Information Communications Technology and Economic Growth in Sub-Saharan Africa: A Panel Data Approach

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Abbreviations

ICT Information Communication Technology

SSA Sub-Saharan Africa

ITU International Telecommunication Union

UN United Nations

OECD Organization of Economic Cooperation and Development

Abstract

This research empirically analyzed the impact of mobile phone and the Internet in Sub-Saharan Africa (SSA) for the period of 2006-2015 using unbalanced panel data of 40 countries. We have employed the robust two-step system GMM. Results showed that growth in mobile phone penetration has contributed significantly to the GDP per capita of the region after controlling for a number of other variables. A 10% increase in mobile phone penetration results in a 1.2% change in real GDP per capita. Therefore, improving access to mobile phones will play a critical role in reducing the poverty level of the region through raising the per capita income of the population.

However, the Internet has not contributed to the per capita GDP during the study period. The insignificant impact of the Internet could be due to low penetration of the technology, low ICT skill of Internet users, lack of or insufficient local content on the global network, the relatively immature state of the technology in the region, and a possible misuse of it. Therefore, governments and other stakeholders should design policies that encourage expansion of the Internet until a critical mass of users is achieved. In addition to improving Internet access, policies which focus on ICT skill development and local content creation should also be designed and implemented. Donors and the international community should also give their support directly to those startups which focus on local content production and distribution.

Keywords: Sub-Saharan Africa, Mobile, Internet, GDP per capita, system GMM.

1. Introduction

Countries around the world have given a special attention to the development of telecommunications infrastructure. Roller and Waverman(2001) explained that telecommunications infrastructure can bring economic growth because it increases the demand for inputs which are used in its production and can reduce the transaction cost of firms. It can also have a positive impact because it can improve the production techniques of productive units. Other writers (e.g. Pohjola 2002) have also expressed the dual role of information communication technologies (ICT) in the new economy. ICT influences growth because it is both an output of the ICT using industries and it can enter into the ICT using industries as an input. Van Zon and Muysken(2005) have also explained the influence of ICT on productivity. According to the authors ICT influences productivity through its forward and backward linkages with the rest of the economy, through improving the production processes of the non-ICT sector, improving market processes, and facilitating the creation of new knowledge that enhances productivity. Some authors (e.g. Ding and Haynes 2006) argued that "unlike the traditional infrastructures, telecommunication infrastructure has a potential to lead "leapfrogging" development in developing countries (p. 281-282). Many international organizations including the United Nations also advice developing countries to deploy and use ICT in various sectors including health, agriculture, transport, education, government agencies, etc. Generally, it is believed that ICT has the potential to improve the living standards of society. It generates revenue and creates employment opportunities; it improves productivity of inputs, lowers transaction costs, facilitates the creation of knowledge; it reduces price dispersions and price fluctuations; it makes markets more efficient and promotes investment.

Due to these and other potential benefits of ICT, adoption of telecommunications services, especially mobile phone and the Internet is rising. A report by the African Development Bank released in 2011 shows that from 2000-2010 the private sector alone in Africa has spent a total of 28 billion USD on new mobile networks. As a result of this and other public investment in the technology the penetration rate in mobile phones is rising. The International Telecommunications Union (ITU) reported that in 2015 87.29% of Africa's population had access to mobile phones. The mobile subscription rate for Sub-Saharan Africa for the same period was 83.11%. Unlike the mobile subscription rate the penetration rate for the Internet in the region is, however, low -only 17% of the population had access to the internet in 2015.

ICT has attracted the attention of many researchers in recent times. Roller and Waverman(2001) have studied the impact of telecommunications infrastructure on economic growth of 21 OECD countries over the period of 1970-1990. In investigating the impact they jointly estimate a micro model for telecommunications investment with a macro production function. They found that telecommunications infrastructure affects economic growth positively. Ding and Hynes (2006) have also studied the impact of telecommunications infrastructure on regional economic growth in China. They used a panel data set of 29 regions over the period of 1986-2007.Using the dynamic fixed effects model they found that telecommunications infrastructure had a positive and significant impact on real GDP per capita. Gruber and Koutroumpis(2011) have assessed the impact of mobile phones on annual GDP growth of 192 countries over the period of 1990-1997. They found that mobile adoption had a positive impact on the annual GDP growth.

In the literature we find few empirical studies that investigated the impact of ICTs on economic growth of Sub-Saharan Africa. Most recently, Donou-Adonsou, Lim and Mathey(2016) studied the impact of telecommunications infrastructure in Sub-Saharan Africa over the period of 1993-2012. Applying the instrumental variable generalized method of moments (IV-GMM) they found that mobile and Internet have a positive significant impact on economic growth. Chavula(2013) has also studied the impact of telecommunications on economic growth on Africa between 1990 and 2007.Using the OLS method the study reveals that fixed telephone and mobile telephone had positive and significant impact. However Internet penetration was found to have insignificant impact.

However, these two papers which focus on Africa have methodological problem. The first paper applies the one stage GMM (or the Arellano Bond).This estimation technique is known for its inefficient and biased estimators when there are weak instruments. Researchers showed that most macroeconomic variables, like the per capita GDP, are persistent (see Nelson and Plosser (1982), Stock and Watson (1986), Caporale and Gil-Alana (2004), and LoFaso(2012)).The second paper uses the OLS. However, it is known that this method results in biased and inconsistent estimates when there is endogeneity problem. Therefore, in this study we have deployed system GMM in order to improve efficiency and avoid finite sample bias due to weak instruments. Furthermore the estimation method could improve the biasedness and inconsistency of estimates resulting from using OLS.

Although far behind the developed region, countries in Sub-Saharan Africa have given a special priority to the development of telecommunications infrastructure. As a result, adoption of mobile and internet technologies is increasing. However, the impact of these technologies on economic growth has not been studied adequately. Therefore, it is imperative to ask whether ICT is helping people living in Sub-Saharan Africa in increasing their income or not. Understanding the impact of mobile phones and the Internet in the region will help governments and other stakeholders design policies, strategies, programs, and projects which could maximize the benefits from ICTs.

Using data from the World Bank and the International Telecommunication Union this paper examined the impact of telecommunication infrastructure in the region for the period of 2006-2015 over a panel data of 40 Sub-Saharan Africa countries. Results showed that growth in mobile phone penetration has contributed significantly to the GDP per capita of the region after controlling for a number of other macroeconomic variables. However, the Internet has not contributed to the per capita GDP during the study period. The insignificant impact of the Internet could be due to low penetration of the technology in most of this region. As Roller and Waverman(2001) have explained, telecommunications infrastructure is characterized by *network externalities*. The implication of such externalities is that the growth impact of telecommunications (like mobile phone and the Internet) might not be observed unless a significant network size is achieved. In other words, a *critical mass* is needed to have a significant impact from telecommunications, like the Internet. Therefore, governments and other stakeholders should design policies that encourage expansion of mobile phones and Internet usage. Furthermore, ICT skills and local contents should also be developed and promoted in order to reap the full potential benefits of ICTs.

The paper is organized as follows: Section 2 reviews literatures related to ICT and economic growth. Section 3 presents the methodological approach. Findings of the study and discussion of results are presented in section 4. Finally, section 5 concludes the study.

2. Literature Review

2.1 Theoretical perspectives

2.1.1 Growth theories

In order to explain growth differences across countries and over time economists have suggested a number of growth models. However, the two dominant growth models are the neoclassical growth model (also commonly known as the Solow model) and the endogenous growth model.

According to the neoclassical growth model long-run economic growth is determined by exogenous factors such as population growth and technological change. It assumes variable factor proportions(there is possibility of substituting labor for capital in production), constant returns to labor and reproducible capital, closed economy, diminishing returns to the accumulation of capital, competitive markets, exogenous rate of saving, exogenous rate of capital depreciation, exogenous technological change, two factors (labor and capital), one commodity and exogenous population growth. Neoclassical growth models (Like Solow's 1957 growth model) assume technology to be exogenous, meaning it is publicly available. In Acemoglu's(2009) words "It is publicly available as a non-excludable, non-rival good" (p.28). According to him the implication of this assumption is that firms can get technology from the market without incurring any cost.

In this model production depends on the level of capital and labor. In addition to these inputs it also depends on the level of exogenously determined technology. According to Lucas (1988) the model predicts that countries with the same preferences and technology will converge to identical levels of income and asymptotic rates of growth. That is, countries which have the same levels of technology, saving rates, depreciation rate and population growth rates will eventually converge to the same level of output per capita. Therefore, the country with the lower level of output per capita will have a higher growth rate of output per capita. Thus, poorer countries grow faster than wealthy countries.

Although the model is considered to be a useful tool in understanding sources of economic growth it has attracted a number of criticisms. Especially its assumption on the exogenous technological change and its prediction are the main targets. Many scholars including Rosenberg (1974),Romer (1986), Lucas(1988), Aghion& Howitt (1999), and Acemoglu (2009) have challenged the exogenous assumption of technology made by Solow(1956).They argued that technological progress(or accumulation of knowledge) is obtained because of decision of firms or individuals seeking profit or achieving other objectives.

Therefore, in order to tackle the shortcomings of the neoclassical model economists have devised an alternative model commonly known as the endogenous growth model. This model endogenizes technology in the production process. It also eliminates the assumption of decreasing returns to both physical capital and human capital (knowledge capital). Many (e.g. Aghion & Howitt 1999, Fine 2000) believe that Romer's article which was published in 1986 was the benchmark for the contemporary writings on endogenous growth. Romer (1986) explained that his model can be viewed as "An equilibrium model of endogenous technological change in which long-run growth is driven primarily by the accumulation of knowledge by forward looking profit maximizing agents" p.1003. In a later time Romer(1990) argued that technological change is mainly the result of "intentional actions taken by people who respond to market incentives" p.S72. Aghion and Howitt (1999) have stated that the ideas of endogenous growth theory can be traced back to many writers including Kuznets, Abramowitz, Griliches, Schmookler, Sherer, Rosenberge, and Schumpeter. According to the authors these writers have admitted the significance of endogenous technological progress for economic growth. According to the authors the endogenous growth theory helps us to handle the endogenous technological change and innovation. They also explained that "the purpose of endogenous growth theory is to seek some technological knowledge and various structural characteristics of the economy and the society and how such an interplay results in economic growth."P.1. Mankiw, Phelps, &Romer (1995) have also argued that endogenous growth models can provide us a sensible description of the advances in knowledge around the world.

The theory has its earlier version commonly called the AK model. Acemoglu(2009) has stated that when the assumptions of continuity, differentiability, positive and diminishing marginal products, and constant returns to scale ;and the Inada Conditions imposed on the aggregate production function are relaxed, sustained economic growth could be achieved through capital accumulation. However this model is criticized on a number of grounds. First, its long-run equilibrium is unstable, i.e. its equilibrium is on "a knife-edge". Second, as time passes output will almost entirely depend on capital. This implies that capital is the major factor in understanding economic growth. However, many argue that technological progress plays the key role in understanding the performance of economies (see Acemoglu 2009).

Therefore, following the popularity of the endogenous growth model and its wider application in growth related researches we have used it as a framework in our analysis.

2.1.2 ICT and economic growth

The importance of infrastructure to economic growth is well established in the literature. Especially, after the late 1980s a series of studies have been conducted showing the importance of infrastructure to economic growth (See Bougheas, Demetriades & Mamuneas ,2000). Bougheas et al. explained that infrastructure (including telecommunications infrastructure) could be considered as cost reducing technology. The importance of technological progress to economic growth is also clearly identified in both growth models. Metcalfe (2010) argued that "Technology is capable of many forms of expression, as knowledge and information, as skills and capabilities and as human built structures" (p.168). Czernich, Falck, Kretschmer and Ludger(2011) stated that ICT facilitate growth by enhancing distribution of ideas and information, competition, entrepreneurial activities and job search. According to the authors ICT can also affect economic growth through knowledge spillovers across firms.

Roller and Waverman(2001) explained that telecommunications infrastructure can bring economic growth because it increases the demand for inputs which are used in its production and can reduce the transaction cost of firms. It can also have a positive impact because it can improve the production techniques of productive units.

Pohjola(2002) stated that “Given that ICT is generally regarded as the current manifestation of the ongoing sequence of technological revolutions, it can be seen as the key factor driving economic growth in present-day societies”p.381. He also explained that “ICT plays a dual role in the modern economy” as both an input and output. Dutta(2001) has also explained that telecommunications improvement leads to wider dissemination of market information, more timely market information, lower coordination costs in markets, and improved public services such as health and education.

In another study Van Zon and Muysken(2005) have stated the influence of ICT on productivity. According to the authors ICT influences productivity through a number of ways. First, it can affect productivity through its forward and backward linkages with the rest of the economy. Second, since the non-ICT sector uses ICT goods and services in its production processes it can improve its productivity. Third, market processes will be improved leading to productivity improvement. Forth, because of its network externalities features it can be more productive the more people use it. Finally, ICT catalyzes the creation of new knowledge that enhances productivity. They concluded that the use of ICT in the final output sector can lead to improvement in growth performance. Ding and Haynes(2006) have also explained the various ways in which telecommunications infrastructure could enhance economic performance. According to the authors the telecommunications sector itself serves as a source of revenue and employment. It also reduces transaction costs, provides market information, and facilitates information diffusion. It may also affect economic growth positively by encouraging domestic investment and foreign direct investment.

ICTs can play a significant role in the accumulation and dissemination of knowledge which could in turn lead to long-term economic growth. Jacobson (2003) argued that faster knowledge accumulation stimulates economic growth. Macdouglad(2011) has also argued that ICT(particularly the Internet)reduces search and transaction costs. It also provides new ways for information acquisition and exchange. “This information exchange leads to knowledge, which is fundamental to technological progress.” p.30. Technological progress in turn leads to economic growth. ICT can expand market boundaries and improves information flows (see, Waverman, Meschi, and Fuss, 2005 and Andrianaivo & Kpodar, 2010).

2.1.3 ICT and network effects

In the literature it is widely accepted that telecommunications technologies are characterized by network externalities i.e. as the number of users of the technology increases the benefit that accrued to these users will also rise. Authors like Roller and Waverman(2001) have explained that the impact of telecommunications on growth might be non-linear. As a result the growth impact from telecommunications might be attained if there is a notable network size. This notable network size as they call it is the “critical mass”. They argued that if we achieve this critical mass we might observe a positive impact from telecommunications infrastructure. The implication of this network effect is that as we have more mobile and/or Internet users we will have a higher growth impact from these technologies.

2.2 Empirical evidence

This section provides some empirical evidence on the relationship between ICT (including mobile phone and the Internet) and economic growth.

Bougheas et al. (2000) have studied the impact of infrastructure (including telecommunications) on economic growth of 119 countries over the period of 1960-1989. Extending Romer’s(1987) endogenous growth framework and applying various cross country regression models they showed that telecommunications infrastructure, as measured by telephone lines per thousand inhabitants, has a positive impact on long-run economic growth. Pohjola(2002) has studied the impact of ICT on growth. Using the neoclassical growth model and taking a sample of 42 countries over the period of 1985-1999 he found no significant correlation between ICT investment and economic growth. Jacobson (2003) investigated the impact of telecommunications on economic growth of 61 developing and 23 developed countries using the seemingly unrelated regression technique (SUR) over the period of 1990-1999.The author has adopted the simultaneous equations models of Roller and Waverman(2001). The study showed that a positive relationship between economic growth and telecommunications exist. Furthermore, it was found that the growth effect from telecommunications expansion in developing countries exceeds that of developed countries. Choi and Yi(2003) have studied the impact of the Internet on economic growth of 207 economies over the period 1991-2000. Using the endogenous growth models they found a positive and significant impact of the Internet on the growth rate of GDP per capita. Similar results have also been obtained by the same authors in 2009. Gruber and Koutroumpis(2010)assessed the impact of mobile telecommunications on economic development of 192 countries over the period 1990-2007. Using similar structural equations to Roller and Waverman(2001) and estimating it with 3SLS technique they found a positive and significant impact of mobile phones. Macdougald(2011) has studied the impact of Internet use on four measures of economic development - per capita GDP, per capita export revenues, per capita market capitalization, and societal wellbeing covering 202 countries over the period 1996-2007 using dynamic panel data and finite mixture model estimation techniques. Results show that in low income countries (30 SSA countries included) Internet has a positive and significant impact on per capita GDP and overall welfare. Meah(2012) has studied the impact of the Internet on 244 countries over the period 1990-2011 using the framework used by Barro(1996). Fixed effects model is used. Although a positive and significant effect is registered for the world as a whole the result for South Asian countries only shows unfavorable impact. A 10% increase in internet users decreases GDP per capita by -4.65% at the 5% significance level.

Roller and Waverman(2001) have also investigated the impact of telecommunications infrastructure(as measured by telephone penetration rate) on economic development of a sample of 21 OECD countries over the 1970-1990 period. They jointly estimate a micro model for telecommunication investment with a macro production function. They found that telecommunications infrastructure affects output positively and significantly especially this impact is higher when a universal access is obtained (critical mass is achieved). Based on their findings they concluded that a convergent in telecommunications infrastructure (above the critical mass) would offset divergence in economic performance. Datta and Agarwal(2004) investigated the long-run relationship between telecommunications infrastructure and economic growth in 22 OECD countries over 1980-1992.Following the cross-country framework of Barro (1990) and Levine and Renelt(1992) they formulate a dynamic panel data model which includes telecommunications infrastructure(which is measured in access per 100 inhabitants) as its explanatory variable. They found a positive and significant correlation between telecommunications infrastructure and economic growth. They also found that the positive impact of telecommunications infrastructure on GDP growth is largest for countries with the smallest telecommunications infrastructure. Czernich et al.(2011) have investigated the impact of broadband infrastructure (as measured by broadband penetration rate) on per capita growth using IV-estimation technique. Their sample includes 25 OECD countries over the period 1996-2007.They found that a 10 percentage point broadband penetration raised annual per capita growth by 0.9-1.5 percentage points.

Ding and Haynes(2006) studied the role of telecommunications infrastructure on regional economic growth of China comprising 29 regions for the 1986-2002 period. Employing a dynamic panel data model similar to Datta and Agarwal(2004) they found that China's growth rates are positively related to telecommunications infrastructure(especially mobile phone and fixed line). Most recently, Feng(2016) has studied the impact of the Internet on economic growth of Chinese provinces within the Cobb-Douglas production function under the Solow model over the 2000-2014 period. Results show that Internet development (as measured by the number of Internet users, websites and domain names) has a positive and significant role on Chinese economic growth. A panel data approach of fixed effects and random effects models were used.

Ghosh and Prasad (2012) assessed the impact of telephone on India's economic growth on a panel of states in India. They used annual data for the time span of 1980/81-2006/2007. Though a short term positive relationship was observed, this relationship could not be established in the long-run. Mehmood and Siddiqui (2013) studied the long-run relationship between telecommunications investment and economic growth in 23 selected Asian countries over the 1990-2010 periods. Applying

Pedroni(1999) panel cointegration technique they found a positive impact of telecommunications investment on GDP per capita of Asian countries.

Chavula(2013) has investigated the impact of mobile phone, fixed telephone, and the Internet on per capita income of 49 African countries over the periods of 1990-2007. They found that fixed telephone and mobile telephone have a positive and significant impact .A 1% increase in fixed telephone results in 0.15% increase in per capita GDP while a 1% increase in mobile leads to a 0.22 percentage point increase in per capita GDP growth. However, Internet usage did not have a significant contribution towards economic growth. Lee et.al (2009) has studied the impact of mobile phones on economic growth of 44 Sub-Saharan Africa countries over the 1975-2006 periods. Using the cross-country growth framework of Datta and Agarwal(2004) and applying the two-step GMM estimator of Arellano-Bover(1995) /Blundell-Bond(1998), they found a positive impact of mobile phone on economic growth. Most recently, Donou-Adonsou et al. (2016) have investigated the relation between economic growth and telecommunications infrastructure with a special focus on mobile phone and the Internet in a panel of 47 Sub-Saharan Africa countries over the period 1993-2012. Applying the IV-GMM they found that the Internet and mobile phones have contributed to economic growth. A 1% increase in both technologies results in 0.12 and 0.03 percentage points improvement in per capita GDP growth respectively.

Most of the reviewed empirical studies confirmed that ICT has a positive and significant impact on economic growth of individual countries. However in some instances its impact was found to be negligible and even growth retarding.

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3. Empirical Analysis

3.1 Econometric methods

In order to investigate the impact of mobile phones and the Internet on real GDP per capita we have applied Datta and Agarwal's (2004).This approach used a dynamic panel data model with telecommunications infrastructure included as one of its explanatory variable. But our model is slightly modified.

The model is specified as follows:

$$lnrgdppc_{it} = a_i + \beta_1 lnrgdppc_{i,t-1} + \beta_2 lngovcon_{it} + \beta_3 lnmercha_{it} + \beta_4 lngcf_{it} +$$

$$\beta_5 internet_{it} + \beta_6 mob_{it} + \beta_7 inf_{it} + \beta_8 popg_{it} + year + v_t + \varepsilon_{it}$$

$$E(v_t)=E(\varepsilon_{it})=E(v_t\ \varepsilon_{it})=0$$

$$I\ \beta_1 I<1$$

$$i = 1,2,\ldots,N;\ t = 2,3,\ldots,T.$$

Where $lnrgdppc_{it}$ is the logarithm of real GDP per capita of individual countries at time t; a_i is a constant term; $lnrgdppc_{i,t-1}$ is the one period lagged logarithm of real GDP per capita of individual countries. It is assumed to be endogenous, hence we have used lags 2 and above as instruments for the differenced equation and lag 1 for the equation in levels. β_1 is a measure of the speed of mean reversion (the tendency of real GDP per capita to converge (revert) slowly to its equilibrium or long run level, i.e. the mean, after a shock) and we expect β_1 to be positively related with *lnrgdppc; $lngovcon_{it}$* is general government final consumption expenditure as a percentage of GDP (in log form).It includes all government current expenditures for purchases of goods and services including most expenditures on national defense and security. In the literature the effect of government consumption on real GDP per capita is mixed so we have to determine it in our estimation; $lnmercha_{it}$ is merchandise trade as a percentage of GDP (in log form). It is the sum of merchandise exports and imports divided by the value of GDP in current

US dollars. It is a measure of trade openness and its expected sign is positive; $lngcf_{it}$ is gross capital formation as a percentage of GDP (in log form). It is the summation of expenditures on additions to the fixed assets of the economy and net changes in the level of inventories. We expect it to have a positive impact on real GDP per capita; $internet_{it}$ is the percentage of individuals using the Internet in each country and we expect it to have a positive contribution on growth; mob_{it} is cellular telephone subscription per 100 inhabitants in each country and its expected sign is positive. Both Internet usage and mobile subscription rates are assumed to be endogenous, hence we have used lags 2 and above as instruments for the differenced equation and lag 1 for the equation in levels; inf_{it} is annual inflation rate of each country. Based on various literatures its expected sign is negative; $popg_{it}$ is annual population growth rate of individual country. We expect population growth to have a negative impact on economic growth; v_{it} is the unobserved country specific effects. It is the "permanent" effect associated with individual country which captures unobserved individual heterogeneity. It captures the impact of time-invariant individual characteristics such as geographical area. ε_{it} is the time variant error term. The βs are parameters to be estimated. Finally, time dummies are included in the regression in order to prevent any possible cross-individual correlation.

In order to investigate the relation between economic growth and telecommunications infrastructure we have deployed the Windmeijer corrected two-step system GMM. According to Roodman(2006) the System GMM is used to improve efficiency of estimators as well as to avoid finite sample biases that result from weak instruments. Furthermore, he explained that System GMM is used in situations where we have few time periods and large number of samples, distributed fixed individual effects, endogenous regressors, and heteroskedasticity and serial correlation of idiosyncratic disturbances. The estimator uses lagged first differences as instruments for the level equations in addition to lagged levels as instruments for the differenced equation.

In the literature it is shown that most macroeconomic variables, including the per capita GDP, are persistent (see Nelson and Plosser (1982), Stock and Watson (1986), Caporale and Gil-Alana (2004), and LoFaso(2012)). Hence, per capita GDP of individual countries may be dynamic i.e. current per capita GDP of countries may depend on past GDP per capita. Thus, if we have persistent variables system GMM could give us better results.

Blundell and Bond(1998) have shown that compared to the usual first-differenced GMM estimator and the non-linear GMM estimators, the estimators from system GMM perform well in terms of their asymptotic efficiency for the simple AR(1) model. In their simulation they showed that the linear generalized method of moments (GMM) estimator of Arellano and Bond (1995) has large finite sample bias and poor precision.

Using data from Arellano and Bond (1991) and Blundell and Bond (2000) Windmeijer(2005) found that estimated standard errors of the two step GMM estimator are downward biased in small samples and concluded that this phenomenon could lead to a very poor performance of the Wald test. He stated that the usual standard errors for the two step estimator are much smaller than the standard errors for the one step estimator. However, he argued that this perceived increase in precision is due to downward bias of the estimates of standard error and he devised a mechanism to correct this problem. He showed that in a Monte Carlo study of a panel data the corrected variance leads to more accurate inference.

Despite the above benefits the methodology has some limitations. First, the System GMM can generate too many instruments. Roodman(2006) has expressed his concern about the proliferation of instruments in the GMM. Second, according to Roodman(2009) this instrument proliferation could weaken the Hansen test. He indicated that in finite samples, like in our case, the sample may lack enough information to estimate the large matrix well. This could affect the efficiency of our estimates. However, he argued that there is no consensus on the limit of the instrument count because even we have few instruments our estimators may be still biased. Third, as our instrument count rises the bias of the estimates would also increase leading to a failure to eliminate the endogenous components of our endogenous variables.

3.2 Data

The research is based on data from 40 Sub-Saharan Africa countries for the period of 2006-2015. Due to incomplete data Cape Verde, Djibouti, Eritrea, Sao Tome and Principe, Seychelles, Somalia, South Sudan, and Zambia, are not included in the study. Macroeconomic data and telecommunications data are taken from the World Bank and the International Telecommunication Union respectively.

4. Findings of the Study and Discussion of Results

As we can see from the summary statistics in appendix 1 the mean natural logarithm of real GDP per capita for all countries in the study is 6.9 with a standard deviation of 1.1, a maximum amount of 9.97 and a minimum amount of 5.04. The mean individual Internet usage for all countries is about 8.1 with a standard deviation of 9.8. The maximum amount of Internet usage is 51.9%. Although the Internet penetration is low in the region mobile subscriber's number is growing rapidly. The mean subscriber's number for the whole group is 54.33 with a standard deviation of 36.75. In some countries the mobile subscriber's rate has surpassed their population reaching up to 171%. We have also reported the trends in real GDP per capita income of individual country in each time period, Internet penetration and mobile phone subscribers for the last decade.

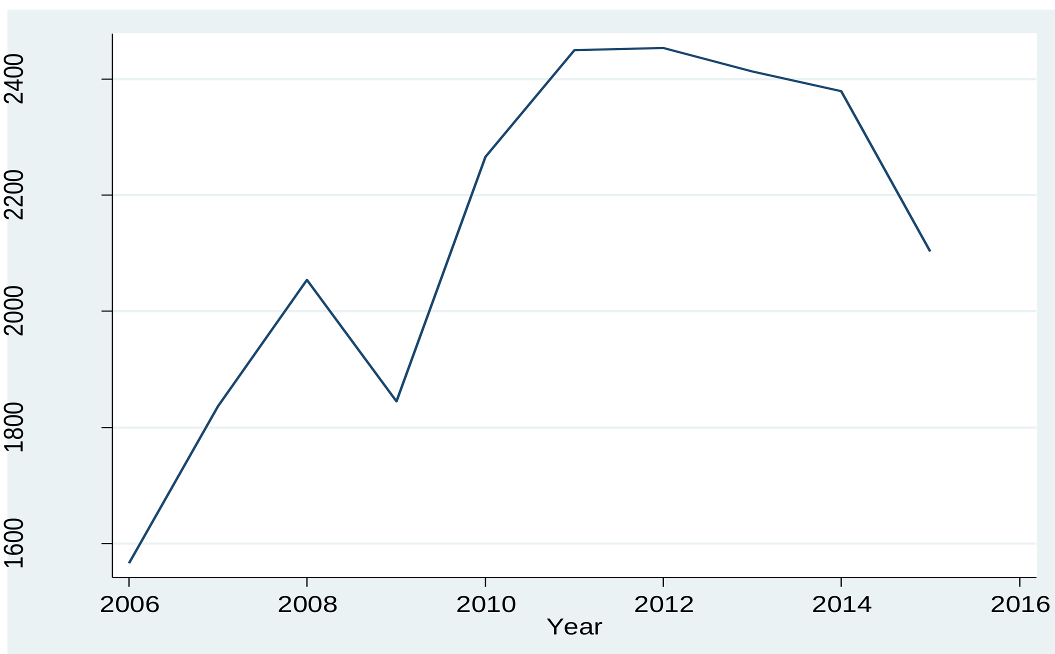

Figure 1: Average real GDP per capita income (in US dollars).

Source: Own computation (Based on World Bank data)

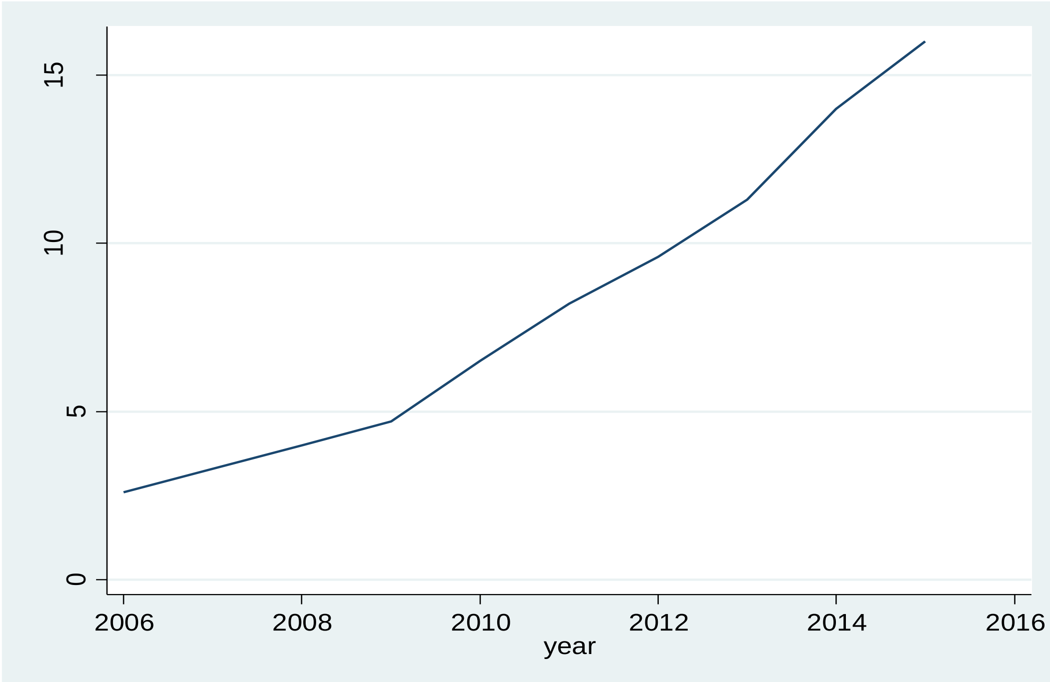

Figure 2: Average annual Internet users per 100 people.

Source: Own computation (Based on data from International Telecommunication Union)

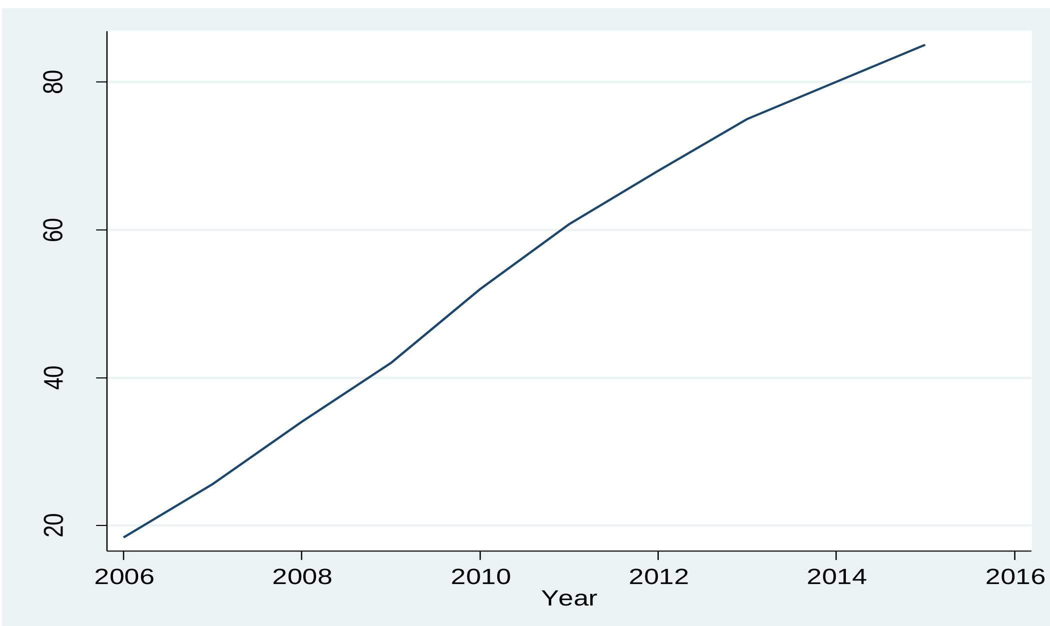

Figure 3: Average number of mobile phone subscribers per 100 people

Source: Own computation (Based on data from the International Telecommunication Union)

Figure 1 indicates that from 2006 to 2008 the per capita GDP of the region moves upwards. However in 2009 it declines. Starting from 2010 it grows continuously until its inertia is halted in 2013. This trend has continued until 2015 putting the life of people in the region in worse conditions. From figures 2 and 3 we observe that the average number of mobile phone subscribers and Internet users is increasing for the last decade indicating the importance of ICTs in people's lives.

Appendices 2 and 3 present results from xtabond2 regressions performed on Stata 12. Estimation results with collapsed instruments are presented on appendix 2 while results from the full instrument sets are presented on appendix 3. In the model with full instrument sets although all the tests perform well, instrument proliferation has been observed. There are 146 instruments for 40 groups. In the literature (see Roodman 2009) it is well documented that as our instrument count rises the bias of the estimates also increases leading to a failure to eliminate the endogenous components of our endogenous variables i.e. the instruments for the Internet and mobile subscribers. High instrument count has also made our Hansen test to be extremely good which has p-values of 1.000.However the results in appendix 2 are different. Results from the estimation procedure with callapsed instruments show that the null hypothesis of joint insignificance of the coefficient of all independent variables is rejected. This is confirmed by the Wald- test. This shows that variables selected for the estimation procedure are valid jointly i.e. Internet penetration; number of mobile subscribers; lagged real GDP per capita, logs of government consumption, gross capital formation, trade openness; inflation; and population growth are relevant in explaining the change in the real GDP per capita income of Sub-Sahara Africa jointly. The Arellano-Bond test for zero autocorrelation in first differenced errors at order 1 and order 2 shows that errors are not serially correlated implying consistency of the parameters. Hence, our instruments are valid in predicting current levels of real GDP per capita. The Hansen test of overidentifying restrictions also shows that we fail to reject the null hypothesis of joint instrument validity implying that our instruments are indeed jointly valid. The difference-in-Hansen test for GMM instruments for levels show that the instruments (lagged differences) are exogenous to the error term in the level equations. Based on this test we can conclude that our system GMM is working well and results are reliable. Therefore, the assumptions needed for the system GMM estimator to be valid are not ruled out. The two Hansen tests for excluding group for both instruments in levels in the GMM and the IV instruments have p-values of 0.357 and 0.143 respectively. This implies that we cannot reject the null hypothesis that the instruments are correctly excluded. Since these values are far below 1.000, instrument proliferation may not be a problem in our case. The test also fails to reject the hypothesis of instrument exogeniety in both the GMM instruments for levels and the IV. Based on the diagnostic tests we conclude that our system GMM is working well and results are reliable. Therefore, the assumptions needed for the system GMM estimator to be valid and consistent are not ruled out.

Results also show that all variables have their expected sign. The coefficient on the lagged value of the real GDP is 0.906042 and it is significant at $p < 1\%$ level. From the estimation results we observe that past GDP per capita in the region affects current GDP per capita income positively, showing persistence of the macroeconomic variable. The variable's coefficient indicates that our model is indeed dynamic showing a convergence towards equilibrium values in the region.

From appendix 2 we can also see that both mobile telephone and the Internet contributed to the real GDP per capita of people living in Sub-Saharan Africa. The result is in line with previous studies conducted by Lee et al. (2009), Chavula (2013), and Donou-Adonsou et al. (2016). Especially, the contribution of mobile telephone is positive and significant at the 10% significance level. A 10% increase in mobile phone subscribers raises real GDP per capita income by 1.2%. Although Internet's contribution is positive it is statistically insignificant at all commonly used significance levels. The insignificant impact of the Internet could be due to low penetration of the technology in most of this region. As Roller and Waverman(2001) have explained telecommunications infrastructure is characterized by *network externalities*. The implication of such externalities is that the growth impact of telecommunications might not be observed unless a significant network size is achieved. In other words a *critical mass* is needed to have a significant impact from telecommunications, like the Internet (See p. 911). The other explanation could be related to the lack of ICT skill of Internet users. In order to fully realize the potential of the Internet individual users must have appropriate ICT skills. Studies show that ICT skills are crucial for economic growth and development. This implies that a low level of ICT skill will have an insignificant impact on economic activities. The other reason could be related to the adoption time of the technology. The development of ICT, especially, the Internet is a recent phenomenon in SSA. Therefore, although the Internet has an insignificant impact on the GDP per capita income change it has the potential to affect income of the people of the region significantly through time. The other factor to the insignificant impact of the Internet could be related to the unavailability of local content on the global network. It is known that SSA is rich in cultural and linguistic diversity. However, it is underrepresented on the global network. In other words, local content is scant. This might have prevented users from exploiting the full potential of the Internet and hence affecting their income significantly.

The other commonly used variables which determine economic growth such as government consumption, and annual inflation rate affect per capita income negatively and significantly at $p < 1\%$ significance level. Annual population growth was also found to affect per capita income negatively, though insignificantly at any of the commonly used significance levels. Total expenditures on additions to the fixed assets of individual country (gross capital formation) affects per capita income positively and significantly at $p < 5\%$ significance level. Furthermore, each country's openness to the global economy has contributed to the region's economic activity positively, although the impact was insignificant at any of the conventional significance levels.

5. Conclusion and Recommendation

Many people in Sub-Saharan Africa are suffering from lack of food, clean water, improved health services, electricity, shelter, education and other basic services such as telecommunications. In order to reduce such problems African governments and the international community have been engaged in various poverty reduction programs. Among those efforts the commitment to expand ICT access is worth mentioning. A number of ICT policies have been designed and implemented during the last decade. As a result the number of mobile subscribers and Internet users has been boosted. As our estimated results showed this ICT expansion in the form of increasing mobile phone subscribers and rising Internet users has impacted the per capita income of the people in the region in a favorable way. During the last ten years the expansion in mobile phones has improved the per capita income of the region. Therefore, promoting mobile phone usage will play a critical role in reducing the poverty level of the region through raising the per capita income of the population. Our results imply that a "critical mass" of users of mobile phones has been achieved in SSA. Thus, in addition to improving access to mobile phones in the region all stakeholders should look for ways which could maximize the potential benefits of mobile phones. Governments should design and implement policies which promote the expansion of mobile phones. Telecommunications companies should also play their role in making telecom services affordable.

As our results show the Internet has not been a critical contributor to the per capita GDP income during the study period. Despite the steady rise in the number of Internet users in the region its positive impact is statistically not notable. This could be due to low penetration of the technology in most of the region. The other explanation could be related to the lack of ICT skill. In order to fully realize the potential of the Internet individual users must have appropriate ICT skills. Furthermore, the development of the Internet is a recent phenomenon in SSA. As a result any significant impact would take time to show up. Scarcity of local content on the Internet could also be one of the reasons preventing the technology to have any notable impact on the income of people in SSA. Therefore, governments and other stakeholders should design policies that encourage expansion of the Internet until a critical mass of users is achieved. In addition to improving Internet access, policies which focus on ICT skill development should be designed and implemented. It is also widely known that SSA is rich in cultural and linguistic diversity. However, it is underrepresented on the global network. This might have prevented users from exploiting the full potential of the Internet in enhancing economic growth. Therefore, governments should design policies which encourage the presence of local contents, preferably produced in local languages, on the Internet. Telecommunications companies should also revise their Internet access prices in order to increase the number of Internet users. Donors and the international community should also give their support directly to those startups which focus on local content production and distribution.

Appendix 1: Summary statistics

Variable		Mean	Std. Dev.	Min	Max	Observations
lnrgdppc	overall	6.938206	1.095849	5.04278	9.966791	N = 400
	between		1.083739	5.375732	9.728726	n = 40
	within		0.2299707	6.272862	9.025262	T = 10
lngovcon	overall	2.58731	0.4228531	0.6931472	3.678829	N = 395
	between		0.3780397	1.548057	3.600212	n = 40
	within		0.2066524	0.8571699	3.38689	T-bar = 9.875
lnmercha	overall	4.009908	0.4463769	2.624669	5.103518	N = 398
	between		0.4196297	3.173401	4.982807	n = 40
	within		0.1633689	3.313155	4.520981	T = 9.95
lngcf	overall	3.027383	0.4526481	0.4700036	4.238445	N = 396
	between		0.3813701	1.866687	3.957047	n = 40
	within		0.2493689	1.157726	4.032548	T = 9.9
internet	overall	8.060354	9.763988	0	51.9	N = 396
	between		7.779102	1.01	31.49	n = 40
	within		6.049863	-12.58965	31.91035	T-bar = 9.9
mob	overall	54.33568	36.75265	1.1	171.4	N = 398
	between		27.55801	15.76	124.1	n = 40
	within		24.5986	-21.56432	129.8557	T-bar = 9.95
inf	overall	73.03005	1243.244	-35.8	24411	N = 386
	between		503.2076	1.73	3189.487	n = 40
	within		1157.389	-3118.857	21294.54	T-bar = 9.65
popg	overall	2.57175	0.7139687	0.1	4.2	N = 400
	between		0.6973021	0.29	3.88	n = 40
	within		0.1857114	1.76175	3.56175	T = 10

Appendix 2: Dynamic panel-data estimation, two step system GMM(Instruments are collapsed)

Dependent variable: logarithm of real GDP per capita(lnrgdppc)

Variable	Coef.	Corrected Std. Err.	z	P>z	[95% Conf.	Interval]
lnrgdppc L.1	0.9060462	0.0584609	15.5	0.000*	0.791465	1.020628
lngovcon	-0.0745640	0.0277070	-2.69	0.007*	-0.128869	-0.020259
lnmercha	0.0346075	0.0616460	0.56	0.575	-0.086216	0.155431
lngcf	0.0491633	0.0232818	2.11	0.035**	0.003532	0.094795
internet	0.0033255	0.0029750	1.12	0.264	-0.002506	0.009156
mob	0.0012131	0.0006973	1.74	0.082***	-0.000154	0.002580
inf	-0.0000136	0.0000041	-3.31	0.001*	-0.000022	-0.000006
popg	-0.0306409	0.0190808	-1.61	0.108	-0.068039	0.006757

Wald	chi2(18) = 3.73e+07 Pr > chi2 = 0.000
Arellano-Bond test for AR(1) :	z = -1.1 Pr > z = 0.268
Arellano-Bond test for AR(2) :	z = 0.95 Pr > z = 0.340
Sargan test of overid. Restrictions:	chi2(21) = 8.39 Pr > chi2 = 0.993
Hansen test of overid. Restrictions:	chi2(21) = 22.26 Pr > chi2 = 0.385
Difference-in-Hansen tests of exogeneity of instrument subsets:	
GMM instruments for levels	
Hansen test excluding group:	chi2(18) = 19.58 Pr > chi2 = 0.357
Difference(Null H=exogenous):	chi2(3) = 2.68 Pr > chi2 = 0.444
iv(exogenous regressors)	
Hansen test excluding group:	chi2(7) = 10.90 Pr > chi2 = 0.143
Difference(Null H=exogenous):	chi2(14) = 11.36 Pr > chi2 = 0.657
Number of observations	340
Number of groups	40
Number of instruments	40

Note: Variables with "*", "**", and "***" are significant at p<1%, p<5%, and p<10% respectively.
Year dummies are also included in the estimation.

Appendix 3: Daynamic panel-data estimation, two step system GMM(With full instrument sets)

Dependent variable: logarithm of real GDP per capita(lnrgdppc)

Variables	Coef.	Corrected Std. Err.	z	P>z	[95% Conf.	Interval]
lnrgdppc L1.	0.9227605	0.0735915	12.54	0.000*	0.778524	1.066997
lngovcon	-0.0156519	0.0499125	-0.31	0.754	-0.113479	0.082175
lnmercha	0.0264935	0.0478069	0.55	0.579	-0.067206	0.120193
lngcf	0.0805538	0.0625194	1.29	0.198	-0.041982	0.203090
internet	0.0032648	0.0032589	1.00	0.316	-0.003123	0.009652
mob	0.0013865	0.0014469	0.96	0.338	-0.001449	0.004222
inf	-0.0000050	0.0000045	-1.09	0.275	-0.000014	0.000004
popg	0.0196037	0.0430766	0.46	0.649	-0.064825	0.104032

Wald	chi2(18) = 35516.85 Pr > chi2 = 0.000
Arellano-Bond test for AR(1) :	z = -1.12 Pr > z = 0.264
Arellano-Bond test for AR(2) :	z = 0.95 Pr > z = 0.340
Sargan test of overid. Restrictions:	chi2(127) = 118.31 Pr > chi2 = 0.697
Hansen test of overid. Restrictions:	chi2(127) = 25.59 Pr > chi2 = 1.000
Difference-in-Hansen tests of exogeneity of instrument subsets:	
GMM instruments for levels	
Hansen test excluding group:	chi2(103) = 24.41 Pr > chi2 = 1.000
Difference(Null H=exogenous):	chi2(24) = 1.18 Pr > chi2 = 1.000
iv(exogenous regressors)	
Hansen test excluding group:	chi2(114) = 24.12 Pr > chi2 = 1.000
Difference(Null H=exogenous):	chi2(13) = 1.47 Pr > chi2 = 1.000
Number of observations	340
Number of groups	40
Number of instruments	146

Note: The variable with "*"is significant at p<1%.
Year dummies are also included in the estimation.

List of countries included in the study

Angola
Benin
Botswana
Burkinafaso
Burundi
Cameroon
Central African Republic
Chad
Comoros
Congo(Brazzavelle)
Congo(Democratic Republic)
Cote d'Ivoire
Equatorial Guinea
Ethiopia
Gabon
Gambia
Ghana
Guinea
Guinea-Bissau
Kenya
Lesotho
Liberia
Madagascar
Malawi
Mali
Mauritius
Mozambique
Namibia
Niger
Nigeria
Rwanda
Senegal
Siera Leon
South Africa
Sudan
Swaziland
Tanzania
Togo
Uganda
Zimbabwe

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