INFRASTRUCTURE DEVELOPMENT AND ECONOMIC GROWTH IN SUB-SAHARAN AFRICA: Insight from Electricity, Internet Usage and Mobile Phone

Clement Atewe Ighodaro

Department of Economics, University of Benin, Benin City, Nigeria

ABSTRACT

This paper used panel data for the period 2000 to 2017 for 38 SSA countries to examine the link between infrastructure and economic growth. Most previous studies did not disaggregate information communications technology while some of them used government expenditure on energy/power to capture electricity infrastructure. This paper departs from previous studies by using internet usage and cellular phones to capture information communications technology and electricity access. The variants of infrastructure used have significant and direct effect on the economic growth of SSA. However, electricity accessibility was not significant. It is recommended that policy should be put in place to encourage government efforts to improve the variants of infrastructure used in this paper. Furthermore, government should improve on mobile phones and internet infrastructure policy by increasing the quantity and quality of this infrastructure.

Key words: Economic growth, Fixed effect, Infrastructure, Sub-Saharan African

JEL classification: 04, H54

1. Introduction

Infrastructure is vital to the socio-economic development of any nation or region. Inadequate infrastructure denies the citizens access to markets and other opportunities. Aschauer (1989) popularized the importance of infrastructure to economic growth as adequate infrastructure is critical to growth and development. In sub-Saharan Africa, almost all dimensions of infrastructure rank low compared to other developing economies (Calderón, Cantú & Chuhan-Pole, 2018). Mobile phones are used by many people in SSA to communicate and get information about happenings around the world (Calderón et al., 2018). Storeygard (2016) argued that inadequate infrastructure could reflect the high population density and poor maintenance culture in SSA. As at 2014, 633 million people did not have electricity access talk less of addressing electricity problems (OXFAM, 2017). This reduces economic opportunities hence poverty, which may lead to premature death because of inability to meet health demands. The IEA (2016) noted that due to poor electricity supply and access in SSA, people are forced to use charcoal from woods for cooking. Households, businesses and public institutions may not perform efficiently where there are poor internet facilities. For example, households can use internet facilities to source for opportunities in business and other life opportunities.

Infrastructure in this paper refers to physical infrastructure such as access to internet usage, energy in particular, electricity access, and mobile phone usage. Public infrastructure can provide services that may augment capital and labour in production (Ayogu, 2017). Ajakaiye and Nkube (2010) noted that effective utilization of infrastructure enhances human development through improved productivity and sustainable economic growth.

Previous literature were country-specific studies such as Loayza and Odawara (2010); Keho and Echui (2011); Oyeniran and Onikosi-Alliyu (2016); Owusu – Manu, Jehuri, Edwards, Boateng and Asumadu (2019) for Ghana; Bogetic and Somogo (2005); and Calderon and Serven (2003a) among others, were for a panel of countries. Since studies on internet usage and mobile phones are not common, this paper examines the link between infrastructure and economic growth of SSA. It is different from other related empirical literature because it disaggregates ICT to internet usage and mobile cellular phone usage such that their individual effects on economic growth are established. Following section 1, section 2 presents the review of relevant literature and discusses the growth performance of infrastructure and economic growth performance in SSA. The methodology is explained in section 3 and section 4 presents the estimated results and interpretation while section 5 is the conclusion and recommendations.

2. Literature Review

2.1 Infrastructure and economic growth performance in SSA

On the average, SSA had an annual real gross domestic product per capita growth rate of 2.5 percent from 2005 to 2009 (Heston, Summers and Aten, 2011) and as at 1990 to 1994, it became negative, ranging from -0.43 percent in 1990 to -1.52 percent in 1994. This represents, on the average, a growth rate of -2.30 percent. This became positive from 0.62 percent in 1995 to 0.88 percent in 1997. Considering 2009 to 2017, the average growth rate of GDP per capita in SSA was 1.09 percent (WDI, 2017) as shown in figure 1. Chen and Ravallion (2010) noted that the growth performance was impressive because for over forty years, real gross domestic product per capita growth in SSA averaged less than 0.5 percent per annum. Infrastructure deficiency may have been the cause of these low growth rates over time.

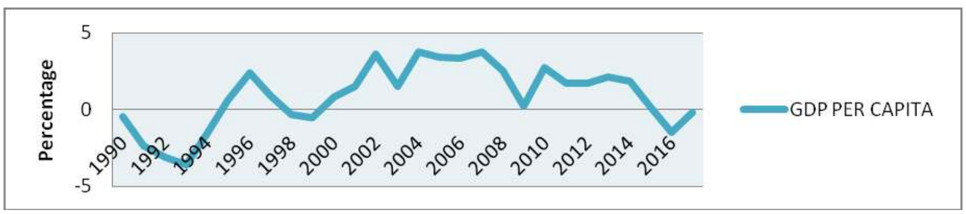

Figure 1. GDP Per Capita for SSA 1990 - 2017.

Source: WDI (2017).

Between 1995 and 2005, there was rapid expansion in the ICT industry in SSA because private investors and operators invested about $25billion. Calderon et al. (2018) noted that between 1998 and 2002, only seven SSA countries had fixed broadband services. However, between 2008 and 2012, Mauritius took the lead in Africa while Ethiopia, Malawi, and Guinea were behind. Calderon et al. (2018) further noted that the median number of fixed and mobile phone lines per 1,000 people in SSA increased significantly from about three in 1990 to 736 in 2014.

The WDI (2017) documented that in the period 1990 to 1999, mobile cellular phone subscription by the population of SSA was less than one percent as shown in figure 2. Though, the increase in subscription rate was rapidly high, this was on the average 4.03 percent between 2000 and 2004, it increased significantly between 2013 and 2017 to an average of 70.81 percent. Global System for Mobile Association, GSMA (2017) noted that there were 420 million unique mobile subscribers as at the end of 2016, representing a penetration rate of 43 percent. In 2016, mobile technologies and services generated $110 billion in the region and this is about 7.7 percent of total GDP. Adoption of mobile phones in SSA was about 25 percent at the beginning of this decade but as at 2017, it increased to 44 percent (GSMA, 2017).

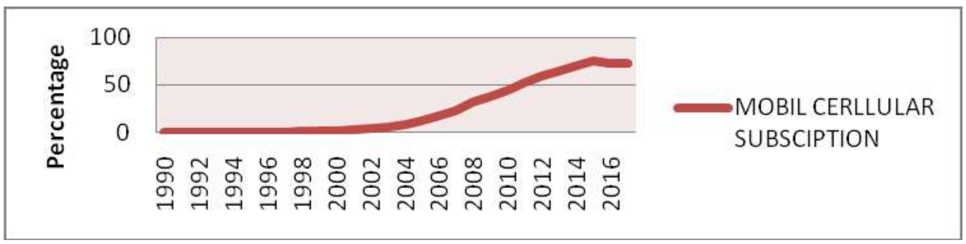

Figure 2. Mobile Cellular Subscription in SSA between 1990 – 2017.

According to the World Economic Forum (2018), electricity installed capacity in the region was 96 gigawatts in 2015, compared with 325 gigawatts and 1,519 gigawatts in India and China respectively. Agrawal (2015) noted that SSA makes up 13 percent of the world's population, yet about 48 percent of her population has no electricity access compared to South Asia which is made up of 23 percent of the world's population and relatively fewer people have no access to electricity.

While several SSA countries have made progress in expanding access to electricity, the overall status of African electrification is still far from what is required to achieve economic growth and development (World Bank, 2019). Castellano, Kendall, Nikomarov and Swemmer (2015) noted that on the average, it will take about 25 years to get from 20 to 80 percent electrification of households which is about 2.4 percent per year. While Vietnam took only 9 years, Brazil took more than 40 years. Between 1990 and 2017, electricity access in SSA has been on the increase, though less than 43 percent of the population have access. As shown in figure 3, between 1990 and 1995, access to electricity by the population was on the average 18.55 percent while this increased to 29.17 percent in 2003. Between 2013 and 2017 in SSA, access to electricity by the population was on the average 40.35 percent. This implies that most households in SSA still do not have access to electricity.

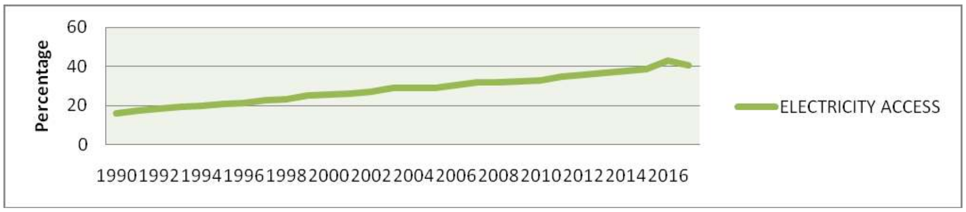

Figure 3. Access to Electricity in SSA between 1990 – 2017.

Source: WDI (2017).

Internet usage has been on the increase in SSA, from 0.07 percent in 1996 to 22.12 percent in 2017. Between 1996 and 2002, less than one percent of the population embraced internet usage. This increased slightly to 3.89 percent in 2008 and increased further to 22.12 percent in 2017 as revealed in figure 4. SSA is yet to have universal access to internet (Mahler, Montes and Newhouse, 2019). According to ITU (2013), between 2006 and 2010, the average growth in the number of internet users in sub-Saharan Africa was about 35 percent, though with significant disparities among countries. For example, the average growth for the Central African Republic was 160 percent, Angola was 106 percent, Malawi was 106 percent, Nigeria was 103 percent and Mozambique, 99 percent. Also, between 2006 and 2010, the number of internet users per hundred inhabitants showed that for all countries in SSA, only Cape Verde crossed the bar of 30 users per 100 inhabitants. While Cape Verde was 30 users per 100 inhabitants, Seychelles was 41 users per inhabitant. Nigeria and Mauritius were 28 and 25 users per 100 inhabitants respectively. The ITU (2017) documented that in SSA, only 1 in every 5 persons used the internet in 2017, whereas more than 50 percent of the population used the internet in South Africa. In West Africa, users were close to 30 percent but only about 10 percent in Central Africa. These figures show that physical infrastructure like electricity, internet access and mobile telephoning are still not well developed in SSA.

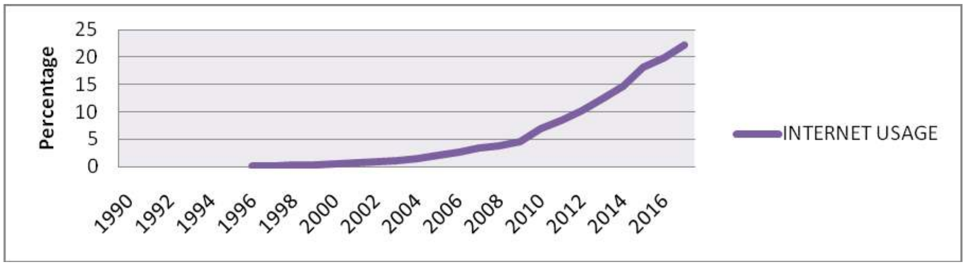

Figure 4. Internet Usage in SSA from 1996 – 2017.

2.2 Empirical literature review

Several studies exist in the literature. Antle (1983) examined the contribution of transportation and communication industries per square kilometre of land area in 47 developing and 19 developed countries respectively to factors of production. He established that transportation significantly contributed to production in both countries. Aschauer (1989) used data from 1949 to 1985 and noted that public infrastructure stock was a significant determinant of total factor productivity in the USA. He further established that highways, airports and electrical facilities and sewers were very significant in the determination of productivity. Cronin, Parker, Colleran and Gold (1991) used the Granger and modified Sims test to establish the existence of feedback process in which economic activities and growth stimulate demands for telecommunication services. As the economy grows, more telecommunications facilities were needed to support the increased business transactions. Norton (1992) used data from 47 countries and estimated the effect of the average stock of telephones between 1957 and 1977 on the mean of annual growth rate. He established that telecommunications infrastructure reduces transactions costs.

Canning and Fay (1993) used panel data from 152 countries for the period 1950 – 1995 to establish the effect of different infrastructure on economic growth. They found that telephone and paved roads were generally the most vital variables that promote growth, but these were either over-supplied or undersupplied in some countries. Stephan (1997) carried out a study of growth differential between Eastern and Western Germany. He noted that other exogenous factors, though not stated, were more relevant than the growth of length of paved road which he used as proxy for road stock in explaining total factor productivity. Kneller, Bleaney and Gemmell (1999) examined expenditure on some infrastructure on economic growth in 22 OECD countries. They found that government expenditure on transport and communication enhanced growth while non-productive ones like social security and welfare did the contrary.

Fernald (1999) carried out a study on the contribution of infrastructure to different industries in the USA between 1953 and 1989. He found that roads contributed significantly to productivity growth in the different industries. Canning and Pedroni (1999) used length of paved roads, kilowatt per hours of electricity generating capacity for 100 developing and developed countries. They found no evidence of worldwide infrastructure shortage of telephones or paved roads. Felloni, Wahl, Wandschneider and Gilbert (2001) examined the importance of infrastructure on productivity in China. They found that road density per hectare of agricultural land lead to significant economic growth through positive and significant impact of agricultural production.

Fan and Cham-Kang (2005) examined road development, economic growth and poverty in rural China. They found that road investment yielded the highest economic returns in the Eastern and Central regions of China. Destefanis and Sena (2005) applying panel data of the Southern regions of Italy to establish the impact of some infrastructure on total factor productivity, found that roads, airports, habours, railroads, water, electricity and communications significantly impacted total factor productivity. Demurger (2001) used panel data of 24 provinces and autonomous regions within the period 1985 – 1998 to examine infrastructure and productivity growth and found that transport and telecommunication were significant for productivity growth. Calderon and Serven (2003a) used GMM and cross-country panel data set for Latin America to establish the link between infrastructure and growth. They found that telecommunication, transport and power contributed significantly to growth. Kim and Haque (2003) used a dynamic panel approach to examine the link between public infrastructure investment and economic growth and found that public investment in transport and communication has delayed impact on growth.

Fedderke, Perkins and Luiz (2005) examined the effect of public infrastructure on long-run growth in South Africa. They used VECM and found that infrastructure investment directly and indirectly contributed to growth. Bogetic and Fedderke (2005), in a similar study in South Africa, concluded that infrastructure does not contribute significantly to productivity. They further concluded that new investment in infrastructure is needed in South Africa to reverse the investment decline of the past several years. Bogetic and Sanogo (2005) found that poor infrastructure, like poor road network, constrained productivity in both primary and tertiary industries in Côte d'Ivoire. They opined that this may be because of the problem involved in transporting goods from urban to rural areas. Loayza and Odawara (2010) examined infrastructure and economic growth in Egypt using data from 1960 to 2007 and the methodology of regression analysis. They found that the variants of infrastructure used had a positive relationship with economic growth in Egypt.

Keho and Echui (2011) used different estimation techniques to examine investment in transport infrastructure in relation to sustained economic growth in Côte d'Ivoire. They used data that covered the period 1970 to 2002 and found that public and private investments in transport infrastructure and economic growth have a long-run relationship. They also found a one-way causality between public investment in transport and economic growth with causality from economic growth to transport investment. Ahmed and Ridzuan (2013) used the panel estimation approach to examine the impact of ICT on the economic growth of eight East Asian countries with data from 1975 to 2006. They found a significant and positive link between ICT and economic growth in the economies of the eight East Asian economies.

Oyeniran and Onikosi-Alliyu (2016) used data from 1980 to 2012 and the ARDL bounds approach to examined the link between investment in information and telecommunication infrastructure and economic growth in Nigeria. They found that foreign direct investment in ICT impacted positively and significantly on economic growth in Nigeria compared to government investment. Kondonga and Ojah (2016) used data for the period 2000 - 2011 on 45 SSA countries to explain the impact of infrastructure on economic growth. They used the GMM estimation methodology and found a significant link between infrastructure spending and economic growth for developing economies but not for the relatively more developed economies. Calderón et al. (2018) provided a scorecard on the quantity, quality and access of telecommunications, electric power, transportation, and water and sanitation in SSA over time. They found that there is a large infrastructure gap, though the magnitude of the gap depended on the sector, dimension, and country/group. Owusu–Manu et al. (2019) used an ARDL framework and data from 1980 to 2016 to consider the short and long-run impacts of the selected infrastructure on the economic growth of Ghana. They found that the capacity to generate electricity has significant positive impact on economic growth while the electricity distribution loss has a significant negative effect on economic growth in both the short run and long run.

The empirical studies showed mixed results among countries and regions. This may be as a result of the methodology used, the data set and the number of observation. While most of the studies used only transport infrastructure as it relates to sector specific like commerce and industry, some used airport infrastructure as it relates to productivity; road and electricity as they relate to agricultural output and some others were on infrastructure investment. It is also important to note that most of the previous studies used infrastructure stock rather than infrastructure access and usage as used in this paper.

3. Methodology

3.1 Theoretical framework, model specification and estimation technique

The basic theoretical framework for infrastructure and economic growth was first developed by Arrow and Kurz (1970) through public capital while Domar (1946) examined the role of resource factors in growth and noted that growth of the economy depends on three factors which were modelled as:

$$Y_{it} = f\left(K_{it}, L_{it}, R_{it}\right) \tag{1}$$

where:

K = productive capital;

L = labour; and

R = resource factors used to increase production.

As opined by Thong and Hao (2019), the link between economic growth and capital needs to be established by considering the relationship among savings (S), investment (I), productive capital (K) and production capacity (Y). Harrod-Domar argued that savings and investment lead to increased capital stock and productive capital which influences economic growth. The neoclassical growth model also known as the Solow (1965) and Swan (1956) growth model extended the Harrod–Domar (1946) model to include labour as one of the factors of production. The neoclassical model assumes that capital is subject to diminishing returns to scale and can be written as:

$$Y(it) = F\left[K_{it}^{\alpha}\left(A_{it}L_{it}\right)\right]^{\beta} \tag{2}$$

where:

Y = output;

K = capital stock;

(AL) = augmented labour;

subscript t = time frame; and

F = level of the technology that transforms the inputs to output.

The neoclassical growth theory posits that in the short run, the rate of economic growth is determined by the accumulation of capital, which is influenced by the savings and depreciation rates. On the contrary, long-run growth is determined by technological progress and labour force growth as a result of change in population and shocks in infrastructure stock that can have only temporary effects on income. Following Solow (1965) and Mankiw, Romer, and Weil (1992) and following from equation (2), the simplest form of the endogenous growth (AK) model can be written in Cobb–Douglas form as:

$$Y_{it} = A_{it}K_{it}^{\alpha}L_{t}^{\beta} \tag{3}$$

where: α and β are the shares of capital and labour in output and A is constant.

To determine the link between infrastructure and economic growth, this study uses production functions as they relate to growth as modelled in equation (3) and includes infrastructure as the main variable that impacts economic growth. In the static panel, the three categories of models used are the pooled regression, fixed effect model and random effect model. This is necessary in order to check the consistency of results obtained. However, the results and interpretation are based on the most appropriate model which is determined on the basis of the results of the Hausman and Wald tests. Therefore, to estimate the impact of infrastructure on economic growth in SSA, an endogenous growth model as used in the study by Kondongo and Ojah (2016) can be formulated.

Pooled regression or pooled least squares:

$$y_{it} = \alpha + \beta' x_{it} + \mu_{it} \tag{4}$$

Fixed effect model:

$$y_{it} = \alpha_i + \beta' x_{it} + \mu_{it} \tag{5}$$

where unobserved heterogeneity is captured by α_i.

Random effect model:

$$y_{it} = \alpha_i + \beta' x_{it} + \mu_{it} + \varepsilon_{it} \tag{6}$$

where:

y_{it} is the log of per capita GDP proxy for economic growth;

x_{it} is vector of infrastructure variables

μ is random disturbance characterizing country *i*.

In this model, it is assumed that individual effects are not correlated with other explanatory variables, hence, $E(X, \mu) = 0$.

Based on the theoretical framework, the log of equation (3) can be modelled as:

$$LNY_{it} = LNA_{it} + \alpha LNK_{it} + \beta LNL_{it} \tag{7}$$

Recall that the paper is basically considering the impact of infrastructure on economic growth, and from equations (3) and (4), *A* is assumed to be constant. The final model estimated can be written as:

$$LNGDPPC_{it} = \alpha + \alpha_1 LNELAC_{it} + \alpha_2 LNINTUS_{it} + \alpha_3 LNMOCE + \mu_{it} \tag{8}$$

where:

LNGDPPC	=	Log of real per capita GDP, proxy for economic growth
LNELAC	=	Log of access to electricity, proxy for electricity infrastructure
LNINTUS	=	Log of internet users, proxy for ICT infrastructure
LNMOCE	=	Log of mobile cellular subscription, also proxy for ICT infrastructure

A priori, it is expected that all the independent variables will have positive impact on the economic growth of SSA.

3.2 Data sources

The dataset is an unbalanced panel, consisting of 38 countries and 18 years of observations between 2000 and 2017. All the data were sourced from the WDI (2017).

3.3 Estimation techniques

The study tested for panel unit root and started with a pooled estimation, followed by fixed and random effect estimations. The pooled estimation takes the intercepts of the countries in the estimation to be the same and does not control for country-specific factors. In the panel data analysis, the Hausman and Taylor (1981) test helps to choose the better between the fixed effect model and the random effects model while the Wald test helps to choose between the fixed effect model and the pooled regression.

4. Results and Interpretation

4.1 Descriptive statistics

Descriptive statistics presented in table 1 show basic characteristics within the series. These are reported and explained below.

Table 1. Descriptive Statistics for Pooled Sample

	Mean	Max.	Min.	Std. Dev.	Skewness	J-B stat	Prob.
GDPPC	2145	22742	111.3	3337	2.921	3784.9	0
ELAC	36.51	100	0.01	27.02	0.752	68.503	0
INTUS	8.167	58.76	0.005	12.01	2.238	1176.7	0
MOCE	43.13	176.5	0.018	41.6	0.907	106.29	0

Source: Estimation from Eviews 9.

From table 1, average GDPPC growth rate is about 2145 for the period. This is however unstable due to the high standard deviation value of 3337. The skewness is relatively low compared to the mean and standard deviation, indicating that GDPPC growth rate figures lie to the left (are less than) of the mean value. The J-B has a high value of over 3784 and it passes the significance test at the 1 percent level. This indicates that the density function of the series is non-normally distributed. With respect to electricity access (ELAC), the mean value is about 36.51for the period. This is relatively stable due to the relatively low standard deviation value of 27.02 compared to GDPPC. The skewness value of 0.75 is low indicating that the ELAC growth rate figures lie to the left (are less than) of the mean value. The J-B of over 68.5 passes the significance test at the 1 percent level. This also shows that the density function of the series is non-normally distributed.

Again, the mean value of internet users (INTUS) is about 8.16 for the period. This is stable due to the low standard deviation value of 12.01. The skewness is low showing that the INTUS growth rates lie to the left (are less than) of the mean value. Also, the high J-B statistics of 1176.7 passes the significance test at the 1 percent level. This shows that the density function of the series is non-normally distributed. Lastly, the mean value of mobile cellular subscription (MOCE) is about 43.13 for the period. This is fairly stable due to the relative low standard deviation value of 41.60. The skewness is also low showing that the MOCE growth rates lie to the left (are less than) of the mean value. The high J-B statistics of 106.29 passes the significance test at the 1 percent level. This once more shows that the density function of the series is non-normally distributed.

4.2 Panel unit root

The panel unit root results were based on the methods proposed by the Fisher-PP tests of Maddala and Wu (1999). The main advantage of this test is that it does not require a balanced panel as in the case of the IPS test. Furthermore, different lag lengths can be used in the individual ADF regression (Maddala & Wu, 1999).

4.3 Panel stationarity result

Table 2 presents the panel stationarity results using the PP – Fisher Chi -square panel unit root test results

Table 2. PP – Fisher Chi –square Panel Unit Root Test Results

Variable	Individual Effects			Individual Effects, Individual Linear Trends		
	Statistic	Probability	Remark	Statistic	Probability	Remark
LNGDPPC	233.93	0.0000***	I(0)	186.616	0.0000***	I(0)
LNELEC	731.813	0.0000***	I(0)	350.379	0.0000***	I(0)
LNINTUS	398.427	0.0000***	I(0)	268.7	0.0000***	I(0)
LNMOCE	559.826	0.0000***	I(0)	272.136	0.0000***	I(0)

(***) significant at (1%)

Probability for Fisher tests are computed using an asymptotic Chi-square distribution.

Source: Author's computations.

Using the individual effects as well as individual intercept and trend, the variables were stationary at levels, hence they are all I(0), implying that cointegration among the variables may not exist.

4.4 Panel least squares estimate

The panel least squares estimation technique is a modified Ordinary least squares (OLS) technique with common constant, fixed and random effects as variants. The result of the panel least squares shows that only mobile cellular subscription was not significant in the determination of economic growth in SSA, though, it had a positive relationship as expected. The results (panel A) reveal that a 10 percent increase in mobile cellular subscription will increase economic growth by about 0.5 percent while a 10 percent increase in access to electricity and internet users will increase economic growth by about 4 percent and 2.5 percent respectively as revealed in table 3. Both are significant at 1 percent levels of significance. The coefficient of determination revealed that more than 56 percent of the dependent variable was determined by the independent variable. The F-statistic shows that all the variables are jointly significant in the determination of economic growth in SSA.

Table 3. Panel Estimation Results

Dependent Variable: LNGDPPC			
Sample: 2000 – 2017			
Total observations: 676			
Independent variables	(A) Panel Least Squares	(B) Random Effect	(C) Fixed Effect
LNELAC	0.395796***	0.064774***	0.036499
	(0.0000)	(0.0150)**	(0.1809)
LNINTUS	0.238866***	0.141966***	0.138269***
	(0.0000)	(0.0000)	(0.0000)
LNMOCE	0.052097	0.099306***	0.104891
	(0.1450)	(0.0000)	(0.0000)
Constant	5.254359***	6.265353***	6.350854***
	(0.0000)	(0.0000)	(0.0000)
R^2	0.5587	0.580987	0.930071
$\bar{R}^2$	0.55673	0.579116	0.925666
F-statistic	283.5911	310.5896	211.1413
Prob (F-statistic)	0	0	0

Figures in parentheses are the probability values

***(**) Significant at 1(5) percent levels of significance

Source: Author's computation E-Views 9.0.

4.5 Random effect estimation result

The result from table 3 panel (B) shows that access to electricity (LNELAC) is statistically significant and positively related to economic growth (LNGDPPC) to the tune of about 0.064. The coefficient of internet users (LNINTUS) shows a positive relationship with economic growth. The result also shows that all the variables used are significant and positive in the determination of economic growth in SSA. It shows that a 1 percent increase in all the independent variables will lead to a less than 1 percent increase in the dependent variable. The R-square and the adjusted R-square values of 0.58 (58%) and 0.57 (57%) show that more than 58 percent of the dependent variable is explained by the independent variables. The F-statistic value of over 310 also shows the overall good fit of the explanatory variables in the model as shown in table 3.

4.6 Fixed effect estimation result

The result from table 3 (panel C) shows that all the independent variables are positively related to economic growth, though the electricity variable is not significant. An increase in the infrastructure variable by, say, one percent will increase economic growth by less than one percent. The R-square and the adjusted R-square values of 0.93(93%) and 0.92 (92%) attest to the explanatory suitability of the regressors with respect to variation in the dependent variable. The F-statistic value of over 211 also shows the overall good fit of the regressors in the model.

4.7 Correlated random effect – Hausman test

It is important to state that the choice of the appropriate model to use between fixed and random effects is determined by the Hausman test. The Hausman test is the standard test to check for correlation between the unique errors and the regressors in a model. It helps to reveal the preference for the random effects model compared to the fixed effects model. The Hausman test for random argument reveals that the Chi-square statistics of 37.6 (with a probability value of 0.00) is greater than the critical Chi-square value of 3 as shown in table 4.

Table 4. Correlated Random Effect – Hausman Test

Correlated Random Effects – Hausman Test

Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Cross-section random	37.645039	3	0

This provides a strong argument against the null hypothesis that there is no misspecification when the random effects model is employed and thus provides the justification for the rejection of the random effects estimates. The implication of this is that the random effects model will be biased and inconsistent as shown in table 4.

4.8 Wald test

Since from the Hausman test, the fixed effect was better than the random effect, the need arose to chose between the fixed effect and panel least squares using the Wald test as shown in table 5.

Table 5. Wald Test

Test Statistic	Value	df	Probability
F-statistic	326.6183	(3, 672)	0
Chi-square	979.8549	3	0

The results of the Wald test revealed that the fixed effect model is the most appropriate for pooled regression. Therefore, both the Hausman and the Wald tests revealed that fixed effect estimation is the most appropriate. Therefore, on the basis of the fixed effect model, the result revealed that access to electricity (LNELAC) is in line with *a priori* expectation and positively related to per capita GDP, though not significant at the conventional one percent, 5 percent and 10 percent respectively. The result revealed that if electricity infrastructure is increased say, by 10 percent, economic growth will increase by about 0.4 percent. The result obtained confirms the earlier one obtained by Aschauer (1989) and Calderon and Serven (2003a) but is contrary to the one obtained by Calderon and Serven (2003b). Electricity infrastructure is a major contributor to the economic growth and development of any region or country. It is used to propel most aspects of our daily lives and is also one of the sources of energy for so many sectors of the economy. It is used in hospitals, airports, and for agricultural activities which contribute to overall economic growth.

With respect to internet and mobile phone usage, both are significant at 1 percent level of significance and they are positively related to economic growth. The results are in line with the one obtained by Norton (1992); Canning and Fay (1993); Cadot, Roller and Stephen (1999). Studies like Roller and Waverman (2001) and Ahmed and Ridzuan (2013) noted that ICT influences economic growth through the provision of an effective and efficient information production process.

5. Conclusion and Recommendations

This paper examined the link between infrastructure and the economic growth of SSA countries with panel data for the period 2000 to 2017. While the study showed that infrastructure development has improved in SSA, it has been at a relatively slower pace when compared with other regions of the world. All the variants of infrastructure used in the study revealed positive links with economic growth, though, electricity access was not significant. Also, in the empirical analysis, it was found that on the average, the elasticity of output with respect to the variants of infrastructure used were positive but less than one. The paper opined that electricity has not impacted the economic growth of SSA significantly compared to internet usage and cellular phones. This implies that ICT is growth-enhancing in the region. It is recommended that policy should be put in place to encourage government efforts to further improve on the variants of infrastructure used in this paper. Furthermore, government should pursue mobile phone and internet infrastructure growth policy by increasing the quantity and quality of this infrastructure in SSA.

References

Agrawal, K.K. (2015). 45% people in sub-Saharan Africa have no access to electricity. Retrieved from https://www.downtoearth.org.in/news/45-people-in-subsaharan-africa-have-no-access-to-electricity-49165.

Ahmed, E.M. & Ridzuan, R. (2013). The impact of ICT on East Asian economic growth: Panel estimation approach. *Journal of Knowledge Economics*, 4, 540 – 555.

Ajakaiye, O., & Nkube, M. (2010). Infrastructure and economic development in Africa. *Journal of African Economies,* 19(1), 3-12.

Antle, J. M. (1983). Infrastructure and aggregate agricultural productivity: International evidence. *Economic Development and Cultural Change,* 31, 609 – 619.

Arrow, K. J., & Kurz, M. (1970). *Public Investment, the Rate of Returns and Optimal Fiscal Policy.* Baltimore: Johns Hopkins University Press.

Aschauer, D. A. (1989). Is public expenditure productive? *Journal of Monetary Economics,* 23 (2), 177–200.

Ayogu, M. (2007). Infrastructure and economic development in Africa: A review. *Journal of African Economies,* 16(1), 75-126.

Bogetic, Z., & Sanogo, I. (2005). *Infrastructure, Productivity and Urban Dynamics in Côte d' Ivoire – An empirical analysis and policy implications.* African regional working paper series, 33167, Washington D.C.: World Bank.

Bogetic Z., & Fedderke, J.W. (2005). Infrastructure and growth in South Africa: Benchmarking, productivity and investment needs. Paper presented at the Bi-annual Conference of the Economic Society of South Africa, Durban, South Africa. September 7 - 9.

Cadot O., Roller, L.H. & Stephan, A. (1999). *A Political Economy Model of Infrastructure Allocation: An empirical assessment*. CEPR Discussion Paper, 2336.

Calderón, C., Cantú, C., & Chuhan-Pole, P. (2018). *Infrastructure development in Sub-Saharan Africa: A scorecard*. World Bank Policy Research Working Paper 8425. World Bank.

Calderon, C. & Serven, L. (2003a). The output cost of Latin America' infrastructure gap. In Easterly. W. & L. Serven (Eds). *The Limits of Stabilization: Infrastructure, Public Deficits and Growth in Latin America*. Stanford University Press and the World Bank, 95 – 118.

Calderon, C. & Serven, L. (2003b). Macroeconomic Dimensions of Infrastructure in Latin America. Presented at the Fourth Annual Stanford Conference on Latin American Economic Development, November 13-15.

Canning, D. & Fay, M. (1993). *The Effect of Transportation Networks on Economic Growth.* Colombia University Working Paper, New York.

Canning, D. & Pedroni, P. (1999). *Infrastructure and Long-run Economic Growth.* CAER II Discussion Paper, 57. Harvard Institute for International Development, US.

Castellano, A., Kendall, A., Nikomarov, M. & Swemmer, T. (2015). Powering Africa. Retrieved from https://www.mckinsey.com/industries/electric-power-and-natural-gas/our-insights/powering-africa.

Chen, S. & Ravallion, M. (2010). The developing world is poorer than we thought, but no less successful in the fight against poverty. *Quarterly Journal of Economics*, 125(4), 1577–1625.

Cronin, F.J., Parker, E.B., Colleran, E.K., & Gold, M.A. (1991). Telecommunications infrastructure and economic growth: An analysis of causality. *Telecommunications Policy*, 529 -535.

Demurger, S. (2001). Infrastructure development and economic growth: An explanation for regional disparities in China? *Journal of Comparative Economics,* 29, 95 -117. .

Destefanis, S. & Sena, V. (2005). Public capital and total factor productivity: New evidence from the Italian regions 1970 – 1998. *Regional Studies*, 39(5), 603 -617.

Domar, E. (1946). Capital expansion, rate of growth, and employment. *Econometrica*, 14, 137-47.

Fan, S. & Cham-Kang, C. (2005). *Road Development, Economic Growth, and Poverty Reduction in China*. Research Report 138. Washington D.C.: International Foods Policy Research Institute (IFPRI).

Fedderke, J.W., Perkins, P. & Luiz, J.M. (2005). Infrastructure investment in long run economic growth: South Africa: 1875 – 2001. Paper presented at the 10th African Econometrics in South Africa. July.

Felloni, F., Wahl, T., Wandschneider, P., & Gilbert, J. (2001). *Infrastructure and Agricultural Production: Cross-country Evidence and Implication for China* ITW - 2001 - 103. Pullman: Washington State University.

Fernald, J.G. (1999). Road to prosperity? Assessing the link between public capital and productivity. *The American Economic Review,* 89(3), 619 – 638.

Global System for Mobile Association, GSMA (2017). The Mobile Economy in sub-Saharan Africa 2018. Retrieved from https://www.gsma.com/r/mobileeconomy/sub-saharan-africa/.

Hausman, J.A., & Taylor, W.E. (1981). Panel data and unobservable individual effects. *Econometrica*, 49(6), 1377-1398.

Heston, A., Summers, R., & Aten, B. (2011). *Penn World Table Version 7.0*. Center for International Comparisons of Production, Income and Prices, University of Pennsylvania, May 2011.

IEA (International Energy Agency). (2016). *World Energy Outlook 2016*. Paris.

International Telecommunication Union, ITU (2013). Study on International Internet Connectivity in sub-Saharan Africa. Retrieved from: https://www.itu.int/en/ITU-D/Regulatory.../IIC_Africa_Final-en.pdf. Accessed 27th June, 2019.

International Telecommunication Union, ITU (2017). ICT Facts and Figures, 2017. Retrieved from https://www.itu.int/en/ITU-D/Statistics/.../facts/ICTFactsFigures2017.pdf.

Keho, Y., & Echui, A.D. (2011). Transport infrastructure investment and sustainable economic growth in Côte d'Ivoire: A cointegration and causality analysis. *Journal of Sustainable Development*, 4(6), 23 – 35.

Kim, D. H. &. Haque, M.E. (2003). *Public investment in transportation and communication and growth. A dynamic panel approach*. Centre for Growth and Business Cycle Research CGBCR). The University of Manchester, 031.

Kneller, R., Bleaney, F.M., & Gemmell, N. (1999). Fiscal policy and growth: Evidence from OECD countries. *Journal of Public Economics*, 74(2), 171 - 190.

Kondonga, O., & Ojah, K. (2016). Does infrastructure really explain economic growth in sub-Saharan Africa? *Review of Development Finance*, 6(2), 105 -125.

Loayza, N.V., & Odawara, R. (2010). *Infrastructure and economic growth in Egypt*. World Bank Policy Research Working Paper 5177. Retrieved from http://documents1.worldbank.org/curated/en/693911468022759281/pdf/WPS5177.pdf

Mahler, D.G., Montes, J., & Newhouse, D. (2019). Internet access in sub-Saharan Africa. *Poverty and Equity Notes*, 13.

Maddala, G.S., & Wu, S. (1999). A comparative study of unit root tests with panel data and a new simple test. *Oxford Bulletin of Economics and Statistics*, Special issue, 631- 652.

Mankiw, N.G., Romer, D., & Weil, D.N. (1992). A contribution to the empirics of economic growth. *Quarterly Journal of Economics*, 107(2), 407-437.

Norton, S.W. (1992). Transaction costs, telecommunications and the microeconomics of macroeconomic growth. *Economic Development and Cultural Change*, 41(1), 175 - 196.

Owusu-Manu, D.G., Jehuri, A.B., Edwards, D.J., Boateng, G., & Asumadu, G. (2019). The impact of infrastructure development on economic growth in sub-Saharan Africa with special focus on Ghana.. *Journal of Financial Management of Property and Construction*, 24(3), 253 – 273.

OXFAM. (2017). The energy challenge in sub-Saharan Africa: A guide for advocates and policy makers. Retrieved from https://www.oxfamamerica.org/static/.../oxfam-RAEL-energySSA-pt1.pdf.

Oyeniran, W.O., & Onikosi-Alliyu, S. (2016). Information and telecommunication infrastructure and economic growth: An experience from Nigeria. *Serbian Journal of Management* 11(2), 275 – 289.

Roller, L-H., & Waverman, L. (2001). *Telecommunication infrastructure and economic development: A simultaneous approach*. Wissenschaftszentrum Berlin Fur Socialforschung W2B, Discussion Papers.

Solow, R. (1965). A contribution to the theory of economic growth. *Quarterly Journal of Economics*, 70(1), 65 – 94.

Stephan, A. (1997). *The impact of road infrastructure on productivity and growth: Some preliminary results for the German manufacturing sector*. Discussion paper FS IV 97 - 47, Wissen-Schaftszantrum Berlin.

Storeygard, A. (2016). Farther on down the road: Transport costs, trade and urban growth in sub-Saharan Africa. *Review of Economic Studies* 83(3): 1263–95.

Swan, T.W. (1956). Economic growth and capital accumulation. *Economics Record*, 32(63), 334 –361.

Thong, L.N., & Hao, N.T. (2019). The Harrod-Domar growth model and its implications for economic development in Vietnam. *International Journal of Humanities, Social Sciences and Education,* 6(4), 11-17.

World Bank. (2019). Electrification efforts in sub-Saharan Africa must address root causes of low access. Retrieved from https://www.worldbank.org/en/region/afr/publication/electricity-access-sub-saharan-africa.

World Economic Forum. (2018). More people than ever now have electricity in Africa, but 600 million are still in the dark. Retrieved from https://www.weforum.org/agenda/2018/05/more-people-than-ever-now-have-electricity-in-africa-but-600-million-are-still-in-the-dark.