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Article

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FINANCIAL ECONOMICS | RESEARCH ARTICLE

Financial development and economic growth nexus in SSA economies: The moderating role of telecommunication development

Mac Junior Abeka^{1*}, Eric Andoh¹, John Gartchie Gatsi¹ and Seyram Kawor¹

Abstract: The economic growth of most sub-Saharan African countries in the past years has not been able to equalize with other regions. Even though financial development has been highlighted in several empirical literature as a factor that could spur up economic growth, the level of financial development in sub-Saharan Africa is not effectively channeled into desired levels of economic growth. However, there is an indication in the literature that financial development will be more relevant to the economic growth of sub-Saharan African economies that have strong telecommunication infrastructure. Using the system General Method of Moment estimation technique, the paper found that telecommunication infrastructure enhances the effect of financial development on the economic growth of sub-Saharan African economies. It is therefore recommended that sub-Saharan African economies should apply appropriate measures to boost their telecommunication infrastructure so that gains from the financial sector can effectively be channeled into economic growth.

Subjects: Economics; Econometrics; Finance

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PUBLIC INTEREST STATEMENT

The study examines the impacts of financial development on the economic growth of sub-Saharan African economies that have strong telecommunication infrastructure. Using the system General Method of Moment estimation technique, the paper finds that telecommunication infrastructure enhances the effect of financial development on the economic growth of sub-Saharan African economies. It is therefore recommended that sub-Saharan African economies should apply appropriate measures to boost their telecommunication infrastructure so that gains from the financial sector can effectively be channeled into economic growth.

Keywords: economic growth; financial development; sub-Saharan Africa; telecommunication infrastructure

1. Introduction

The empirical and theoretical discourse on the relationship between financial sector development and economic growth remains a controversy in both economics and finance literature. Theoretically, a vast amount of literature on the finance–growth nexus emanates from the earlier work of Schumpeter (1911), which emphasized that expansion of the financial sector will generate the finances needed for the growth of the real sector. Subsequently, studies such as Demirgüç-Kunt and Levine (1996), Levine and Zervos (1998), Beck et al. (2000), and Beck and Levine (2004) have supported this stance. Despite this theoretical stance, the empirical discourse on the effect of financial development (FD) on economic growth somewhat remains inconclusive. This is because the relationship between FD and economic growth can be less general than the traditional literature thought (Andersen & Tarp, 2003). Recently, some scholars (such as Berkes et al., 2012; Cecchetti & Kharroubi, 2012; Dabla-Norris & Srivisal, 2013; Gennaioli et al., 2012; Law & Singh, 2014) have told a different story that “too much finance” can deteriorate economic growth. The underlining argument of these studies is that excessive development of the financial sector will draw human capital away from the real sector, thereby causing macro and financial fragility which eventually makes the general economy more susceptible to economic busts.

Based on the argument that “too much finance” can deteriorate economic growth, we argue that telecommunication could complement the human capital in the financial sector such that human capital does not slip from the real sector. The beginning point of our discussion is from the endogenous growth theories. The Solow growth model initially highlighted that output per worker depends mainly on savings, population growth, and technological change (Solow, 1956). Subsequently, the Romer (1986, 1987) AK model considered telecommunication infrastructure as important sources of technological change, spillovers, and human capital augmentation of ideas across countries. Telecommunications, as noted by Romer (1986) and Sala-i-Martin (1996), involve significant components of technological transfers and spillover. These spillover effects cause telecommunications to enhance the growth process of countries that pursue telecommunication-based FD strategies such as mobile banking policies, ATM, and others, rather than the ordinary banking system. In view of this, we argue that telecommunication infrastructure could condition the effect of FD on economic growth because it could augment the human capacity in the financial sector.

A suitable testing ground for our argument is sub-Saharan Africa. To begin with, although economic growth rate in SSA has not followed a distinct pattern over the years, growth has always been slightly weaker than expected, as the SSA region continues to experience negative per capita income growth, weak investment, and a decline in productivity growth (World Bank, 2018). This calls for investigation into nascent and fledging factors in the SSA region that could enhance the level of economic growth aside traditional factors like trade openness, inflation, school enrollment, general government final consumption expenditure, natural resources, population growth, and gross capital formation (Akinsola & Odhiambo, 2017; Menyah et al., 2014). Indeed, over the last few years, technological progress has become the driving force of the financial sector of most SSA economies. The advent of telecommunication infrastructure in the financial sector of SSA economies has the potential to strengthen and accelerate important gains in FD achieved in sub-Saharan Africa over the past two decades (IMF, 2019).

According to IMF (2019), although the standard indicators of FD, such as the ratio of private sector credit to GDP and broad money to GDP, have significantly improved over the years, FD in sub-Saharan Africa remains low as compared to other regions. Among other factors, poor infrastructure in the financial sector has partly contributed to this (IMF, 2019). Rioja and Valev (2004) earlier hinted that finance has a lesser positive effect on growth in higher FD regions but insignificant in low FD region. This provides some form of evidence that improving FD by building

telecommunication infrastructure will make the sector more effective in improving the level of economic growth. In recent years, mobile money has underpinned a radical improvement in the delivery of financial services in sub-Saharan Africa. In consequence of this, “the region has become the global leader in mobile money innovation, adoption, and usage, with close to 40 out of 45 sub-Saharan African countries actively using this new financial technology” (IMF, 2019). Thus, in this study, in addition to the use of mobile phones in the financial sector, we explore other avenues for infrastructure development that could enhance the capacity of the financial sector to improve the real sector. We follow such an approach to examine how mobile telephone service, fixed broadband subscriptions, fixed telephone subscriptions, as well as Internet services enhance the capacity of the financial sector in terms of boosting economic growth.

This study extends the existing literature in a few important respects. Recently, Asongu and Odhiambo (2019) provided some evidence that information and communication technology (ICT) modulates the effect of foreign direct investment on economic growth dynamics in sub-Saharan Africa. Given the premise that ICT modulates the effect of investments on economic growth, our first contribution is to examine why and how SSA economies’ financial sector could explore telecommunication infrastructure avenues for building the capacity needed to improve the growth of the real sector. Such an approach is different from existing studies that have examined the individual effects of FD and telecommunication infrastructure on economic growth (see Myovella et al., 2020; Solomon & van Klyton, 2020; Owusu-Agyei et al., 2020; Nair et al., 2020; Assefa & Mollick, 2017; Oluitan, 2012) and studies that have rather examined the absorptive capacity role of other factors like institutional arrangements (Kacho & Dahmardeh, 2017) and democracy (Ishtiaq et al., 2016). Our second contribution is to undertake a more focused investigation of how specific telecommunication infrastructures can be deployed as effective instruments in financial sector policies and programmes for achieving economic growth in low- and middle-income countries like SSA countries. We do this by employing a uniquely rich dataset of 44 SSA economies covering the period 1996– 2017.

The rest of the paper is organized as follows: Section 2 provides a brief literature review on FD, telecommunication infrastructure, and economic growth. Section 3 presents the theoretical and empirical models, the data measurement and sources, and the econometric methodology. Section 4 presents the empirical results. Finally, section 5 presents the summary, conclusions, and policy recommendations.

2. Financial development, telecommunication infrastructure, and economic growth: an overview of theoretical and empirical literature review

2.1. Supply-leading hypothesis

The relationship between FD and economic growth derives its roots from the supply-leading hypothesis put forth by Schumpeter (1911). The “Schumpeterian theory” emphasizes that expansion of the financial sector will generate the finances needed for the growth of the real sector. Further, McKinnon (1973) and Shaw (1973) highlight that a well-developed financial sector is usually characterized by minimal transaction cost, reduced monitoring costs, and minimal information asymmetry. Thus, FD improves financial intermediation and makes more finance available to economic agents to engage in productive activities. Adeyeye et al. (2015) elaborate on the supply-leading hypothesis in two main respects. FD enables the transfer of resources from the traditional low-growth sectors to the modern high-growth sectors and also it promotes and fuels an entrepreneurial response in these modern sectors. The testing of this theory is particularly important for SSA economies because the majority of these economies are characterized by very traditional sectors.

2.2. Endogenous growth theory

Also, this study examines how telecommunication complements FD in engineering economic growth. Such argument stems from the endogenous growth theory. The endogenous growth theory holds that economic growth is primarily determined by internal factors and not external forces. In the new endogenous growth model, Romer (1986, 1987) has reminded us that telecommunications could be a very important source of technological change, factor spillovers, and human capital augmentation

of ideas across countries needed to increase economic growth. Therefore, the spillover effects from the technological change could complement labor from the financial sector to enhance the growth process of countries that pursue FD strategies. Theoretically denoted, technological progress in developing countries is relatively low as these countries inadequately have technological progress. This to a large extent accounts for the relatively low proportion of economic growth experienced by the SSA region. According to the new growth models, developing countries have low technological progress and this constrains them from investing in the telecommunications industry which is confirmed to generate new knowledge/technology effects. Given this, the knowledge created in developing countries through telecommunications could affect the economic growth of the SSA region and therefore complement the efforts made by the financial sector. Thus, telecommunications could be a strong factor for FD to promote economic growth.

2.3. Empirical literature

2.3.1. *The financial development and economic growth nexus*

Following the arguments by Schumpeter (1911), Shaw (1973), and McKinnon (1973), there has been a number of empirical studies on the relationship between the FD and growth. Indeed, some studies (like Christopoulos & Tsionas, 2004; Hsueh et al., 2013; Kar et al., 2011) find evidence in support of the supply-leading hypothesis. Huang and Lin (2009) reexamined the finance–growth nexus using a novel threshold regression with the instrumental variables approach and found that FD has a positive effect on economic growth especially in low-income countries. Bist (2018) investigated the long-run relationship between FD and economic growth using panel unit root and panel cointegration analysis in 16 selected African and non-African low-income countries. The study found that FD proxied by credit to private sector has a long-run positive and significant impact on growth. Ncanywa and Mabusela (2019) determined the influence of financial sector development on economic growth in five selected sub-Saharan African countries. By using panel cointegration, their study found that bank credit to the private sector and liquid liabilities will contribute positively to the growth of the economy.

However, Naceur and Ghazouani (2007) propose that the relationship between the FD and growth can be less general than the traditional literature suspected. Favarra (2003) revisited the finance–growth nexus using a variety of econometric methods on a panel of 87 countries. His results do not point to a robust positive linkage between finance and growth. In the same vein, Naceur and Ghazouani (2007) found evidence of a positive effect of stock market development but a meaningful negative effect of bank development on growth on a sample of 10 MENA countries. Barajas et al. (2011) confirm the negative effect of private credit on growth in MENA region. Ngongang (2015) sought to analyze the relationship between FD and economic growth, using a sample of 21 SSA countries during the period 2000–2014, and found that the absence of the relationship between FD and economic growth might be linked to the underdeveloped financial systems of sub-Saharan African economies. Based on the inconclusiveness in the empirical literature, our thinking is that since economic growth is endogenous, the relationship between FD and economic growth may depend on certain absorptive capacities like telecommunication infrastructure. Thus, from the arguments advanced by the literature reviewed so far, we hypothesise that, without sound absorptive capacities:

H₁: There is a significant positive effect of financial development on economic growth in SSA economies, but such effect may be weak.

2.3.2. *The financial development and economic growth nexus: the role of telecommunication infrastructure*

Recently, telecommunication has become increasingly blatant in SSA economies. Lee et al. (2012) emphasize that both mobile cellular and land-line telephone are important to the growth of SSA economies. Also, Donou-Adonsou et al. (2016) find that fixed-line and mobile telecommunications have a positive and significant impact on the economic growth of SSA economies. Yet, the complementary role of telecommunications in the relationship between FD and economic growth in Sub-

Saharan Africa has not been the topic of many theoretical and empirical contribution discussion. The literature on finance–growth nexus and telecommunications–growth nexus is well developed, but very few studies investigate the absorptive capacity role of telecommunication infrastructure in the relationship between FD and economic growth. Claessens et al. (2002) earlier provided some evidence that developing countries need to promote ICT sector and exploit opportunities for leapfrogging even with the weak financial system. Shamim (2007) also finds that a financial sector, developed by better ICT infrastructure, is positively associated with long-run economic growth in the MENA region. Kpodar and Andrianaivo (2011) investigated whether ICT diffusion is one of the channels through which financial inclusion influences economic growth and found that the effect of financial inclusion on growth is more important for countries with a high level of mobile phone development. Based on the ongoing empirical discourse, telecommunication strategies could be relevant in explaining how FDs contribute to economic growth. This provides a firm basis on which to undertake a more focused investigation of how several telecommunication infrastructures may be deployed as effective instruments in financial sector policies and programme for achieving economic growth in low- and middle-income countries like SSA countries. Based on the ongoing discussions, we hypothesis that

H₂: The higher (lower) the improvement in telecommunication infrastructure, the stronger (weaker) the relationship between financial development and economic growth in SSA economies.

3. Methodology

3.1. Theoretical framework

To determine the effect of FD and telecommunications on economic growth, this study adopts the endogenous growth model. Makki and Somwaru (2004) specify a general production function to be estimated as:

$$Y_{it} = A_{it}K_{it}^{\alpha} \tag{1}$$

where y_{it} and k_{it} are real GDP per capita and capital (as represented by FD) respectively, of country i at year t . A_{it} represents the total factor productivity (TFP) and it captures the growth in total output not due to FD but determined by other factors.

3.2. Linking theoretical and empirical frameworks

Based on the central aim of this study, and the endogenous growth literature which allows other theoretically informed factors to affect real GDP per capita possibly through the TFP, we assume A_{it} to be a number of factors that have been identified by empirical literature to affect economic growth. The study assumes A_{it} to be a function of the following: (i) the preexisting economic conditions (captured by the lag of real GDP per capita), (ii) telecommunication infrastructure ($TELE_{it}$), (iii) interaction effect of FD and telecommunications ($FD_{it} * TELE_{it}$), and (iv) a vector of control variables of economic growth (Z_{it}) comprising government spending ($GOVEXP_{it}$); a measure of population growth ($POPGROW_{it}$); trade openness ($Trade_{it}$); natural resources ($NATRES_{it}$); gross capital formation (GCF_{it}); school enrolment ($School_{it}$), and inflation rate (INF_{it}).

3.3. Model specification

From the link between the theoretical and empirical model, the study specifies the empirical model through a number of steps. First, A_{it} can be stated in the following functional form:

$$A_{it} = B(y_{it-1})^{\beta} e^{\lambda TELE_{it} + \theta(FD_{it} + TELE_{it}) + \gamma Z_{it}} \tag{2}$$

Putting Equation (2) into Equation (1) and taking the natural logarithm of both sides, the study obtains the following econometric equation:

$$\ln y_{it} = \sigma + \beta \ln y_{it-1} + \delta FD_{it} + \lambda TELE_{it} + \theta (FD_{it} * TELE_{it}) + \gamma Z_{it} + \eta_i + \mu_t + \varepsilon_{it} \quad (3)$$

for $i = 1, 2, \dots, N$ and $t = 2, 3, \dots, T$

where the intercept, $\sigma = \ln B$, η_i and μ_t represent the full set of unobserved country-specific effects and time-specific effects, respectively. ε_{it} is the error term. i is the country index, whereas t is the time index. All other variables are as previously defined. By deducting $\ln y_{it-1}$ from both sides of Equation (3), the study arrives at the following linear dynamic panel growth equation:

$$\Delta \ln y_{it} = \sigma + \pi \ln y_{it-1} + \delta FD_{it} + \lambda TELE_{it} + \theta (FD_{it} * TELE_{it}) + \gamma Z_{it} + \eta_i + \mu_t + \varepsilon_{it} \quad (4)$$

for $i = 1, 2, \dots, N$ and $t = 2, 3, \dots, T$

where $\Delta \ln y_{it}$ denotes log difference of real GDP per capita, measuring economic growth. The coefficient of $\Delta \ln y_{it-1}$ ($\pi = \beta - 1$) denotes the speed of conditional convergence of real GDP per capita to its long-run or steady-state level. In the above econometric model, the coefficients needed to examine the impact of FD on economic growth in the presence of telecommunications are δ and θ . Similarly, λ and θ are needed to examine the impact of TELE on economic growth in the presence of FD. The vector coefficients (γ) measure the impact of the control variables considered. η_i and μ_t are as previously defined, and ε_{it} is the error term.

It is important to note that the presence of the interaction term in Equation (4) could alter the interpretation of the estimated coefficients, δ and λ . This is so because Equation (4) is not just an additive equation but an interaction equation which makes (FD_{it}) and $(TELE_{it})$ dependent on each other. Therefore, the effects of FD on economic growth at any given time period are conditional on reasonable values of TELE. Thus, to make the interpretation of the moderating effect meaningful, the study computes the net effects of FD on economic growth. Thus, the study follows the approach of Kromrey and Foster-Johnson (1998), Echambadi and Hess (2007), and Dalal and Zickar (2012) to estimate and compute net effects. The conditional effect is computed by taking the partial derivative of economic growth with respect to FD as specified in the following equation $\frac{\partial \ln y_{it}}{\partial FD_{it}} = \lambda + \theta * TELE_{it}$.

3.4. Estimation technique

The dynamic econometric Equation (4) cannot be estimated by the pooled OLS estimator as this bias will increase the value of the right-side lagged real GDP per capita variable. This is so because, in this model, there is a positive correlation between the unobserved country-specific effects and the lagged real GDP per capita. One way to address the issue specifically by removing the country-specific effects is the use of fixed-and random-effects methods. Notwithstanding, the model cannot also be estimated by the aforementioned techniques as there is presence of endogeneity and/or simultaneity bias. In the context of this study, FD and telecommunications (TELE) are considered as potentially endogenous. This is so because, in the finance-growth literature, the study notes that FD affects economic growth. Similarly, as economic growth is a determinant of telecommunications in that telecommunication infrastructure are attracted to countries with sustained growth performance (Wolde-Rufael, 2007). Equally, while telecommunications may attract FD as such, liberal environment creates a new and large market for the financial sector to operate, and economic growth also impacts FD (Kaushal & Pathak, 2015). Therefore, if these reverse causalities not modeled as part of Equation (4) are true, then an estimation of Equation (4) would be spurious.

To overcome these, Arellano and Bover (1995) and Blundell and Bond (1998) developed the system-GMM (SGMM) estimator. The estimator helps increase efficiency as it gives more efficient and less biased estimates. Specifically, the study makes use of the two-step SGMM as it gives efficient estimates and is more robust to heteroscedasticity and autocorrelation than the one-step estimator. Further, as argued by Arellano and Bond (1991), consistent estimates from this estimation method are highly possible provided time-series dimension (T) is lesser than the cross-sectional dimension (N),

which in this study $T = 22$ and $N = 44$. The SGMM estimator also deals with the endogeneity problem. Since the consistency of the SGMM estimator hinges crucially on the validity of the instruments, the study utilizes the Sargan test of overidentifying restrictions to check whether instruments used are valid or not. Failure to reject the null hypothesis of instrument validity assumed by this test means instruments are valid. Similarly, and as expected that there should be no second-order autocorrelation among the disturbance terms, the study uses the Arellano–Bond test of autocorrelation for second-order serial correlations in the first-differenced errors. Failure to reject the null hypothesis that the disturbance term is uncorrelated means that the SGMM estimator is consistent.

3.5. Data and measurements

The study considers time-series data of 44 sub-Saharan African countries from 1996 to 2017 for the analysis. The countries include Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Central African Republic, Chad, Comoros, Congo, Dem. Rep., Congo, Rep., Cote d’Ivoire, Equatorial Guinea, Eritrea, Eswatini, Ethiopia, Gabon, The Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Seychelles, Sierra Leone, South Africa, Sudan, Tanzania, Togo, Uganda, Zambia, and Zimbabwe. The choice of this period was informed by the availability of data for the variables of interest. The data used in this study were secondary annual data drawn from the World Development Indicators published by World Bank and ITU World Telecommunications Indicators published by the International Telecommunication Union. These sources provide quantitative data which could be easily retrieved from the archives to provide data in the interest of this study.

3.5.1. Measuring economic growth

We measure economic growth by real GDP per capita. The economic strength of every economy lies in its GDP. Thus, measuring economic growth by the GDP per head is especially crucial and comprehensive for developing economies such as that of SSA. Developing countries are usually saddled with relatively low levels of growth and therefore growth per head (*also known as growth for all*) will be a more accurate measure of economic growth (Barro & Sala-I-Martin, 1995). In essence, the GDP per capita (current US\$) from the World Development indicators is used in this study.

3.5.2. Measuring financial development

We measure FD by domestic credit to private sector. As defined by the World Bank, “Domestic credit to private sector as a proxy for financial development refers to financial resources provided to the private sector by financial corporations, such as through loans, purchases of non-equity securities, and trade credits and other accounts receivable, that establish a claim for repayment”. We employ this proxy because the private sector is said to be the engine of economic growth for several developing economies like those in SSA (Obeng-Amponsah et al., 2019).

3.5.3. Measuring telecommunication infrastructure

In this study, we limit ourselves to telecommunication infrastructure that can complement the human capacity in the financial sector and also directly connected to productivity growth. Earlier studies on telecommunications have focused on the fixed telephone line and its importance to productivity growth, but there has been a large increase in people connected to the telephone network since the introduction of cellular telephones in the worldwide market. Further, telephone banking and mobile banking have become increasingly blatant in the financial sector of developed countries. Thus, we find it essential to include both cellular telephones and fixed telephones as part of telecommunication infrastructure to examine their relevance in the financial sector of developing countries like that of SSA.

Due to the importance of the Internet in today’s society, we include a variable that measures this development in finance. We, therefore, employ the number of Internet subscribers as another proxy for telecommunication infrastructure. It is a more precise indicator of users than access; it does capture the fact that numerous people obtain their access through work, school, as a member of

a household, or from community locations such as cyber cafés. Finally, we employ fixed broadband subscriptions as the last proxy for telecommunication infrastructure. Fixed broadband subscriptions refer to fixed subscriptions to high-speed access to the public Internet (a TCP/IP connection), at downstream speeds equal to, or greater than, 256 kbit/s. We include this because fixed broadband is increasingly becoming common in the telecommunication industry of many developing countries and thus the need to examine its usefulness in the financial sector of SSA economies.

3.5.4. Control variables

We control for a number of variables due to the relevance in a standard economic growth model. From theory, economic growth (the rate of output) is influenced by capital and labour. Thus, we employ population growth and school enrollment as quantitative and qualitative measures of labour, respectively. Further, we employ natural resources, gross capital formation, and government expenditure as measures of capital. Finally, we control for inflation and trade openness because they are crucial to growth performance, given their impact on key macroeconomic variables.

Therefore, a summary of the dataset employed in this research work, unit of measurements, and sources of the data are presented in [Table 1](#).

4. Empirical results and analysis

In this section, we present and discuss the results from the empirical analysis. First, we present the descriptive statistics, which enable us to gain a summary view of the data which was used in the empirical analysis. Thereafter, we examine the pairwise correlation among the variables. This is essential as to aid us minimize issues of multicollinearity. Finally, we present empirical analysis to establish the role telecommunication infrastructure plays in the relationship between FD and economic growth.

Table 1. Description of variables and sources of data

Variable	Measurement	Data source
Economic growth	GDP per capita	World Development Indicators 1996–2017
Financial development	Domestic credit to private sector	World Development Indicators 1996–2017
Telecommunications (mobile cellular)	Mobile cellular subscriptions (per 100 people)	International Telecommunication Union (ITU) 1996–2017
Telecommunications (fixed telephone)	Fixed telephone subscriptions (per 100 people)	International Telecommunication Union (ITU) 1996–2017
Telecommunications (Internet)	Individuals using the Internet (% of population)	International Telecommunication Union (ITU) 1996–2017
Telecommunications (fixed broadband)	Fixed broadband subscriptions (per 100 people)	International Telecommunication Union (ITU) 1996–2017
Trade openness	Trade (% of GDP)	World Development Indicators 1996–2017
Natural resources	Total natural resources rents (% of GDP)	World Development Indicators 1996–2017
Gross capital formation	Gross capital formation (current US\$)	World Development Indicators 1996–2017
Government consumption expenditure	General government final consumption expenditure (% of GDP)	World Development Indicators 1996–2017
School enrollment	School enrollment, secondary (% gross)	World Development Indicators 1996–2017
Population growth	Population growth (annual %)	World Development Indicators 1996–2017
Inflation rate	Inflation, CPI	World Development Indicators 1996–2017

4.1. Descriptive statistics

The descriptive statistics presented in this section is the mean, which is the measure of average, the standard deviation which is the measure of the degree of variability, the minimum and the maximum values for each variable, as well as the number of observations.

Table 2 presents descriptive statistics. The average GDP per capita is US\$1,770.783 within the ranges of US\$102.645 and US\$22,742.38. Further, the statistics show that the average per capita income in SSA is low because the World Bank classifies countries with per capita income of less than US\$1,036 as low-income countries and countries with a per capita income of US\$1,036 to \$4,085 as the lower-middle-income countries. With reference to World Bank classification, the study found that, on average, SSA countries fall into the lower-middle income category (World Bank, 2017). Over the period 1996–2017, FD to SSA averaged approximately 18.474% of GDP within the range of 0.40% and 160.13%. This indicates that FD has been an important source of development for SSA countries.

The results also suggest that telecommunication in SSA as a whole is weak with an average of approximately 0.668% of fixed broadband subscriptions (per 100 people) with ranges of 0% to 19.45%, 0.588% of fixed telephone subscriptions (per 100 people) within ranges of 0% to 32.65%, and individuals using the Internet (% of the population) accrued 6.422% within the ranges of 0% to 58.77%. Population growth which represents an annual population growth rate of a country indicated an average of approximately 2.579% within the range of -2.629% and 7.918%. General government final consumption expenditure (% of GDP) which is measured by all government current expenditures for purchases of goods and services indicated an average of approximately 14.905% within the range of .911% and 69.543%.

Gross capital formation (current US\$) which is measured by outlays on additions to the fixed assets of the economy plus net changes in the level of inventories accrued an average of approximately 5.08e+09% within the range of -2.06e+07% and 8.98e+10%. Moreover, the data suggest that SSA is

Table 2. Descriptive statistics of the regressand and the regressor

Variable	Obs.	Mean	Std.Dev.	Min.	Max.
GDPPC	958	1770.783	2930.755	102.645	22,742.38
DCPS	918	18.474	23.442	.403	160.125
Mobile100	963	33.973	39.596	0	176.575
Telephone100	960	2.588	5.502	0	32.653
Internet	949	6.422	10.431	0	58.77
FB100	533	.668	2.336	0	19.445
POPGROW	962	2.579	0.918	-2.629	7.918
Trade	917	72.467	37.555	17.859	311.354
NATRES	954	12.985	12.294	.001	84.24
GCF	910	5.080	1.210	-2.060	8.980
GOVEXP	895	14.905	7.255	.911	69.543
School	572	39.331	22.483	5.21	114.381
INF	856	15.781	145.546	-9.616	4145.106

GDPPC represents real GDP per capita, FD represents financial development, Mobile100 represents first proxy of telecommunication which is measured by mobile telephone service that provide access to the PSTN using cellular technology, and FB100 represents telecommunication which is measured by fixed broadband subscriptions (per 100 people) as a second proxy. Telephone100 represents telecommunication which is measured by fixed telephone subscriptions (per 100 people) as a third proxy. Internet100 represents telecommunication which is measured by individuals using the Internet (per 100 people) as a fourth proxy. POPOGROW represent annual population growth rate. Trade represents Trade openness as measured by the trade (imports and exports) as a percentage of GDP. NATRES represents total natural resources rents (% of GDP). GCF represents gross capital formation (current US\$), and GOVEXP represents general government final consumption expenditure (% of GDP). SCHOOL represents school enrollment, secondary (% gross) which is measured by ratio of total enrollment, regardless of age, to the population. INF represents inflation.

highly open to international trade, with the sum of exports and imports averaging approximately 72.467% within the range of 17.859% and 311.354% of the total GDP. Human capital, as measured by the second school enrollment, registers a mean of 22.48%. Thus, the level of human development in SSA is below 50%, which indicates that the level of human development in Africa is very low (Agbloyor et al., 2016). Finally, inflation recorded an average of 15.781%.

4.2. Correlation results

Table 3 presents the pairwise correlation matrix for all the variables employed in our empirical analysis. It could be observed that there could be no multicollinearity problems because the independent variables do not exhibit a high correlation of 0.9 as suggested by Kennedy (2008). Although not up to the coefficient of 0.90, there are some few instances the telecommunication infrastructure proxies exhibit a high pairwise correlation with each other. This is probably due to the fact that they are all telecommunication infrastructure. Thus, in the regression analysis, they do not enter the same model.

4.3. Unit root tests

To assess whether there are structural breaks in the dataset, we perform a unit root or stationary test. There are a variety of unit root tests for panel data. However, taking into consideration the unbalanced nature of the panel dataset, the most appropriate unit root test that will suffice is the Fisher-ADF (Choi, 2001). The Fisher-ADF test has the null hypothesis that all the panels contain a unit root and alternative hypothesis that all the panels do not contain a unit root. Table 4 presents the stationary results for the dataset at levels.

From the results in Table 4, at both 5% and 10% significant levels, all four of the tests strongly reject the null hypothesis that the panels contain unit roots. Choi's (2001) simulation suggests that the inverse normal Z statistic offers the best trade-off between size and power, and he recommends using it in applications. Based on inverse normal Z, apart from FB100, there is no doubt about the stationarity of all the variables. However, this does not pose any problem because the stationarity of FB100 is significant at the 10% significance level. On the overall, there is an overwhelming evidence that all the variables employed in the regression analysis are stationary at levels.

4.4. Regression results on relationship among financial development, telecommunications, and economic growth in SSA

The hypotheses of this study are tested in this subsection. The regression results are presented in Tables 5 and A1. Table 5 presents the results of the separate effects of FD and telecommunications on the economic growth of SSA economies. Table A1 presents the results for the moderating role of telecommunications in the relationship between FD economic growths of SSA economies. Domestic credit to the private sector as a proxy for FD is employed in this section. The proxy has been used thoroughly in the literature. According to Sassi and Goaid (2013), FD measures bank development and includes only credit to private sectors, which is the engine of growth in developing countries. Table 5 shows the empirical individual effects of FD and telecommunications on the economic growth of SSA economies. The Model 1–model 4 in Table 5 present the effect of FD as well as telecommunication infrastructure on the economic growth of SSA countries.

At a significant level of 0.1%, the results in Table 5 (model 1—model 4) show a meaningful positive effect of financial sector development on economic growth on SSA countries. This finding may be partly explained by the competition and innovation nature in SSA banking systems. Our results support the predictions of the supply-leading hypothesis, endogenous growth models, and the results of some empirical studies such as Choong et al. (2003) and Christopoulos and Tsionas (2004). Therefore, SSA countries need to increase the innovational behavior towards the banking system, and this would boost the economic growth of their economies. Also, in order to increase economic growth, SSA economies need to improve the quality of the banking system by strengthening its financial sector policies.

Table 3. Correlation analysis

	GDPPC	DCPS	Mobile100	telephone100	Internet100	FB100	POP~	Trade	NATRES	GCF	GOVEXP	School	INF
GDPPC	1												
DCPS	0.5064	1											
Mobile100	0.6035	0.4053	1										
telephone100	0.8364	0.566	0.4667	1									
Internet100	0.7457	0.424	0.8433	0.6218	1								
FB100	0.8078	0.3643	0.5845	0.7706	0.729	1							
POPGROW	-0.6153	-0.5873	-0.4331	-0.7345	-0.5417	-0.5250	1						
Trade	0.632	0.0786	0.4149	0.5709	0.4141	0.4987	-0.4509	1					
NATRES	-0.2662	-0.2759	-0.1545	-0.4035	-0.3754	-0.298	0.4634	0.0248	1				
GCF	0.1898	0.5123	0.2193	-0.0086	0.2155	-0.0506	-0.1234	-0.2478	0.0215	1			
GOVEXP	0.2951	0.1386	0.2393	0.2228	0.2204	0.2076	-0.3182	0.5455	-0.0971	-0.1598	1		
School	0.742	0.7214	0.6649	0.7385	0.6931	0.5564	-0.7459	0.4106	-0.4368	0.3007	0.2027	1	
INF	-0.0406	-0.1133	-0.1187	-0.1026	-0.0217	-0.1352	-0.0013	-0.0522	0.0549	0.1425	-0.1793	-0.0053	1

GDPPC is the real GDP per capita. DCPS refers to domestic credit to private sector. Mobile100 represents mobile phones subscriptions (per 100 people). FB100 refers to fixed broadband subscriptions (per 100 people). Telephone100 represents fixed telephone subscriptions (per 100 people). INTRNT is the individuals using the Internet (% of population). POPGROW represents population growth. Trade represents trade openness. NATRES represents total natural resources rents (% of GDP). GOVEXP represents general government final consumption expenditure (% of GDP). GCF represents gross capital formation (current US\$). SCHOOL represents school enrollment, secondary (% gross). INF represents inflation.

Table 4. Stationarity tests of the variables at levels

Variable	Inverse chi-squared	Inverse normal	Inverse logit	Modified inv. chi-squared
GDPPC	182.6421 [0.0000]	-7.2221 [0.0000]	-6.8851 [0.0000]	7.1339 [0.0000]
DCPS	222.3665 [0.0000]	-8.5127 [0.0000]	-8.5582 [0.0000]	10.1283 [0.0000]
Mobile100	230.7448 [0.0000]	-7.5555 [0.0000]	-8.1840 [0.0000]	10.7598 [0.0000]
Telephone100	284.7351 [0.0000]	-11.0687 [0.0000]	-11.4868 [0.0000]	14.8295 [0.0000]
Internet100	151.674 [0.0000]	-2.9319 [0.0017]	-3.3401 [0.0005]	4.7996 [0.0000]
FB100	96.1229 [0.0801]	-1.5333 [0.0626]	-1.4727 [0.0712]	1.4510 [0.0734]
POPGROW	461.4254 [0.0000]	-15.7446 [0.0000]	-19.0135 [0.0000]	28.1480 [0.0000]
Trade	222.9995 [0.0000]	-8.6265 [0.0000]	-8.6901 [0.0000]	10.4461 [0.0000]
NATRES	270.3047 [0.0000]	-10.2832 [0.0000]	-10.7120 [0.0000]	13.7417 [0.0000]
GCF	104.8081 [0.0821]	-2.0580 [0.0198]	-2.0044 [0.0231]	1.4341 [0.0758]
GOVEXP	247.0049 [0.0000]	-9.6814 [0.0000]	-9.9640 [0.0000]	12.5761 [0.0000]
School	131.7553 [0.0000]	-5.2932 [0.0000]	-5.8041 [0.0000]	7.8206 [0.0000]
INF	410.3576 [0.0000]	-14.7497 [0.0000]	-17.1930 [0.0000]	25.1790 [0.0000]

P-Values in squared parentheses. The values that are outside the parentheses are p, Z, L*, and Pm values of Inverse chi-squared, Inverse normal, Inverse logit and Modified inv. chi-squared, respectively.

GDPPC represents real GDP per capita, FD represents financial development, Mobile100 represents first proxy of telecommunication which is measured by mobile telephone service that provide access to the PSTN using cellular technology, FB100 represents telecommunication which is measured by fixed broadband subscriptions (per 100 people) as a second proxy. Telephone100 represents telecommunication which is measured by fixed telephone subscriptions (per 100 people) as a third proxy. Internet100 represents telecommunication which is measured by individuals using the Internet (per 100 people) as a fourth proxy. POPOGROW represents annual population growth rate. Trade represents trade openness as measured by the trade (imports and exports) as a percentage of GDP. NATRES represents total natural resources rents (% of GDP). GCF represents gross capital formation (current US\$), and GOVEXP represents general government final consumption expenditure (% of GDP). SCHOOL represents school enrollment, secondary (% gross) which is measured by ratio of total enrollment, regardless of age, to the population. INF represents inflation

At the same significant level of 0.1%, the results given in Table 5 (model 1–model 4) show that some of the coefficients of telecommunication proxies were negative, while others were positive. This is due to the inefficient utilization of the telecommunications industry in the region. Specifically, mobile telephone and fixed broadband have a significant and positive effect on economic growth. This is in accordance with the findings of Sassi and Goaid (2013), which highlights that telecommunication is essential to growth, necessary to develop a country's productive capacity in all sectors of the economy, links a country with the global economy, and ensures competitiveness. Meanwhile, Inthe ernet had a negative effect on economic growth. This may probably due to the fact that the use of telephone technology (fixed and mobile) is widespread as compared to the use of personal computers and Inthe ernet (Kpodar & Andrianaivo, 2011).

Table 5. Linear causal link of financial development and telecommunication on growth system-GMM estimates, two-step result-dependent variable GDP per capita growth

	Model 1	Model 2	Model 3	Model 4
GDPPC(-1)	1.007*** (0.004)	0.908*** (0.003)	0.975*** (0.003)	0.977*** (0.007)
DCPS	1.996*** (0.305)	2.515*** (0.154)	3.476*** (0.153)	3.782*** (0.757)
Mobile100	4.458*** (0.105)			
Telephone100		35.77*** (1.643)		
Internet 100			-10.20*** (0.318)	
FB100				18.35*** (1.756)
Contrl Var				
POPGOW	-8.291*** (1.439)	28.42*** (2.604)	-19.52*** (2.525)	-80.41*** (1.499)
Trade	5.083*** (0.139)	4.135*** (0.115)	4.554*** (0.231)	4.933*** (0.268)
NATRES	18.19*** (0.834)	20.97*** (1.072)	17.65*** (0.755)	34.45*** (1.666)
GCF	4.900*** (3.410)	3.180*** (2.530)	3.560*** (1.780)	-1.830*** (3.850)
GOVEXP	-17.24*** (0.748)	-15.77*** (0.511)	-7.925*** (1.024)	-19.36*** (1.819)
School	9.423***	8.120***	9.324***	11.340***

(Continued)

Table 5. (Continued)

	Model 1	Model 2	Model 3	Model 4
INF	(0.287) -24.02*** (0.256)	(0.303) -25.04*** (0.286)	(0.314) -20.28*** (0.414)	(0.976) -32.79*** (0.275)
_cons	-368.2*** (18.87)	-397.4*** (23.17)	-555.6*** (18.33)	-702.3*** (52.87)
Diagnostics				
Wald Test	867,857.79	3.58e+06	5.94e+06	1.74e+06
Prb.(Wald)	0.0000	0.0000	0.0000	0.0000
AR(1)z	-1.7523	-1.7674	-1.6873	-1.644
P-value	0.0797	0.0772	0.0916	0.1002
AR(2)z	-1.3531	-1.5043	-5.0629	-5.5725
P-value	0.1760	0.1325	0.6127	0.5774
Sargan chi2	28.69596	29.81876	28.71529	26.17824
Prb.(Sargan)	0.8120	0.9216	0.8211	0.8021
Obs	440	441	436	276

Standard errors in parentheses.

* represents $p < 0.05$, ** represents $p < 0.01$, *** represents $p < 0.001$.

GDPPC represents real GDP per capita, FD represents financial development, Mobile100 represents first proxy of telecommunication which is measured by mobile telephone service that provide access to the PSTN using cellular technology, and FB100 represents telecommunication which is measured by fixed broadband subscriptions (per 100 people) as a second proxy. Telephone100 represents telecommunication which is measured by fixed telephone subscriptions (per 100 people) as a third proxy. Internet100 represents telecommunication which is measured by individuals using the Internet (per 100 people) as a fourth proxy. POPOGROW represents annual population growth rate. Trade represents trade openness as measured by the trade (imports and exports) as a percentage of GDP. NATRES represents total natural resources rents (% of GDP). GCF represents gross capital formation (current US\$), and GOVEXP represents general government final consumption expenditure (% of GDP). SCHOOL represents school enrollment, secondary (% gross) which is measured by ratio of total enrollment, regardless of age, to the population. INF represents inflation. The diagnostics section presents the values of the Wald test, probability values of the Wald test, z values of AR(1), probability of z values of AR(1), probability of z values of AR(1), probability of z values of AR(1), and the number of observations in order as shown in diagnostics section of Table 4.

The lagged form of the economic growth variable was included in all the models to allow for the partial adjustment of economic growth to its long-run equilibrium value. This is because economic growth is a process, and thus, previous levels of economic growth affect current levels. It can be seen from all the regression results that the coefficient of the lag economic growth variable was positive and significant. The positive sign of the coefficient means that economic growth of SSA economies in previous periods contributes positively to that of the current periods. The significance of the lagged dependent variable also shows that the SGMM is an appropriate estimator, and the empirical results can be relied upon for statistical inference. Finally, most of the control variables were found to be significant predictors of economic growth in SSA.

4.5. The moderating effect of telecommunication infrastructure on the relationship between financial development and economic growth in SSA

In this section, we present the results on the moderating effect of telecommunication infrastructure on the relationship between FD and economic growth in SSA. This result enables us to explain why economies that are characterized by high levels of telecommunication infrastructure in the financial sector may better enhance the growth of the real sector as compared to economies with low levels of telecommunication infrastructure in the financial sector. [Table A1](#) shows the moderating role played by each of the telecommunication infrastructures in the relationship between FD and economic growth in SSA (see model 5—model 8).

The results from [Table A1](#) (models 5—model 8) indicate the effect of the interaction term between FD and telecommunications on the economic growth of SSA economies. The introduction of the interaction term (INTER 1) causes the FD variable to attain a coefficient of 4.407 as compared to model 1 results ($\beta = 1.996$) in [Table 5](#). Notwithstanding, the interacting term itself is negatively significant. Further, the introduction of the interaction term (INTER 2) causes the FD variable to attain a coefficient of 8.831 as compared to model 2 results ($\beta = 2.515$) in [Table 5](#). Again, the interaction term INTER 2 is negative and significant.

The introduction of the interaction term INTER 3 causes the FD variable to attain a significant coefficient of 3.696 as compared to a coefficient of 3.476 in model 3 of [Table 5](#). Also, the coefficient of INTER 3 is insignificant.

Finally, the introduction of the interaction term INTER 4 causes the FD variable to attain a coefficient of 8.563 as compared to a coefficient of 3.782 in model 4 of [Table 5](#). Also, the coefficient of INTER 4 is negative and significant. These results have far-reaching implications. First, we observe that the introduction of the interaction terms in all the models led to a stark improvement in the coefficient of FD across all the results in [Table A1](#). However, the interaction terms were negative and in one instance insignificant. This could probably mean that telecommunication infrastructure could generally enhance the capacity of the financial sector to engineer high levels of economic growth. Despite this, the relatively low level of technological advancement in SSA may drag the efforts of the financial sector if more investments are not made in the telecommunication infrastructure. We, therefore, compute the marginal effects to assess the net effects of FD on economic growth, conditional on the four proxies of telecommunication infrastructure.

4.5.1. Marginal effects

In [Table A1](#), telecommunication penetration is proxied by the penetration of mobile phones, fixed telephone lines, Internet users, and fixed broadband on growth. Net effects are computed in order to assess the overall effect from the interaction between FD and telecommunication variables. The net effect from the interaction between FD and mobile phones is computed using the following equation:

$$\frac{\partial Y_{it}}{\partial TELE_{it-1}} = 4.407 - 0.0279 (TELE_{it-1})$$

In the computation, the mean value of mobile phones is 33.973; the unconditional effect of FD is 1.996, while the conditional effect from the interaction between FD and mobile phones is 3.459. The conditional effect ($\beta = 3.459$) is greater than the unconditional effect ($\beta = 1.996$).

Table 6. Interaction effect of financial development and telecommunications on growth system-GMM estimates, two-step result-dependent variable GDP per capita growth

	M13	M14	M15	M16
GDPPC(-2)	1.006*** (0.00541)	0.901*** (0.00367)	0.977*** (0.00361)	1.006*** (0.00701)
DCPS(-1)	4.667*** (0.648)	5.343*** (0.409)	3.041*** (0.468)	8.015*** (0.815)
Mobile100(-1)	-3.438*** (0.412)			
Inter1(-1)	-0.0438*** (0.00705)			
Telephone100(-1)		53.62*** (1.692)		
inter2(-1)		-0.304*** (0.0245)		
Internet100(-1)			-11.25*** (0.739)	
Inter3(-1)			-0.0527*** (0.00928)	
FB100(-1)				51.01*** (4.092)
Inter4(-1)				-1.208*** (0.0943)
Control Var				
POPGROW(-1)	-5.105* (2.064)	39.81*** (2.608)	-7.534*** (2.270)	-72.92*** (2.729)
Trade(-1)	5.119*** (0.169)	4.218*** (0.227)	4.989*** (0.277)	3.021*** (0.298)
NATRES(-1)	18.81*** (0.688)	21.95*** (1.280)	17.50*** (1.068)	34.09*** (1.824)
GCF(-1)	1.06e-08*** (7.76e-10)	4.68e-09*** (7.93e-10)	8.55e-09*** (4.26e-10)	-7.03e-10 (8.47e-10)
GOVEXP(-1)	-13.93*** (0.830)	-20.17*** (1.219)	-6.129*** (1.507)	-17.86*** (2.074)
School(-1)	7.562*** (0.424)	7.936*** (0.541)	8.434*** (0.416)	2.705 (1.529)
INF(-1)	-23.99*** (0.361)	-25.14*** (0.600)	-20.61*** (0.604)	-29.58*** (0.176)
_cons	-413.7*** (36.99)	-516.9*** (23.17)	-546.1*** (25.45)	-179.7** (68.04)
Diagnostics				
Wald Test	3.47e+06	2.20e+06	6.37e+06	1.07e+08
Prb.(Wald)	0.0000	0.0000	0.0000	0.0000
AR(1):z	-1.7540	-1.7822	-1.7068	-1.6808
P-value	0.0794	0.0747	0.0879	0.0928
AR(2):z	-1.3664	-1.5852	-0.49728	-0.90024
P-value	0.1718	0.1129	0.6190	0.3680

(Continued)

	M13	M14	M15	M16
Sargan chi2	29.53382	30.46083	31.99431	23.70054
Prb.(Sargan)	0.9645	0.8957	0.8920	0.8834
N	426	425	422	263

Standard errors in parentheses.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

INTER 1 represents the interaction term between financial development and mobile phone subscriptions, INTER 2 represents the interaction term between financial development and fixed telephone subscriptions, INTER 3 represents the interaction term between financial development and Internet usage, and INTER 4 represents the interaction term between financial development and mobile-fixed broadband subscriptions. All the other variables in this table are the same as previously defined in [Table A1](#).

The marginal effect from the interaction between FD and fixed telephone is computed as from the following equation

$$\frac{\partial Y_{it}}{\partial TELE_{it-1}} = 8.831 - 0.474 (TELE_{it-1})$$

In the computation, the mean value of fixed telephones is 2.588; the unconditional effect of FD is 2.515, while the conditional effect from the interaction between FD and telephones is 7.60%. The conditional effect ($\beta = 3.588$) is greater than the unconditional effect ($\beta = 2.515$).

The marginal effect from the interaction between FD and Internet is computed as from the following equation

$$\frac{\partial Y_{it}}{\partial TELE_{it-1}} = 3.696 - 0 (TELE_{it-1})$$

In the computation, the mean value of Internet is 6.422; the unconditional effect of FD is 3.476, while the conditional effect from the interaction between FD and Internet is 3.696.

Finally, the marginal effect from the interaction between FD and fixed broadband is computed from the following equation

The marginal effect from the interaction between FD and fixed broadband is computed as from the following equation

$$\frac{\partial Y_{it}}{\partial TELE_{it-1}} = 8.563 - 0.871 (TELE_{it-1})$$

In the computation, the mean value of fixed broadband is 0.668, the unconditional effect of FD is 3.782, while the conditional effect for FD is 7.98. Based on the above, it is indubitable that building a more robust telecommunication infrastructure will boost the capacity of the financial sector to engineer the growth of the real sector. This finding is in line with the results of Datta and Agarwal (2004) as well as Kpodar and Andrianaivo (2011).

Finally, it is good to indicate that the Wald tests, the Arrelano and Bond serial correlation and the Sargan tests showed that all the models estimated in [Tables 5](#) and [A1](#) are adequate.

4.6. Robustness test

This study employs a robustness check to assess the sensitivity of the regression results. The robustness check of the results in [Tables 5](#) and [A1](#) is presented in [Tables A2](#) and [Tables 6](#), respectively, as shown in the appendix. The robustness check involves lagging all independent variables and regressing them on the dependent variable. The thinking here is that the level of economic growth could be improved based on

historical data, and thus, all the independent variables that are considered to have influence on the level of economic growth in our sampled economies will become evident next period onwards. The results of this technique are quite similar to those presented in Tables 5 and A1. Thus, it can be concluded that the quality of our results is not doubtful.

5. Conclusion and policy recommendations

5.1. Summary

The bivariate framework of the finance–growth nexus argument is inconclusive due to mixed empirical results. Existing literature concludes that telecommunication infrastructure could enhance the effectiveness of the financial sector as well as contribute to economic growth. This study further contributes to this argument by empirically testing the role played by telecommunication infrastructure in the relationship between FD and economic growth. By considering 44 SSA countries for the period 1996–2017, the SGMM results revealed that telecommunication infrastructure could enhance the capacity of the financial sector in terms of boosting economic growth. Further, the results revealed that building a robust telecommunication infrastructure will also have a direct effect on economic growth.

5.2. Contribution

Although the literature on economic growth theoretically links the economic growth to FD, the empirical discourse on the relationship between FD and economic growth is somewhat mixed. First, we contribute to the extant literature by examining how actual FD affects economic growth, taking into consideration the unique characteristics of SSA countries. Second, following the theoretical propositions of the supply-leading hypothesis and the endogenous growth theory, we examined how telecommunication infrastructure could boost the effect of FD on economic growth. Thus, another major contribution of our paper is that it examines how telecommunication infrastructure acts as absorptive capacities in the relationship between FD and economic growth in SSA.

5.3. Policy implications

The results reaffirm that telecommunication infrastructure in SSA reduces transaction costs associated with the financial system. Telecommunication infrastructure network enhances flexibility and contributes to the emergence of branchless banking services which improves financial services. This improvement in financial services for underserved people resolves the Solo growth theory and supply-leading hypothesis gap, especially in SSA economies, where the costs of distance and time are very high for formal banking services. Therefore, telecommunication infrastructure could improve access to credit, allow more efficient allocation of credit, facilitate financial transfers, and improve FD. Based on the findings, there should be a more robust financial system in the SSA economies. The most important policy implication of these study findings is that policy-makers should be focused on long-run policies to enhance the financial sector development in SSA countries. The policy-makers should also focus on formulating the policies that provide a favorable environment for the private sector to grow, like creating easy accessibility and improved financial sector efficiency that is good for sustainable growth in sub-Saharan Africa. Finally, government policies should aim at creating a conducive environment for the interaction of financial sector development and telecommunications by promoting sound framework and fundamental support of the development of mobile banking and branchless banking and creating favorable conditions for banks to develop new products. In this context, if the decision-makers increase the financial system and telecommunication infrastructures in the SSA economies, there would be consistent and reliable economic growth in SSA countries.

5.4. Limitations

Our study is associated with some limitations. We employed data from 44 SSA economies and, thus, generalizing the results to countries in SSA is quite puzzling. However, this was due to the data availability for the variables of interest. Since SSA economies have homogeneous characteristics, the results could conveniently be generalized for the entire sub-region.

5.5. Avenue for future research

The study analyzed the role of telecommunication infrastructure in the relationship between FD and economic growth for only SSA economies, which made the findings of the study one sided. This study suggests that future studies could focus on a comparative study for both developing and developed countries. Again, given that inclusive growth (“growth for all”) has become very important for developing countries, further studies could examine the role of telecommunication infrastructure in the relationship between FD and inclusive growth.

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APPENDIX

Table A1. Interaction effect of financial development and telecommunications on growth, system-GMM estimates, two-step results-dependent variable : GDP per capita growth

	Model 5	Model 6	Model 7	Model 8
GDPPC(-1)	1.012*** (0.005)	0.933*** (0.006)	0.977*** (0.003)	0.984*** (0.007)
DCPS	4.407*** (0.490)	8.831*** (0.514)	3.696*** (0.272)	8.563*** (0.561)
Mobile100	3.387*** (0.499)			
INTER1	-0.0279*** (0.008)			
Telephone100		60.86*** (0.993)		
INTER2		-0.474*** (0.022)		
Internet100			-9.575*** (1.240)	
INTER3			-0.009 (0.017)	
FB100				51.570*** (4.646)
INTER4				-0.871*** (0.006)
Control Var.				
POPGROW	-9.958*** (1.683)	33.42*** (2.448)	-18.31*** (1.384)	-80.39*** (2.630)
Trade	4.739*** (0.163)	2.439*** (0.244)	5.069*** (0.188)	4.075*** (0.300)
NATRES	18.20*** (0.727)	21.32*** (0.867)	17.27*** (1.001)	31.54*** (1.649)
GCF	6.170*** (6.300)	6.790 (7.100)	3.150*** (3.170)	-2.060*** (5.580)
GOVEXP	-15.11*** (0.789)	-22.74*** (0.814)	-9.760*** (1.402)	-16.52*** (1.405)
School	7.820*** (0.291)	4.984*** (0.403)	8.802*** (0.315)	5.693*** (0.693)
INF	-23.96***	-24.47***	-21.21***	-28.82***

(Continued)

Table A1. (Continued)

	Model 5	Model 6	Model 7	Model 8
	(0.368)	(0.288)	(0.508)	(0.254)
_cons	-372.2***	-239.3***	-508.7***	-545.0***
	(20.57)	(19.17)	(33.60)	(60.98)
Diagnostics				
Wald Test	1.90e+06	580,771.28	2.22e+06	7.53e+06
Prb.(Wald)	0.0000	0.0000	0.0000	0.0000
AR(1):z	-1.7564	-1.7849	-1.7091	-1.6631
P-value	0.0790	0.0743	0.0874	0.0963
AR(2):z	-1.3522	-1.6603	-5.0881	-7.7068
P-value	0.1763	0.0969	0.6109	0.4409
Sargan chi2	28.80049	29.12004	27.72625	25.56535
Prb.(Sargan)	0.9383	0.8751	0.8821	0.8783
Obs	272	441	436	276

Standard errors in parentheses.

*represents $p < 0.05$, ** represents $p < 0.01$, *** represents $p < 0.001$.

INTER 1 represents the interaction term between financial development and mobile phone subscriptions, INTER 2 represents the interaction term between financial development and fixed telephone subscriptions, INTER 3 represents the interaction term between financial development and Internet usage, INTER 4 represents the interaction term between financial development and mobile-fixed broadband subscriptions. All the other variables in this table are the same as previously defined in Table 4.

Table A2. Linear causal link of financial development and telecommunication on growth system-GMM estimates, two-step result-dependent variable GDP per capita growth

	M9	M10	M11	M12
GDPPC(-2)	0.995***	0.891***	0.972***	0.982***
	(0.00459)	(0.00425)	(0.00349)	(0.00493)
DCPS(-1)	0.799	1.547***	1.350*	3.367***
	(0.415)	(0.297)	(0.596)	(0.596)
Mobile100(-1)	-5.016***			
	(0.0921)			
Telephone100(-1)		38.87***		
		(1.287)		
Internet100(-1)			-14.06***	
			(0.425)	
FB100(-1)				-35.16***
				(1.261)
Control Var.				
POPGROW(-1)	-3.049	36.11***	-7.841***	-75.39***
	(2.288)	(1.994)	(1.794)	(1.533)
Trade(-1)	6.086***	5.088***	5.689***	5.431***
	(0.133)	(0.290)	(0.294)	(0.188)
NATRES(-1)	18.37***	21.98***	16.27***	36.46***
	(0.549)	(1.390)	(0.845)	(1.294)
GCF(-1)	8.26e-09***	4.98e-09***	7.86e-09***	-1.04e-09

(Continued)

	M9	M10	M11	M12
	(6.00e-10)	(6.05e-10)	(3.84e-10)	(9.10e-10)
GOVEXP(-1)	-18.44*** (0.867)	-16.70*** (0.888)	-10.79*** (2.198)	-17.74*** (1.218)
School(-1)	10.11*** (0.413)	9.401*** (0.531)	9.807*** (0.347)	9.868*** (1.289)
INF(-1)	-24.85*** (0.384)	-26.17*** (0.533)	-21.52*** (0.680)	-34.07*** (0.227)
_cons	-392.4*** (36.93)	-586.7*** (34.37)	-500.7*** (30.25)	-470.0*** (53.31)
Diagnostics				
Wald Test	1.23e+10	7.34e+06	3.42e+06	5.77e+06
Prb.(Wald)	0.0000	0.0000	0.0000	0.0000
AR(1):z	-1.7594	-1.7819	-1.72	-1.647
P-value	0.0785	0.0748	0.0854	0.0996
AR(2):z	-1.3268	-1.3739	-0.47946	-0.62186
P-value	0.1846	0.1695	0.6316	0.5340
Sargan chi2	28.09886	29.46975	30.11342	28.38043
Prb.(Sargan)	0.8992	0.8795	0.8994	0.8973
N	426	427	422	263

Standard errors in parentheses.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

GDPPC represents real GDP per capita, FD represents financial development, Mobile100 represents first proxy of telecommunication which is measured by mobile telephone service that provide access to the PSTN using cellular technology, FB100 represents telecommunication which is measured by fixed broadband subscriptions (per 100 people) as a second proxy. Telephone100 represents telecommunication which is measured by fixed telephone subscriptions (per 100 people) as a third proxy. Internet100 represents telecommunication which is measured by individuals using the Internet (per 100 people) as a fourth proxy. POPOGROW represents annual population growth rate. Trade represents trade openness as measured by the trade (imports and exports) as a percentage of GDP. NATRES represents total natural resources rents (% of GDP). GCF represents gross capital formation (current US\$), and GOVEXP represents general government final consumption expenditure (% of GDP). SCHOOL represents school enrollment, secondary (% gross) which is measured by ratio of total enrollment, regardless of age, to the population. INF represents inflation. The diagnostics section presents the values of the Wald test, probability values of the Wald test, z values of AR(1), probability of z values of AR(1), z values of AR(1), probability of z values of AR(1), probability of the Sargan test, and the number of observations in order as shown in diagnostics section of [Table A1](#).



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