.38] (0.000)	1.697*** {10.10} (0.000)	0.917*** [17.68] (0.000)	0.043*** [10.21] (0.000)	-0.055*** [-2.73] (0.007)	0.009 {0.78} (0.437)	0.043*** [12.63] (0.000)
URB	1.312*** [2.71] (0.007)	17.761*** [15.22] (0.000)	10.518*** {9.96} (0.000)	1.124*** [3.44] (0.001)	1.355** [2.07] (0.039)	23.475*** [15.08] (0.000)	13.906*** {9.75} (0.000)	1.152** [2.58] (0.010)	0.448*** [10.93] (0.000)	0.474*** [2.90] (0.004)	0.408*** {4.00} (0.000)	0.448*** [29.99] (0.000)
LIT	-0.111 [-0.31] (0.756)	1.900*** [3.26] (0.001)	1.972*** {3.15} (0.002)	-0.422*** [-2.77] (0.006)	-0.263 [-0.54] (0.587)	2.496*** [3.21] (0.001)	2.562*** {3.04} (0.002)	-0.668*** [-3.52] (0.000)	0.125*** [4.12] (0.000)	0.078 [0.95] (0.342)	0.128** {1.96} (0.050)	0.125*** [6.81] (0.000)
Const.	24.975 [0.90] (0.370)	-10.115*** [-27.35] (0.000)	-73.466*** {-15.94} (0.000)	20.695 [0.61] (0.545)	31.349 [0.83] (0.405)	-13.799*** [-27.98] (0.000)	-10.077*** {-16.20} (0.000)	23.186 [0.50] (0.614)	-0.256 [-0.11] (0.914)	16.400*** [3.15] (0.002)	5.833 {1.24} (0.213)	-0.256 [-0.17] (0.862)
Observation	817	817	817	817	817	817	817	817	817	817	817	817
R-square	0.747	0.800	0.787	0.738	0.729	0.803	0.791	0.732	0.630	0.753	0.658	0.630
F-statistics	340.25 (0.000)	473.01 (0.000)		17382.51 (0.000)	310.69 (0.000)	446.58 (0.000)		15802.61 (0.000)	197.08 (0.000)	4.66 (0.000)		6363.08 (0.000)
F-Test		102.94 (0.000)				106.23 (0.000)				26.15 (0.000)		
Wald χ^2 –stat.			1907.04				1901.47				60.35	

	(0.000)	(0.000)	(0.000)
Hausman Test	1312.03 (0.000)	2381.32 (0.000)	93.28 (0.000)
LM Test	1776.33 (0.000)	1771.79 (0.000)	1.44 (0.230)
Heteroscedasticity Tests	28057.34 (0.000)	32382.24 (0.000)	1713.09 (0.000)
Serial Correlation Tests	22.148 (0.000)	22.311 (0.000)	527.666 (0.000)
Cross-sectional dependency Test	12.978 (0.000)	14.808 (0.000)	3.439 (0.001)
Multicollinearity	1.64	1.64	1.64

Source: Research finding.

Note: Values in parentheses [] or { } and () are t-statistics (for OLS, FEM, and PCSE) or z-statistic (for REM) and p-values, respectively.

*, ** and *** are 10%, 5%, and 1% significance levels, respectively.

The results obtained from the Wooldridge test of autocorrelation, Modified Wald test statistic for heteroscedasticity, and Pesaran test for cross-sectional dependence indicate the presence of issues such as autocorrelation, heteroscedasticity, and cross-sectional dependence in the FEM estimates for the three models. Thus, the FEM estimation is no longer valid for decision making and this is corrected by the estimation of panel-corrected standard errors (PCSE). This implies that the estimation of the PCSE is the most appropriate technique for estimating the models for the infrastructure development, physical and social infrastructure.

PCSE estimation results in Table 6 for infrastructure development show that per capita GDP, total government capital expenditure, domestic financial development, governance, population density, and urbanization have positive impacts on infrastructure development. The observed positive effect is consistent with a priori expectations and economic theory, as well as empirical findings from previous studies, including those reported by Akanbi (2012), De (2010), Steckel et al. (2017). Contrary to expectations, the literacy rate exhibits a negative impact on infrastructure development. This may be a result of low literacy rates that are common in SSA nations, which are frequently made worse by extreme poverty and difficult economic conditions. Economically distressed societies may find it difficult to finance infrastructure investments and benefit from them, which would keep them stuck in a cycle of underdevelopment. Moreover, the prevailing perception that public infrastructure is perceived solely as "government's property" makes such facilities susceptible to destruction during public protests against unfavorable government policies. This perspective or mindset can have a significant negative effect on infrastructure development.

The findings indicate that a one-dollar increase in per capita GDP leads to a 0.075 unit increase in infrastructure development. A 1% increase in total government capital expenditure, domestic financial development, and urbanization results in 4.075, 0.868, and 1.124 units of infrastructure development, respectively. A rise in governance quality by one index causes the infrastructure development to increase by 28.569 units, and an increase in the population per land area (km²) pushes the infrastructure development to increase by 0.709 units. However, a one percent decrease in literacy rates will cause the infrastructure development to increase by 0.422 units. Thus, the empirical results suggest that higher per capita GDP, total government capital expenditure, domestic financial development, governance, population density, and urbanization have the potential to increase

infrastructure development in SSA, but the literacy rate has a negative prospect of increasing infrastructure development.

The PCSE estimation results for physical infrastructure development show that per capita GDP, total government capital expenditure, domestic financial development, governance, population density, and urbanization have positive impacts on the development of physical infrastructure. The observed positive effect is consistent with a priori expectations and economic theory, as well as empirical findings from some previous studies reported by Cerra et al. (2017), and Eicher et al. (2018). Literacy rate also has a negative influence on the development of physical infrastructure, which is contrary to the a priori expectation. Limited civic engagement and social advancement participation may also be the cause of this. Citizens may find it difficult to advocate for improvements to the physical infrastructure and to properly convey their concerns in countries where literacy rates are lower. This lack of engagement can interfere with democracy and possibly result in insufficient funding for physical infrastructure.

On account of the observed values of the statistically significant coefficients, a one-dollar increase in per capita GDP leads to a 0.098 unit increase in the physical infrastructure. A 1% increase in total government capital expenditure, domestic financial development, and urbanization results in a 5.558, 1.142, and 1.152 unit increase in physical infrastructure development, respectively. If the governance quality rises by one index, it causes the physical infrastructure to increase by 36.553 units, and an increase in the population per land area (km²) causes the physical infrastructure to increase by 0.917 units. However, it is also observed that a decrease in the literacy rate results in an increase of 0.668 units in the physical infrastructure. The empirical results, therefore, suggest that higher per capita GDP, total government capital expenditure, domestic financial development, governance, population density, and urbanization have the potential to increase the development of physical infrastructure in SSA, but the literacy rate also has a negative prospect for the development of physical infrastructure.

Furthermore, the estimation results for social infrastructure development are presented in Table 6 using PCSE. These results indicate that per capita GDP, domestic financial development, governance, population density, urbanization, and literacy rate have positive effects on the development of social infrastructure. The observed positive effect is consistent with a priori expectations and economic theory, as well as empirical findings from previous studies reported by Akanbi (2012), Cerra et al. (2017), and Eicher et al. (2018). However, it is worth noting that total government capital expenditure demonstrates a negative impact on the

development of social infrastructure, which contradicts the a priori expectation. The negative effects of government capital expenditures on social infrastructure can be ascribed to an increased prevalence of corruption and financial mismanagement in this sector. Consequently, the current inventory of infrastructure may not be increased proportionately to the funds allocated to the sector. Fundamentally, compared to other sectors, social infrastructure is especially vulnerable to the negative effects of corruption and improper financial allocation.

Going by the values of the statistically significant coefficients, a one-dollar rise in per capita GDP leads to a 0.003 unit increase in the social infrastructure. A 1% increase in domestic financial development, urbanization, and literacy rate increases social infrastructure development by 0.037, 0.448, and 0.125 units, respectively. If the governance quality rises by one index, it causes the social infrastructure to increase by 1.611 units, and an increase in the population per land area (km²) will cause the social infrastructure to increase by 0.043 units. However, a decrease in total government capital expenditure causes the social infrastructure to increase by 0.001 units. The empirical results, therefore, suggest that an increase in per capita GDP, domestic financial development, governance, population density, urbanization, and literacy rate have the potential to increase the development of social infrastructure in SSA, but total government capital expenditure has a negative prospect on the development of social infrastructure.

The values of the R-squared for the models reveal that per capita GDP, total government capital expenditure, domestic financial development, governance, population density, urbanization, and literacy rate in SSA account for more than 74, 73, and 63 percent of the variation in infrastructure development, physical and social infrastructure respectively. The collective significance of the regressors, including per capita GDP, total government capital expenditure, domestic financial development, governance, population density, urbanization, and literacy rate in SSA, is assessed using the F-statistic. The null hypothesis states that these variables are not jointly significant for infrastructure development, physical and social infrastructure. The values of the F-statistic are 17382.51, 15802.61, and 6363.08 (with a p-value of less than 1% in each) for the infrastructure development, physical and social infrastructure models. Hence, the study rejects the null hypothesis and supports the alternative hypothesis that the regressors collectively have a significant impact on infrastructure development, physical and social infrastructure in SSA.

Conclusion and Policy Recommendations

Despite the existing studies on infrastructure, there are still some areas that need to be considered or gaps that need to be filled, and this is the motivation behind the current study, which investigates the drivers of infrastructure development and its components in SSA using panel regressions to estimate panel data on 43 SSA countries from 2000 to 2022. The empirical results show that financial development, per capita GDP, governance, population density, and urbanization have positive impacts on infrastructure development and physical and social infrastructure. In addition, total government capital expenditure has positive effects on both infrastructure development and physical infrastructure but it demonstrates a negative effect on social infrastructure. Regarding the literacy rate, which is a variable of interest, the findings indicate a positive influence on social infrastructure while it has negative effects on infrastructure development and physical infrastructure.

Concerning the findings and conclusions highlighted above, one of the distinctive findings from this study pertains to the influence of literacy rate on infrastructure development and its components in SSA. Given the observation that the literacy rate is one of the factors for promoting social infrastructure in SSA, there is a need for the stakeholders to be enlightened and reoriented about the need to protect the existing infrastructure and the demand for more essential infrastructure facilities. In addition, concerning the theoretical implications of infrastructure development that are still at a formative state, the evidence from the present study, coupled with the findings from the previous studies, on the fact that infrastructure development responds positively to GDP (output level), provides some useful insights on the validity of the adopted theory (the accelerator theory of investment) as a theoretical foundation for infrastructure development. The adoption of this theory by future researchers as a theoretical foundation for infrastructure development is therefore recommended.

Evidence from the influence of per capita GDP, level of domestic financial development, and governance are among the key drivers of infrastructure development in SSA. It is recommended that SSA countries should ensure that necessary policies are put in place to increase their per capita GDP, level of domestic financial development, and institutional quality to promote the development of infrastructure. Furthermore, SSA countries should ensure efficient and effective management of their population growth and urbanization to promote infrastructure development as well as reduce the pressure on the existing ones. Finally, given the observation that total government capital expenditure promotes

infrastructure development and physical infrastructure in SSA, it is also recommended that capital expenditure be given priority in the government annual budgets of SSA countries, to increase expenditure on capital projects and thereby augment the existing stock of infrastructure.

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