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ORIGINAL ARTICLE

The effect of infrastructure development on economic growth: The case of sub-Saharan Africa

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ABSTRACT

The significance of infrastructure development as a determinant of economic growth has been widely studied by economists and policymakers. Though there is no much debate about the importance of infrastructure on growth, the extent to which infrastructure affects growth in the long run is often debated among researchers. This paper aims to examine the effect of infrastructure development on economic growth in ten sub-Saharan Africa. This study uses balanced panel data of ten African countries, particularly sub-Saharan Africa over the period of 2010–2020 by analyzing a set of independent variables with relation to the dependent, which is GDP per capita. The study has found that water supply & sanitation index and electricity index have positive and significant relationship with economic growth, while transport index and Information & Communications (ICT) have negative relationship with economic growth in these countries.

KEYWORDS

infrastructure development; economic growth; balanced panel data; sub-Saharan Africa

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1. Introduction

The definition of infrastructure has changed over the years; however, economic infrastructure is now commonly described as a complex array of capital goods that create services in combination with other input (World Bank, 2017). The infrastructure role can be important for development in the sense that it provides both final consumption services to households and key intermediate consumption items for production (Straub and Terada-hagiwara, 2010). Sufficient stock of physical infrastructure, such as roads, railways, ports, enables countries to realize and achieve modernization of their economies and the productive sectors of the economy to be further commercialized, creating income surpluses and capital accumulation. Further, it can be used as the bedrock which can be utilized to expand local industries and expansion of markets for the output of other industries (Bagus et al., 2020). Infrastructure can also improve the quality of life for many people through increasing the value of consumption, enhancing labor productivity and creation of job opportunities. In a macroeconomic sense, the marginal productivity of private capital is increased with the availability of sound physical infrastructure as well as in microeconomic sense, improved physical infrastructures will minimize production costs for the economy. Therefore, it is no surprise that the link between infrastructure development and growth has been extensively studied across academic and policy circles. Both academics and policy makers regarded infrastructure development as a cornerstone for economic development since the work of Aschauer (1989) and the World Bank (2017). Evidently, the importance of infrastructure in unlocking Africa's potential cannot be underestimated.

Overall, the region faces many challenges in terms of infrastructure capacity. According to the African Development Bank (AfDB, 2018), Africa' s infrastructure deficit is a constraint to its growth potential. The key challenges are covering the needs of its burgeoning population with affordable electricity, housing and transport infrastructures. To be more specific, only 53% of the roads are paved, less than half of the population have access to all seasonal roads and road safety is a major issue resulting in approximately 225,000 deaths every year. Furthermore, outdated, and limited maintenance undermines the railway systems in sub-Saharan Africa. On the other hand, water and sanitation costs are valued at 5% of its GDP. To make matters worse, almost half of the people with no access to water and sanitation live on less than two dollars a day. Moreover, the Internet contribution to overall GDP is low although this sector is expected to 5% to 6% level by 2025. On the other hand, household electrification rate stands at only 43%, leaving almost 600 million people without electricity and power demand is projected to grow by 93% between now and 2035 (AfDB, 2018).

Sub-Saharan Africa faces a major obstacle when it comes to building a sound infrastructure network as the region continues to consistently rank at the lowest in all dimensions in terms of infrastructure performance in all developing regions (World Bank, 2017). Sub-Saharan Africa's inherent geographical disadvantages such as the fact that 40% of the region's total population live in landlocked countries and its remoteness from major international markets along with a myriad of other factors such as corruption and lack of institutional quality pose one of the biggest challenges for economic development as landlocked countries are more likely to grow slower than other countries (Servén and Calderón, 2004). However, adequate infrastructure such as good transportation, communication, electricity and water facilities could help override the region's geographical disadvantages (Calderon et al., 2018).

Governments across sub-Saharan Africa have strived to improve infrastructure networks in recent years; however, the quality of infrastructure remains quite poor across the continent (Foster and Briceno-Garmendia, 2010).

The telecommunications infrastructure has witnessed progress in sub-Saharan Africa across all income groups. For example, telecommunications density grew very fast, particularly among low-income countries (LICs). Specifically, in low-income countries (LICs), the number of fixed and mobile phones per 1000 people had risen from three in 1990 to 736 in 2014. The improvement of low income and middle-income countries in terms of telecommunication density has been impressive (World Bank, 2017). For example, upper middle countries' telecommunications density in relation to LICs was 11-fold in 1990, but this figure dropped to only twice as high in UMCs. This increase in telecommunications density (55 lines per 1000 people in 1990 to 1605 in 2015) has ranked UMCs the median of other countries. This can be seen in **Table 1**.

Table 1. Telecommunications quantity trends.

		Region							
	Year	SSA	SA	MENA	LAC	EAP	LICs	LMCs	UMCs
Telecommunications density	1990	3	7	38	55	17	3	5	55
Fixed and mobile telephones per 1000 people (median)	2018	736	807	1323	1240	1444	687	794	1605
Internet density	2005	1.3	2.1	11.2	12	11.8	1.1	1.3	7.5
Number of users per 100 people (median)	2017	16.7	22	48.5	51.6	45	11.4	20.8	50.1
Fixed broadband	2005	0.0	0.1	0.4	0.8	1.4	0.0	0.0	0.3
Number of subscriptions per 100 people (median)	2018	0.2	1.2	4.3	8.1	9.1	0.2	0.1	5.3

Note: EAP = East Asia and Pacific; LAC = Latin America and the Caribbean; MENA = Middle East and North Africa; SA = South Asia; SSA = Sub-Saharan Africa; LICs = low-income countries; LMCs = lower-middle-income countries; UMCs = upper-middle-income countries.
Source: World Development Indicators (World Bank, 2022).

The latest study conducted by the International Energy Agency (2019) has shown that out of 43% of sub-Saharan Africa had access to electricity. It further demonstrated since 2012, 26 million more people have managed to get electricity annually, which was significant increase from 2000 and 2012 when the figures were three times less than the current electricity rates obtained by these countries. Out of the different regions, East Africa enjoyed the most progress. As a result, the number of people without electricity in sub-Saharan Africa declined significantly, leading to electrification efforts to exceed population growth in 2014, which was a new phenomenon in Africa. Despite the progress, sub-Saharan Africa continues to face electricity issues with the number of people without access to electricity still higher in 2018 than it was in 2000.

Since 2013, access to electricity has been on downward trend in sub-Saharan Africa. Countries such as Ivory Coast, Ethiopia, Ghana, Kenya, Sudan, and Tanzania, have undertaken strong campaigns for electrification in their respective countries. The rate of electrification process tripled since 2102 in relation to the pace of electrification between 2000 and 2012. However, the electrification progress remains to be uneven. The study found that only eight countries had an access rate of 80%—Gabon, Mauritius, Reunion, Seychelles, Swaziland, South Africa, Cape Verde and Ghana, with most countries reporting access rate lower than 50%, and some countries had even reported below 25%. As can be seen in **Table 2**, sub-Saharan Africa continues to fall behind other developing benchmark regions such as that of South Asia and Latin America. As a matter of fact, the electricity generating capacity of the region changed little over the last decades. In 2015, sub-Saharan African obtained less than 0.04 megawatts per 1000 people, that is less than third of South Asia with 0.15, and about less than one tenth of that of Latin America (Calderon et al., 2018).

Road networks running through sub-Saharan Africa are estimated to be around 10,000 km long comprising of strategic trading corridors. These trading corridors support around $200 billion worth of trade each year across the continent (PIDA, 2019). Relative to other regions of the world, sub-Saharan Africa lags behind. Its road access rate is only at 34% in comparison with other regions of the world which is at 50%. Furthermore, according to African Union (2014), transport costs are significantly higher. Similarly, sub-Saharan Africa was found to have the lowest road density among

Table 2. Electricity infrastructure quantity.

		Region							
	Year	**SSA**	**SA**	**MENA**	**LAC**	**EAP**	**LICs**	**LMCs**	**UMCs**
Electricity-generating capacity per 1000 people	1990	0.03	0.07	0.25	0.3	0.15	0.02	0.06	0.33
	2015	0.04	0.15	0.4	0.43	0.84	0.03	0.06	0.72

Note: EAP = East Asia and Pacific; LAC = Latin America and the Caribbean; MENA = Middle East and North Africa; SA= South Asia; SSA = Sub-Saharan Africa; LICs = low-income countries; LMCs = lower-middle-income countries; UMCs = upper-middle-income countries.
Source: World Energy Outlook 2019 (International Energy Agency, 2019).

other parts of the developing world in 2014. Furthermore, the only region in the world where road density faced a downward trend is sub-Saharan Africa. The railway networks are also low with less than 0.002 per square km of surface area recorded in 2016 and since then it has been declining. However, the road density in sub-Saharan Africa (SSA) is slightly higher than South Asia and slightly lower than that of Middle East and North Africa (African Union, 2014).

According to AfDB (2018), 300 million people in sub-Saharan Africa face water scarcity. The problem is not lack of water resources but they are poorly developed, underutilized, and it has not been sustainably administered. Only 5% of agriculture used for irrigation (African Union, 2014). Latest statistics by United Nations Children's Fund (UNICEF, 2015) show that only 64% in sub-Saharan Africa had access to improved drinking water with the exception of Oceania where the figures are even worse with 56% having access to improved drinking water. Moreover, sub-Sahara Africa is trailing the rest of the world falling behind the least developed countries average of 66%. According to UNICEF (2015), of the 748 million of who do not have access to improved drinking water, 43% (32 million) are sub-Saharan African residents.

In terms of sanitation, sub-Saharan Africa has witnessed a significant increase in upgrading sanitation facilities, where access to sanitation has doubled. However, relative to other regions of the world, SSA lags behind the rest of the world (AfDB, 2018). According to UNICEF (2015), access to sanitation improved from 15% to approximately 30% in 2016. Against other benchmarks, 55% of South Asia natives accessed sanitation facilities, whereas Latin America, East Asia and Caribbean enjoyed a whopping 80% sanitation facilitating accessibility. But with little over 38%, sub-Saharan Africa urban population is still facing many challenges in terms of sanitation faculties accessibility. In the rural areas, it is even worse, where only 25% of the population has access to improved sanitation in 2016 up from 10 in 1990 (World Bank, 2017). Sub-Saharan Africa countries have improved by doubling total access rates to sanitation, however, this is be-low the access rates enjoyed by other benchmark developing countries (as shown in **Table 3**) in developing regions such as Latin America, where the improved sanitation facilities and South Asia have achieved impressive sanitation access rates, with South Asia recording 55%, while Latin American countries had achieved more than 80% as shown in **Table 4**. However, sub-Saharan Africa had made slight progress since with the continent's sub region achieving just 29% up from 15% in 1990 as shown in **Table 4**. Furthermore, the AfDB (2018) releases a report on the ranking of African countries via its Africa infrastructure development index (AIDI). Countries with the best infrastructure in 2018 were reported to be Seychelles, Egypt, Libya, South Africa, Mauritius, Tunisia, Morocco, Algeria, Cabo Verde and Botswana. These countries remained as the top ten countries with the most advanced infrastructure since 2016. Countries are ranked according to a robust investment across different sectors. Five countries are in North Africa out of ten best ranked nations, while three are small island nations where tourism plays an integral role in their economies. No wonder, these countries spend much of their resources in developing their infrastructure to entice tourists. On the other hand, the bottom ten are dominated by countries in sub-Saharan Africa. They are Central African Republic, Madagascar, Sierra Leone, Ethiopia, Eritrea, Democratic Republic of Congo, Chad, Niger, South Sudan, and Somalia. In the latest ranking, Mozambique was replaced by the Central African Republic. These countries do share certain underlying issues such as low performance in ICT, transport, water and sanitation.

Table 3. Water supply and sanitation infrastructure access.

		Region						
	Year	**SSA**	**SA**	**MENA**	**LAC**	**LICs**	**LMCs**	**UMCs**
Safe water sources								
Total percent of population (median)	1990	51	69	92	86	48	76	93
	2018	77	93	96	94	77	76	93
Improved sanitation facilities								
Total percent of population	1990	15	20	77	66	11	27	71
	2018	29	55	92	83	21	30	66

Note: EAP = East Asia and Pacific; LAC = Latin America and the Caribbean; MENA = Middle East and North Africa; SA = South Asia; SSA = Sub-Saharan Africa; LICs = low-income countries; LMCs = lower-middle-income countries; UMCs = upper-middle-income countries.

Table 4. Summary of statistics.

	LGDP	LEINDEX	LICT	LTINDEX	LWSSINDEX
Mean	7.826212	1.810982	2.327754	2.101584	4.103541
Median	7.832321	1.750924	2.385546	2.282369	4.162536
Maximum	9.021576	4.373868	4.274024	3.296947	4.527965
Minimum	6.19439	−0.462035	−1.347074	0.506818	2.884242
Std. Dev.	0.723574	1.181379	0.988947	0.841594	0.343895

Source: Computed by the authors via EViews.

The objectives of the paper are to examine the relationship between infrastructure development and economic growth in sub-Saharan Africa, a region plagued by underdevelopment in recent decades. Sub-Saharan Africa are considered to be the least developed countries in terms of physical infrastructures among all developing regions and the empirical literature on this issue appears to be scarce; therefore, the present study seeks to complement the past literature on the nexus between long-term growth and infrastructure development in sub-Saharan Africa by exploring the impact of infrastructure, i.e., information & communications, transport, electricity and water supply and sanitation infrastructures on economic growth using the latest available data.

The rest of the paper is structured as follows: Section 2 presents the review of literature; Section 3 discusses the methodology including model specification and estimation methods and Section 4 presents the empirical findings of the paper and followed by the conclusion and some policy recommendations in the end.

2. Literature review

2.1. Neoclassical growth theory

The neoclassical growth theory assumes that steady state growth is driven by exogenous factors, that is, population dynamics and technological change. The most basic form of the neoclassical growth model provides a useful framework in the analysis of the factors that can result in growth of output. The Solow model (1956) describes the various factors and its importance to output in competitive markets. In the Solow model, output, the impact of public infrastructure is added in Total Factor Productivity (TFP) growth. As a result, any effect of public infrastructure is understated in the model, and its accumulation in TFP results in the overstatement of the actual technical change. When public infrastructure is considered to be a public good, that is, (non-rival and non-excludable), any change in its stock is considered as either downward or upward shift in the production function. As a result, the output level as well as the rate of growth will be transitioned to the steady state (Anderson et al., 2006). The neoclassical assumption holds true if there is diminishing returns to all capital (Stiroh, 2001).

In the neoclassical view, capital generates only internal and diminishing returns and as a result, the contribution of infrastructure capital stock is only significant in the short run but the long run, growth is determined by exogenous factors, that is, technological progress. However, in the neoclassical growth theory, it is not clear how firms' decisions and government policies influence long-term growth through technological progress. In their paper, Van Sinderen and Roelandt (1998) critiqued the neoclassical view for neglecting the role of government policies in determining the growth rate. Nevertheless, the subsequent endogenous growth theory provides clearer description of the role of government policies such as investment in public infrastructure. To better understand the impact of public infrastructure on growth, the endogenous growth theory puts greater emphasis on the role of public sector investment than the neoclassical theory. Public sector investment is considered as a primary source in the endogenous growth model, and through this direct channel, endogenous growth models capture its effect. The endogenous growth theory particularly highlights the importance of policy interventions such as public infrastructure investment, in promoting long-term economic growth. It suggests that targeted public infrastructure investments can create positive spillover effects and foster sustained economic growth.

2.2. Endogenous growth theory

The endogenous growth theory seeks to explain long run growth through endogenous mechanisms. These endogenous mechanisms can be either the removal of diminishing returns to capital or giving specific emphasis to certain policy actions that could explain technical change. Thus, total Factor Productivity (TFP) is affected by a range of different of factors such as imperfect competition, externalities and reallocation effects.

The endogenous growth theory is based on the premise that investment in capital and the production of new processes and products is key in determining long-term growth such that there are no diminishing returns. Capital is broadly defined and encompasses many reproducible factors of production such as knowledge and experience gained through human capital training, research & development, and public infrastructure expenditure (Van der Ploeg and George, 1994). This broad definition of capital shows the role infrastructure can play in economic growth with respect to the assumption of constant (increasing) returns in relation to the broad measure of capital. Therefore, the role of infrastructure in economic growth is shown (Barro, 1990). Therefore, these new models, proponents of the endogenous theories have been able to describe the role of government policies in determining growth in the long run through its effect on several factors such as physical infrastructure, human capital development, and markets (Crafts, 1996). The Barro model assumes that constant returns to capital: $y = Ak$, where y is output per worker, k is capital per worker, and A is the constant net marginal product of capital and greater than 0. Barro extended his model to take into account the role of government.

2.3. Emperical literature review

Straub and Terada-hagiwara (2010) studied four various measures of physical infrastructures: telecommunication, electricity, road, and water. They used two distinct approaches: growth regression and growth accounting by examining the link between infrastructure, growth, and productivity among developing Asian countries over the time period of 1971–2006. They found that a number of countries in developing Asia have considerably increased their infrastructure endowments and this significant improvements in infrastructure positively correlated with rise in GDP per capita. In a similar vein, Nugraha et al. (2020) studied the relation between infrastructure and economic development in Indonesia by using panel data of 26 different provinces. He concludes that infrastructure has a significant positive effect on growth, with the infrastructure of electricity having the biggest effect on growth and investment in infrastructure such as electricity generates higher elasticity than investment in non-infrastructure.

Similarly, Seethepalli et al. (2008) examined physical infrastructures, namely electricity production per capita, kilometers of paved road per capita, water as percentage of population with access to improved water source, and sanitation as percentage of population with access to improved sanitation facilities. Using standard growth regression in a panel of 16 East Asian countries, in all measures of physical infrastructure, the paper found positive impact on growth. However, the effects were found to vary across countries because of country specific characteristics. For example, the findings concluded that countries need to exceed certain threshold of income (i.e., transition from low to middle income) to see significant changes in countries' water infrastructure stock. Furthermore, they found elasticity of GDP in relation to road was the highest in poor countries.

Servén and Calderón (2004) gave an interesting perspective in their study of physical infrastructure by extending their model to include both quantitative and qualitative of physical infrastructure. In panel data of 100 countries between the period of 1960–2000, the authors investigated the impact of infrastructure stock not only on economic growth but also on income distribution. The quantitative variables they used are: telecommunication sector (the electricity generating capacity of the economy—in MW per 1000 workers), the power sector (the electricity generating capacity of the economy—in MW per 1000 workers), and the transport sector (the length of the road network—in km per km^2 of land area). Among the qualitative measures, they used waiting time for telephone main telephones for telecommunications, the percentage of transmission and distribution losses in the production of electricity to proxy for power, and percentage of paved roads in total to proxy for transport. Using both disaggregated and synthetic measures of infrastructure quantity and quality, the study found that both quantitative and quality index do not impact positively on growth but also on distribution of income.

According to Kodongo and Ojah (2016), the expenditure on infrastructure and the access of infrastructure positively affect economic growth and development in sub-Saharan Africa. Interestingly, this positive relation is bigger and more important for lesser developed countries, which have infrastructure levels of near-zero in sub-Saharan Africa than those more relatively developed countries of the same region. They further add that infrastructure access and quality also relate positively with economic growth though indirect route via trade openness, capital flows, and trade competitiveness. However, Charles and Michael (2006) go further to ask an important question relevant in the linkages between growth and infrastructure development by asking how much spending should be allocated to infrastructure at different stages of infrastructure development.

Straub (2008) had found that many studies show positive link between growth and infrastructure in key metrics in transport, telecommunications, and electricity, particularly in more developed countries. However, it is hard to find conclusive empirical findings on spending of infrastructure across countries. Some countries in Latin America invest less than 3% of their GDP, while countries like China invest more than 10% of their GDP.

A study conducted by Deininger and Okidi (2003) concluded that households with access to important public amenities such as electricity, were able to enjoy higher incomes and contribute positively to the economic growth of Uganda. To be precise, households with access to electricity enjoyed higher incomes (3.5% points) and expenditures (6% points) compared to those who did not have any access to electricity. In a similar vein, Sahoo et al. (2012) examined the effect of four different types of physical infrastructures using panel data from 1975–2007 in China. In their measurement of physical infrastructures, the proxies they used are: electric power consumption per capita, pave road as percent of total road, energy consumption per capita, telephone lines per thousand, railway line per thousand, and the number of people using airway. After conducting their empirical analysis such as distributed lag autoregressive approach and generalized moments methods, they concluded that investment in physical infrastructures has significant effect on economic growth, adding that investment in infrastructure tends to be greater impact than investments in public and private sector.

3. Methodology and data

The study used a balanced set of panel data from ten countries in sub-Saharan Africa. Four different variables are analyzed to measure the effect of infrastructure development on economic growth. The variables are divided into: one dependent variable and four independent variables. Response variable*:* in the context of this paper, as in many other economics literatures, GDP per capita will be used as a proxy for economic growth. Previous studies have shown that investment in physical infrastructure such as roads and water resources could potentially lead to higher economic growth in the long run.

Explanatory variables: four different variables will be used to examine the effect of infrastructure development on growth. They are: electricity infrastructure, telecommunications infrastructure, transport infrastructure and water supply & sanitation infrastructure. Electricity infrastructure: sufficient supply of electricity infrastructure is deemed important for growth of any country as low cost of electricity bills will encourage greater productivity and more efficiency across different industries of the economy. Continuous supply of power is key for running heavy machines and equipment as this enables undisrupted production process. This will lead to greater productivity and profitability.

In this context of this paper, the electricity index will be used as a measurement for electricity infrastructure. The electricity index denotes the electricity production of countries under study including energy imported from other countries both private and public. The electricity index is measured in millions of kilowatt hour produced per hour and per inhabitants. Transport infrastructure: roads, railways and ports are essential transport infrastructures for any given economy. Good transport system enables trade to run smoothly, businesses tend to operate more efficiently, and consumers pay less as transport costs are reduced in a well-functioning transport infrastructure. Therefore, ensuring the smooth flow of goods and services across regions will clearly lead to greater productivity and thus higher growth. The transport index will be used as a proxy for transport infrastructure, which is measured in total paved roads (km per 10,000 inhabitants) and total road network in km (per km^2 exploitable land area).

Telecommunications infrastructure: the telecommunications infrastructure described as the exchange of information by electronic and electrical means over long distances and it includes telephones, radio, fiber optics, satellites, microwave communication, and the Internet. The Internet has increasingly become an important part and made the telecommunication infrastructure such an important factor to be taken account into nowadays. Ecommerce is widely popular these days, which is described as the buying and selling of goods and services via the Internet. With sound telecommunication infrastructure, businesses will find it easier to reach greater potential clients and consumers will be able to gain access to whole new markets across regions and the world.

Water supply and sanitation infrastructure: water, as we all know, is an essential part of everyday life and basic human need. Productive sectors of the economy require undisrupted supply of water such as the agricultural sector, which needs continuous irrigation. Agriculture sector, in turn, provides raw materials to other important productive sectors of the economy. Moreover, it is essential to ensure supply of safe and clean water to convert raw materials into finished goods, thus water & sanitation infrastructure can influence on the growth rate of any given country.

To study the relation between growth and infrastructure development in sub-Saharan Africa, this study uses the African infrastructure development index (AIDI) developed by AfDB. This is weighted average of nine physical infrastructure measurements, which is divided into four main infrastructure development indicators, namely, electricity, transport, information and communications technology (ICT), and water & sanitation. Quantity is emphasized in the measurement of these key infrastructure indicators; nevertheless, quality is taken into in some cases. For instance, transport infrastructure index measures total road network in km per km^2 exploitable land area. As for water infrastructure, only quality is measured via improved water source and improved sanitation. However, ICT and electricity indexes, quantity measurements are available. These are real values appropriate for the model.

Most studies on the nexus between growth and infrastructure development have used one single variable as a proxy for economic growth. This could raise issues about the unbiasedness of our model because it does not capture the multidimensional nature as well as the heterogeneity across time periods and across entities. To depart from these common oversights of past studies, in this study, the authors use four types of physical infrastructures; electricity, water, transport and information & communications technology against GDP per capita, which is a proxy for economic growth. This is consistent with a study conducted by Kodongo and Ojah (2016), which employed a multidimensional approach to examine the link between growth and economic development in the context of sub-Saharan Africa.

3.1. Model specification and data sources

There are generally two methods that are used in the analysis of panel data: fixed effect (FE) model and random effect (RE). In a fixed effect model, each entity (country, company, etc.) has its own characteristics that may or may not affect the predictors, whereas in Random Effect model, it is assumed that something within the individual could potentially affect the predictor or bias the outcome variables and thus this should be controlled. Furthermore, time invariant characteristics are eliminated in the RE model, so that the net effect of the independent variables on the outcome variable can be evaluated. Therefore, to check which model is appropriate for the analysis of our data, Hausman Test will be conducted.

3.2. Decision rule

Null hypothesis: the RE model is appropriate. Alternative hypothesis: the FE model is appropriate. If the *p*-value is less than 0.005, null hypothesis is rejected and alternative hypothesis will be accepted.

In line with the past literature, the general model under this study can be specified as follows;

$$GDP = f\,(EINDEX, ICTINDEX, TINDEX, WSSINDEX) \quad (1)$$

where Gross Domestic Product is GDP per capita is the dependent variable and proxy for economic growth in constant 2010 $US, hand, the independent variables which are: EINDE is a proxy for electricity index; ICTINDEX is a proxy for information & communication index; TINDEX is a proxy for transport index and WSSINDEX is proxy for water supply & sanitation index. However, the model is transformed into natural logarithm equation for ease of interpreting the results, plus to reduce the data variations, and bring all variables to be in the same state. The final equation is as follows:

$$LGDP = \beta_0 + \beta_1\,LEINDEX_{it} + \beta_2\,LICTINDEX_{it} + \beta_3\,LTINDEX_{it} + \beta_4\,LWSSINDEX_{it} + \mu_{it} \quad (2)$$

where LGDP is the natural logarithm of GDP per capita for country i at time t; LEINDEX is the natural logarithm of electricity of index for country i at time t; LICT is log of information & communication index for country i at time t; LTINDEX is the natural logarithm of transport index for country i at time t; and LWSSINDEX is the natural logarithm of water supply & sanitation for country i at time t. The model is estimated by using panel data analysis of 10 sub-Saharan African countries from 2010 to 2020 on the unrestricted specification; subscript t representing the time period from 2011 to 2020 (10 observations) with subscript i representing 10 sub-Saharan African countries: South Africa, Botswana, Ghana, Namibia, Kenya, Nigeria, Zambia, Gambia, Angola, and Ethiopia. The selection of countries and the time period under study are mainly inspired by the accessibility of data. The data sources for this paper are the World Development Indicators (WDI) (World Bank, 2022) and AfDB (2018). The data of the GDP per capita is extracted from the World Bank's (2022) World Development Indicators (WDI), whereas the data of the electricity index, ICT index, transport index and water supply & sanitation index are obtained from the African

Development Bank (AFD) database.

4. Findings and discussion

Table 4 shows the summary of statistics for the under study. All variables are transformed into their natural logarithm to achieve linearity in the model. The average values of variable electricity, ICT, transport, and water & sanitation are 1.810982, 2.327754, 2.101584 and 4.103541. These values are below 50%, indicating that countries under study have serious infrastructure deficits.

Table 5 demonstrates panel unit root test. The panel unit root is conducted to test to check the order of integration of the variables under study before the macro data analysis is conducted. In this paper, the authors utilized the methods suggested by augmented Dickey and Fuller (1979), Phillips and Perron (1988), to check for order of integration. The panel unit root test statistics shown in **Table 5** shows that all of the variables are not stationary at 5% level of significance. However, all of the variables under study: LGDP, LEINDEX, LECITINDEX, LITINDEX and LWSSINDEX became stationary at first difference at 5% level of significance. Thus, to sum up, it can be shown that the panel variables in our model are integrated in order one (I).

Table 5. Panel unit root test.

Series	LGDP	LEINDEX	LICTINDEX	LTINDEX	LWSSINDEX
Level					
ADF	−2.201334	−2.513813	−2.108373	0.3636	−2.460608
	(0.2072)	(0.1153)	(0.242)	(−2.890926)	(0.1283)
DFGLS	−1.619638	−0.86644	−1.598038	−1.663365	−1.998083
	(0.1085)	(−1.944105)	(−1.944487)	(−1.944105)	(−1.944105)
PP	−2.28383	−2.561903	−3.87281	−1.738563	−2.475271
	(0.1792)	(0.1044)	(−2.890926)	(0.4089)	(0.1246)
KPPS	0.625034	0.832802	0.737805	0.853593	0.621187
	(0.463)	(0.463)	(0.463)	(0.463)	(0.463)
ERS	5.98073	16.55536	3.397404	4.944325	3.858882
	(3.11)	(3.11)	(3.11)	(3.11)	(3.11)
Order of integration	1(0)	1(0)	1(0)	1(0)	1(0)
Remark	Non-stationary	Non-stationary	Non-stationary	Non-stationary	Non-stationary
First difference					
ADF	−6.285506	−9.306083	−2.398074	−11.68649	−2.891234
	0.0000	0.000	0.1452	0.0001	0.000
DFGLS	−6.222724	−9.351025	−1.562745	−11.7472	−10.2275
	−1.944487	−1.94414	−1.944487	−1.94414	−1.94414
PP	−9.616497	−9.296807	−13.92726	−2.891234	−2.891234
	0.000	0.000	0.0001	0.0001	0.00000
KPPS	0.060919	0.063035	0.118876	0.081072	0.077186
	0.463	0.463	0.463	0.463	0.463
ERS	22.97295	0.492074	29.17247	0.505546	0.492372
	3.1072	3.1072	3.1072	3.1072	3.1072
Order of integration	1(1)	1(1)	1(1)	1(1)	1(1)
Remark	Stationary	Stationary	Stationary	Stationary	Stationary

Source: Computed by the authors using EViews 10.

4.1. Panel data estimation

This cross-country panel data was estimated using the panel least square regression method. First, the Hausman test was conducted to check whether it is appropriate to use the fixed effect or random effect estimation method. The fixed effect model is a method where the parameters of the model are constant or have non-random quantities, whereas, the random effect model is a model in which all or some of the estimated variables are deemed to be random variables. The group is considered to be a random sample from population. The result from the Hausman test is shown in **Table 6**.

Table 6. Hausman test.

Correlated random effects—Hausman test			
Equation: untitled			
Test cross-section random effects			
Test summary	Chi-Sq. statistic	Chi-Sq. d.f.	Prob.
Cross-section random	7.42009	4	0.1153

Source: Computed by the authors.

Decision rule: null hypothesis; the random effect model is appropriate; whereas the alternative hypothesis: fixed effect model is appropriate. If the probability value (*p*-value) is 0.005, we reject the null hypothesis and thus accept the alternative hypothesis. **Table 6** demonstrates the result. As we can see from **Table 6**, the *p*-value is greater than 0.005, therefore we accept the null hypothesis, which means the random effect model is more appropriate in this case.

4.2. Multicollinearity test

According to Gujarati (2002), when the correlation coefficient between two variables is greater than 0.8, there is a presence of multicollinearity. Multicollinearity arises when two or more variables within the stated model are found to have a great degree of correlation with each other. If this happens, the estimated coefficient of variables might differ intermittently when the data or the model is modified. This may cause a variable that would have been significant to become insignificant due to the presence of multicollinearity. Generally, a technique that is often used to circumvent the problem of multicollinearity is to run a priori correlation analysis of the variables under study and exclude any variable that has a great degree of correlation in the model. However, after running the model, no evidence of multicollinearity problem was noticed in the model, as all correlation variables of the independent variables do not show the 0.8 correlation benchmark. In other words, there is no presence of multicollinearity in the estimated model as shown in **Table 7**.

Table 7. Multicollinearity test.

	Coefficient	Uncentered	Centered
Variable	Variance	VIF	VIF
C	0.469097	324.5492	NA
LEINDEX	0.002218	7.152774	2.120195
LICTINDEX	0.004614	20.38985	3.091154
LTINDEX	0.005138	18.19287	2.492606
LWSSINDEX	0.041095	482.0978	3.328853

Source: Computed by the authors using Eviews 10.

4.3. Panel least square estimation

Next, the paper examines the correlation among the selected variables in our study namely: dependent variable, which is GDP per capita, the proxy for economic growth with a set of four independent variables which are proxies for physical infrastructures as stated in the equation in previous sections. **Table 8** presents the results.

Table 8. Panel least square estimation.

Variable	Coefficient	Std. error	*t*-Statistic	Prob.
C	−0.106219	0.684907	−0.155086	0.8771
LEINDEX	0.183647	0.047095	3.89953	0.0002
LICTINDEX	−0.216495	0.06793	−3.187041	0.0019
LTINDEX	−0.098485	0.07168	−1.373956	0.1727
LWSSINDEX	2.025268	0.202719	9.990501	0.000
R-squared	0.735086	Mean dependent var		7.82621
Adjusted *R*-squared	0.723932	S.D. dependent var		0.72357
F-statistic	65.90183	Durbin-Watson stat		0.25688
Prob (*F*-statistic)	0.00000			

Source: Computed by the authors using Eviews 10. All variables are in natural logarithm form.

The results from **Table 8** demonstrate that R-squared shows that 74% of variation in economic growth can be explained by the four independent variables in our estimated model namely: electricity index (LEINDEX), information & communications index (LICTINDEX), transport index (LTINDEX), and water supply & sanitation index (LWSSINDEX). From **Table 8**, the electricity index and water supply & sanitation index coefficients show positive and significant relationship with economic growth, whilst the ICT index and transport index coefficients show negative relationship with economic growth, though the transport index indicates a statistically insignificant correlation with growth.

To be precise, a 1% increase in electricity index led to about 18% in economic growth, similarly, an increase in water supply & sanitation index brought about 2% increase in economic growth. The positive relationship shown by both the water supply & sanitation and electricity indexes is hardly surprising and these findings are in line with those of the World Bank report (2017) which indicated that sub-Saharan Africa has taken huge strides in improving its water & sanitation and electricity infrastructures. This may have contributed Africa's recent economic boom; however, electricity is still an expensive commodity in sub-Saharan Africa. Per capita consumption of energy in sub-Saharan Africa, with the exception of South Africa, stands at 180 kWh, for example, in comparison with that of United States, which is 13,000 kWh, and with that of Europe, which is 6500 kWh, as per the World Bank report (2017).

However, a 1% increase in ICT leads to a reduction of 21% in economic growth, while an increase in transport index indicates approximately 9.8 drop of economic growth. One probable explanation for this phenomenon is that sub-Saharan Africa continues to lag in terms of transport facilities. The continent has the lowest road and railway density in the world. This raises the transport costs, eventually stunting the growth levels of these countries. These findings are consistent with those of Limão and Venables (2001). Though the ICT sector has enjoyed an impressive improvement as per World Bank report (2017), this paper finds this sector is still not strong enough to contribute to economic growth, thus the negative coefficient sign.

5. Conclusion

This paper aims to examine the relationship between infrastructure development and economic growth employing a balanced panel data analysis. The study used a sample of ten sub-Saharan African countries within the timeframe from 2010 to 2010. The countries under study are South Africa, Botswana, Ghana, Namibia, Kenya, Nigeria, Zambia, Gambia, Angola, and Ethiopia. The study has found that electricity index as well as water supply & sanitation index have positive and significant relationship with economic growth. On the other hand, the ICT index and transport index were found to have negative relationship with economic growth, though the transport index is statistically insignificant with economic growth. One of the major takeaways from this study is that development in physical infrastructures—roads, railways, internet, and water provision facilities—can help Africa's drive to achieve high productivity levels and economic growth by investing heavily in its poor infrastructure. This study concludes that underdevelopment of sub-Saharan countries can be explained largely by its underdeveloped infrastructure. Countries in sub-Saharan Africa can reduce this infrastructure deficit through investment either by allocating more resources to infrastructure development domestically or collaborating closely with international agencies that are involved in international development such as the World Bank and the United Nations (UN).

It is important to note that despite the findings of positive relationship between economic growth and public infrastructure investment in this paper, existing literature shows mixed results. Some have shown positive link, while others found no significant relationship. Some other studies have displayed more nuanced suggesting that the effect of public infrastructure on economic growth could be context dependent and can be influenced by a wide range of factors such as the quality of infrastructure, the efficiency of public spending, and the overall institutional and macroeconomic environment. That said, the findings of this paper are in line with that of Mutiiria et al. (2020) who found similar positive results. The main consensus among economists is that improved infrastructure will promote growth through job creation, improved factor mobility and access to critical facilities. In this regard, this study can be repeated and extended by considering a wider range of factors in the future.

Author contributions

Conceptualization, AA and LWS; methodology, AA; software, AA; validation, LWS; formal analysis; AA; investigation, LWS; resources; AA; data curation, AA; writing—original draft preparation, AA; writing—review and editing, AA; visualization, AA; supervision, LWS; project administration, AA. All authors have read and agreed to the published version of the manuscript.

Conflict of interest

The authors declare no conflict of interest.

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