Determinants of Digital Transformation in Sub-Saharan Africa: Some Fiscal Policy Implications*

Karline Tryphone,† Cornel Joseph‡ & Michael O.A. Ndanshau§

Abstract
The study examines the determinants of digital transformation by using panel data of 35 countries in sub-Sahara Africa (SSA) for the period 2014–2021. Based on the fixed effect model, the findings established network coverage, ownership of mobile phones, adult literacy rate, and income were positive and significant determinants of internet use in SSA. The empirical findings suggest governments in SSA countries should nurture potential of the internet in the drive to inclusive economic growth and development, as well as digital transformation. To that effect, they should promote investment in internet infrastructure, digital literacy, and refrain from taking actions that would undermine the transformative potential of digital technologies. In relation, the SSA governments could, among others, suspend value-added tax (VAT) on low-end smartphones to render them affordable for low-income earners; and, establish a Universal Service Fund for subsidizing access to lower-cost smartphones in rural areas that are newly connected to 3G and 4G networks; and pay for a subsidized public Wi-Fi hotspot. The SSA government, individually or under the public-private partnership (PPP), could get involved in parts of the value chain of smartphones – including marketing, distribution, and retail.

Keywords: Digital Transformation; Internet Use; Sub-Saharan Africa
JEL Classification Codes: D1, E2, E6.

* This paper is an updated part of a larger Project Report supervised and prepared by the late Professor Benno J. Ndulu, who was the Senior Adviser for Digital Pathways at Oxford and a Visiting Professor at the Blavatnik School of Government, University of Oxford, and was published with Ms. K. Tryphone and Dr. C. Joseph. This paper is being published for wider dissemination of the otherwise very interesting policy relevant findings generated by the project.

† School of Economics,University of Dar es Salaam,E-mail: karlinetryphone@gmail.com
‡ Department of Geography and Economics, Mkwawa University College of Education, E-mail: cornell.mlacha@udsm.ac.tz
§ Corresponding Author, Tumaini University Dar es Salaam College (TUDARCo),E-mail: michaelndanshau@gmail.com

1. Introduction

It is maintained in the literature that there exist internet vast potential for the attainment of inclusive growth and socio-economic development (Mwamba et al, 2021; Niyazbekova et al., 2021). The internet, among others, increase productivity, and innovation that contribute positively to the overall economic development and growth. Besides, the COVID-19 pandemic exposed a sobering reality: internet access remains a rare commodity for many households and firms in sub-Saharan Africa (SSA) and other developing countries. It is acknowledged that 770 million people in SSA are unable to access the internet, meaning they do not enjoy the benefits of connectivity (Ndulu et al., 2020).

Without access to reliable connectivity and devices, billions of people risk being further cut off from vital information on health and safety, online learning, and the opportunity to voice views and engage in commerce (ITU, 2020). This is particularly true in SSA, where a quarter of the population still lacks internet, and a significant number of children could not continue with education when COVID-19 necessitated enforcement of strict social distancing, especially among low-income households (Makwakwa, 2020). A Cisco Systems (2020) survey shows that, even in the Republic of South Africa (RSA), despite being the most technically advanced country in the region, only 37% of businesses were regarded as well prepared for remote working when COVID-19 broke out, having fully rolled out their digital transformation strategies.

Meanwhile, recent years have seen a swift expansion in access to the internet, particularly across the SSA. More than half of the world's population is now using mobile internet, the SSA is home to 47% of the world's uncovered population – an estimated 210 million people in 2020. Evidence also shows that there were approximately 930 million mobile service subscriptions in 2021. Even though, according to Global System for Mobile Communications, also referred to as Global System for Mobile Association (GSMA), State of Mobile Internet Connectivity Report of 2021, significant gains have been made in SSA countries' digital transformation: coverage by both 3G and 4G has been increasing from a low end since 2014. Yet, in 2020 only half of the population (51%) in SSA had access to the 4G network. However, in 2020, mobile operators in SSA accelerated the expansion of 3G networks, with coverage increasing to 81% from 49% in 2014 (GSMA, 2021a). The SSA region still has the highest usage gap, approximately 53% in 2020. This argument seems to be supported by the trends of the proportion of internet users: by 2020, only 30.04% of the population had used the internet in SSA, compared to 66.6% in East Asia & Pacific, 80.4% in Europe & Central Asia, 73.7% in Latin America & the Caribbean, 73.6% in the Middle East & North Africa, and 38.6% in South Asia (ITU, 2021).

In view of the preceding evidence, a begging question important for policy that we pose is: what has been preventing more people from using the internet in SSA? An answer to this question could provide input for policy options for digital transformation in SSA. To maximize the potential benefit of the internet, it is important to identify the main constraints faced by individuals in adopting Internet services. Some previous empirical studies elsewhere point to several important determinants of internet use. Gao et al. (2004) found pricing and taxation of wireless services had negative effect on demand for the internet service in Finland. Also, Leandro and Gomes (2019) found price was an important determinant of the demand for broadband services in Brazil. In addition, Oliveira and Coutinho (2010) found the main drivers of broadband expansion in Brazil and other countries were per capita income, urban population, and ownership of personal computers. Furthermore, Penard et al. (2013) found that education levels, device usage skills, internet accessibility, and affordability were robust determinants of internet adoption in Africa. Also, in another study, Penard et al. (2012) found education and computer skills and knowledge acquired were the primary factors that stimulated internet use in Gabon. The study by Neira et al. (2008) established internet use in Africa was determined by price (the three minutes call cost and the monthly subscription cost) and availability of infrastructure but not income. The factors related to infrastructure availability, that is, personal computers were also important determinants of internet use in Africa (Neira et al., 2008).

Noteworthy, empirical studies on digital transformation in SSA are few. In this regard, the available empirical evidence is quite inadequate to inform policy (Khera, et al., 2021; Myovella, Karacuka & Haucap, 2021; Birba & Diagne, 2012; Pénard, Poussing, Yebe & Ella, 2012; Neira, Jiménez & Ania, 2008). Moreover, most of the studies on digital transformation in SSA focused only on the demand side of internet services. The existing information gap, by no doubt, does not only constrain policy formulation but also constrains maximization of internet benefits by resident users in SSA. Specifically, the poor access to internet services undermines, saving, investment, and trade that are known to impact positively on economic growth and, in tandem, poverty eradication. It is acknowledged in the literature digital transformation has been instrumental to financial deepening and widening and, as a result, financial inclusion, which has been found to impact positively on inclusive economic growth and poverty eradication in developing countries (Iqbal & Sami, 2017; Lenka & Sharma, 2017; Sharma 2016; Dabla-Norris et al., 2015). It is in this context that this paper seeks to establish the main constraints to the use of internet services by individual resident in SSA are identified.

Apart from this introductory section, the rest of the paper is organized as follows. Section 2 sheds light on the state and status of digital transformation in SSA by identifying its key enablers. In relation, the relationships between such enablers and the extent of digitalization across the region are explored in the section. Section 3 presents the conceptual framework. Section 4 describes the data type used, its sources, and comments on its reliability. Section 5 dwells on the methodology used to establish the most important determinants of digital transformation in SSA. Section 6 presents and discusses the findings of the study. Section 7 concludes with a presentation of the main findings and policy implications of the study.

2. State and Status of Digital Transformation in SSA

Digital Transformation (DT) is a broad concept that refers to the spread and use of digital technologies—the internet, mobile phones, and other tools and processes—to collect, store, analyze, and exchange information digitally (World Bank, 2016). Two aspects are central in digital transformation, viz, internet connectivity, which is the ability to access the internet and use (uptake) of the internet once the technologies to connect to the internet is established.

Figure 1 shows that the SSA had the lowest proportion of internet users, relative to other regions of the world in 2020 (ITU, 2021). Specifically, by 2020, on average the population of individual users of the internet in SSA was 30.04% and, while on the low side, it compared favourably with only 16.12% internet users in 2015.

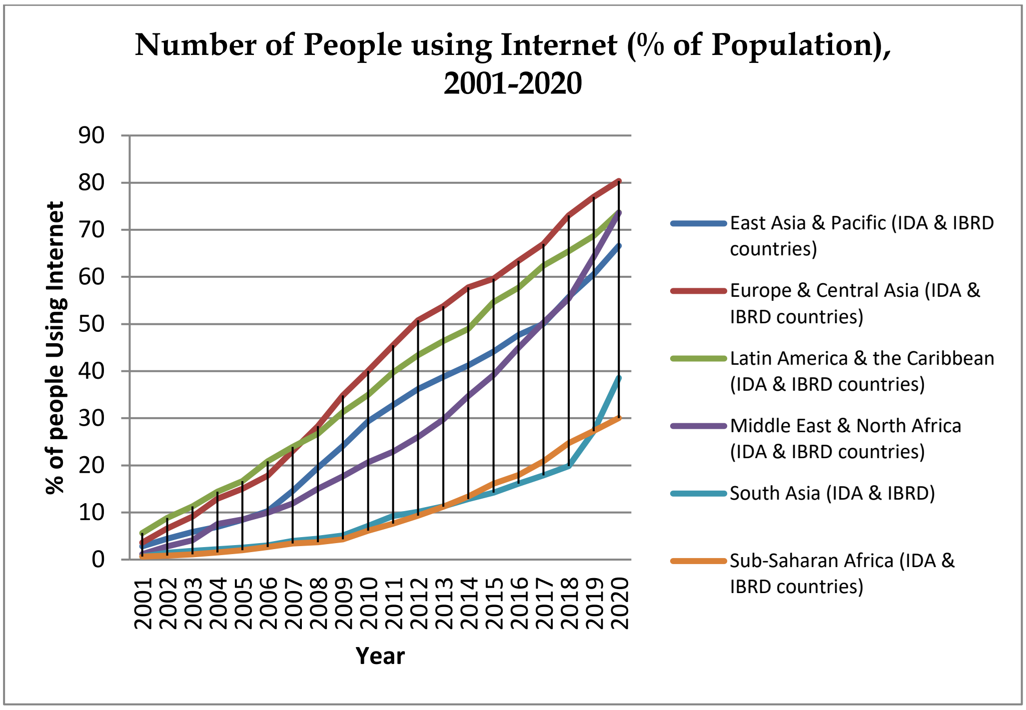

Figure 1: Trends of people using internet by regions, 2001-2020
Source: Data from WDI, 2021.

Figure 2 shows the percentage of individuals using the internet greatly varies across the SSA region. In some countries, namely Mauritius, Senegal, Botswana, Nigeria, Namibia, Lesotho, Cabo Verde, South Africa, Gambia, Ghana, Angola, and Gabon, the proportion of the population using the internet in 2021 was above 30%, but in most other countries, including Tanzania, it was below 30% (Figure 2). According to ITU (2012), the majority of people in SSA do not use the internet mainly because of high cost of smartphones, relative to average income levels, and limited digital skills among rural and less literate populations.

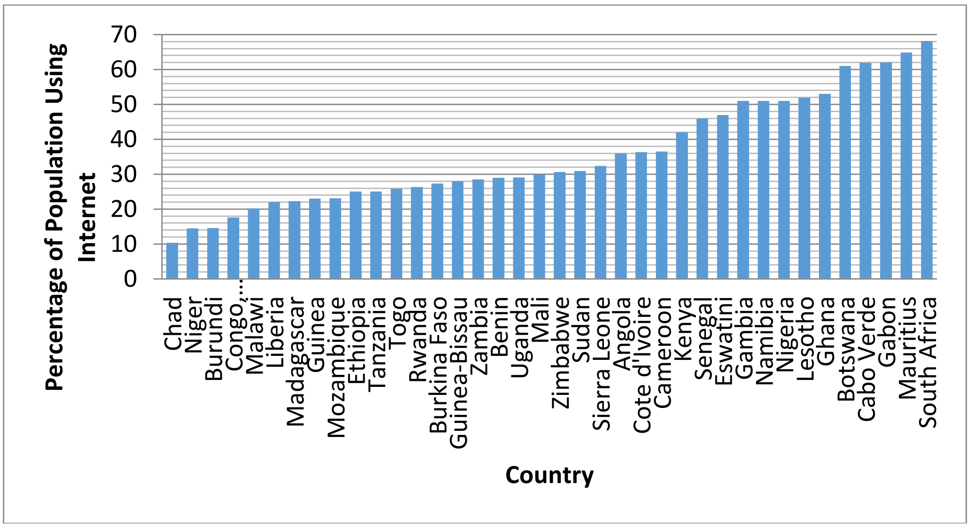

Figure 2: Proportion of People using Internet in SSA by Country, 2021.
Source: Data from WDI, 2021

Noteworthy, the state and status of a country's digital transformation can be explained by five potential key enablers commonly grouped under access/connectivity (3G or higher network coverage, ownership of mobile phone, and access to electricity); and user enablers, which include affordability of internet services and consumer digital capability to use internet services – measured as consumer readiness or digital literacy).

2.1 Access/Connectivity

Three features of connectivity (network coverage, mobile handset ownership, and access to electricity) are deemed to have a significant influence on the extent of use, that is, access (connectivity) of internet services in SSA countries. The SSA has significantly reduced its internet coverage gap for mobile broadband over the past several years, but it still remains a region with the largest coverage gap. In 2021, the number of individuals covered with at least a 3G mobile network in SSA reached 906 million, about 76.8% of its 1.18 billion inhabitants in that period. Moreover, and even more specifically, Figure 3, which shows the share of the population covered by the 3G broadband network in SSA by country in 2021, reveals that during the period 2001-2020, almost all countries covered by the study had coverage of above 60% as of in 2021, except Burundi, Central Africa, Chad, and DRC. Only 4 out of the 42 SSA countries had coverage of less than 60%. The dispersion across the region is, therefore, not very wide. Most countries appear to have been catching up quickly with the rest of the world in this respect.

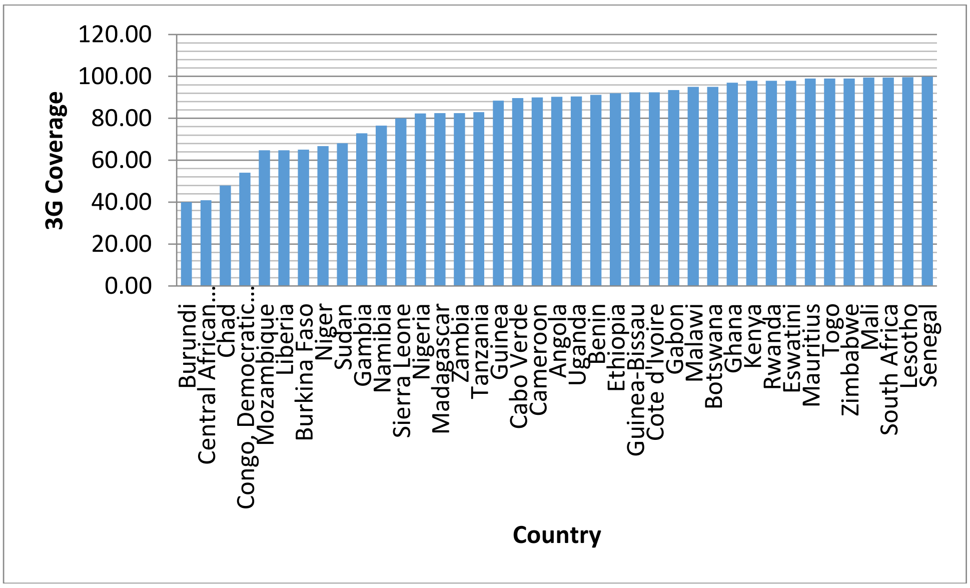

Figure 3: 3G coverage across SSA countries, 2021.
Source: Data extracted from GSMA, 2022.

Suffice it to note that in order to make use of the 3G connectivity for the internet, there are two other conditions to be met: having a smartphone or (for limited use) an internet-enabled feature phone; and connectivity to electricity – a key enabler for the use of the internet. Mobile technology remains the leading method of connectivity for most of the population in SSA.

Given the existence of a low level of fixed broadband penetration, particularly in residential locations, most of the increases in data traffic in SSA are over mobile networks. Some of the most recent mobile usage statistics from a study by Pew Research Center (2017) reveal that approximately 91% of South African adults owned mobile phones, with 51% of adults owning smartphones and the remaining 40% owning standard cell phones. Moreover, as of 2017, Ghana had an 80% ownership rate, and Senegal followed closely behind with a 79% ownership rate, with 34% of adults owning a smartphone and 46% of adults owning a standard smartphone. Also, during the period Nigeria and Kenya also had an 80% ownership rate, while in Tanzania 75% of adults reported owning a mobile phone. Basic phones, such as flip phones or feature phones, are generally the most common type of mobile device owned and used in SSA countries. The exception is in South Africa, where 51% own a smartphone that can access the internet and applications, making it the most common device in that country. In Ghana, Senegal, Nigeria, and Kenya, just about one-third of the adults owned smartphones in 2021. Smartphone ownership is again the lowest in Tanzania (13%).

In addition, the lack of an enabling infrastructure, including a lack of access to reliable electricity, has been a major hurdle to broadband adoption in many SSA countries. Access to reliable and affordable electricity is a major constraint to universal use and affordable internet services, especially in SSA. Figure 4 shows that almost all SSA countries are below 70% of the population with access to electricity. It shows a very wide dispersion across countries. The range of electricity connectivity is very wide --- from almost 6% of the population in South Sudan to 100% coverage in Mauritius in 2021.

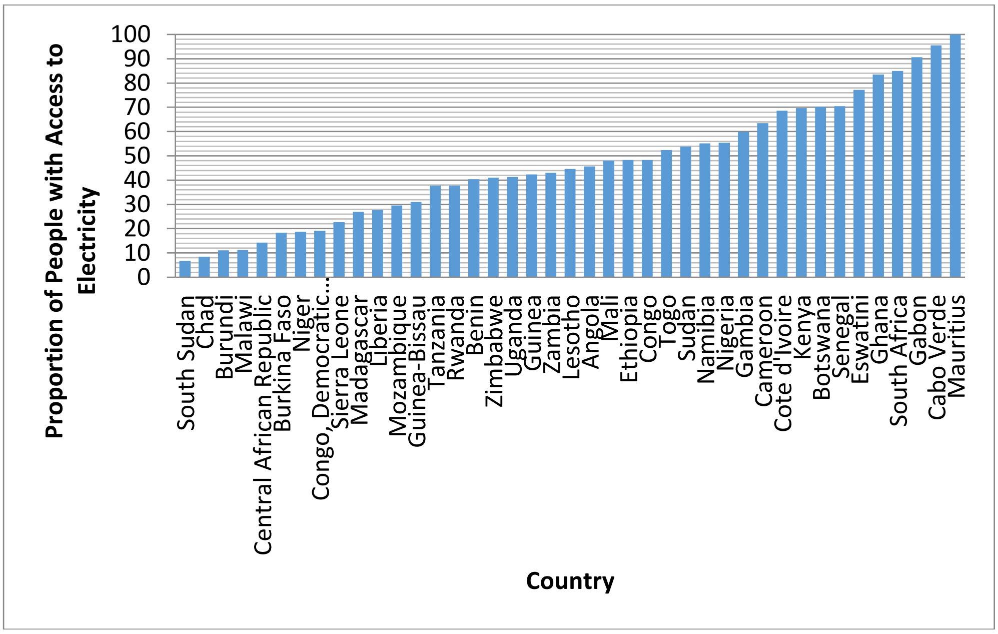

Figure 4: Proportion of People with Access to Electricity in SSA by Country, 2021
Source: Data Extracted from GSMA, 2022.

2.2 User enablers

Once internet connectivity (access) is established, two other key factors significantly serve inclusive uptake or use of digital services: (i) affordability of digital services and mobile devices (smart or feature phone), measured as the share of monthly average income used to access internet service bundle and acquisition of a physical communication device; and, (ii) consumer readiness, which is largely determined by level of education and digital literacy attained.

2.2.1 Affordability

Affordability, in terms of the cost of the device and the cost of the data bundle, is measured as the share of the cost in a monthly average income of an individual user. On the one hand, the cost of a data bundle, measured as the cost of 1 GB of data, has been decreasing over time in other regions, but remained expensive in SSA. According to the Alliance for Affordable Internet (2020), the average cost of 1 GB of mobile data in Africa in 2020 was about USD 7.12, a cost which compares unfavourably with the global average of USD 4.07. Also, anecdotal evidence reveals the median price of 1GB of mobile data in SSA stands at 3.3% of monthly income per capita, "the highest rate globally (Webinar April 12, 2023). In some countries, 1GB costs as much as 20% of the average monthly income per capita, and the median was 15.3% (GSMA, 2021a,b).

Figure 5 shows the Central African Republic (CAR) was the most expensive country in SSA in the supply of mobile data: USD24.59 were required to get a gigabyte (GB) of mobile data. Also, Figure 5 reveals the SSA countries that lie between Guinea Bissau and Tanzania were the other countries with relatively high costs of mobile data (per one GB). Also evident in Figure 5, the countries that lie between Rwanda and Nigeria had a relatively low cost of mobile data. Some SSA countries had the lowest internet prices, including Mauritius, where 1GB of broadband data was priced at USD0.89, followed by Ghana (USD1.14), Botswana (USD1.17), and South Africa (USD1.24). In Tanzania, the cost of a GB of mobile data was USD4.9 in 2021, that is, it was five (5) times lower than the highest cost of data in SSA which was obtained in the CAR (Figure 5)!

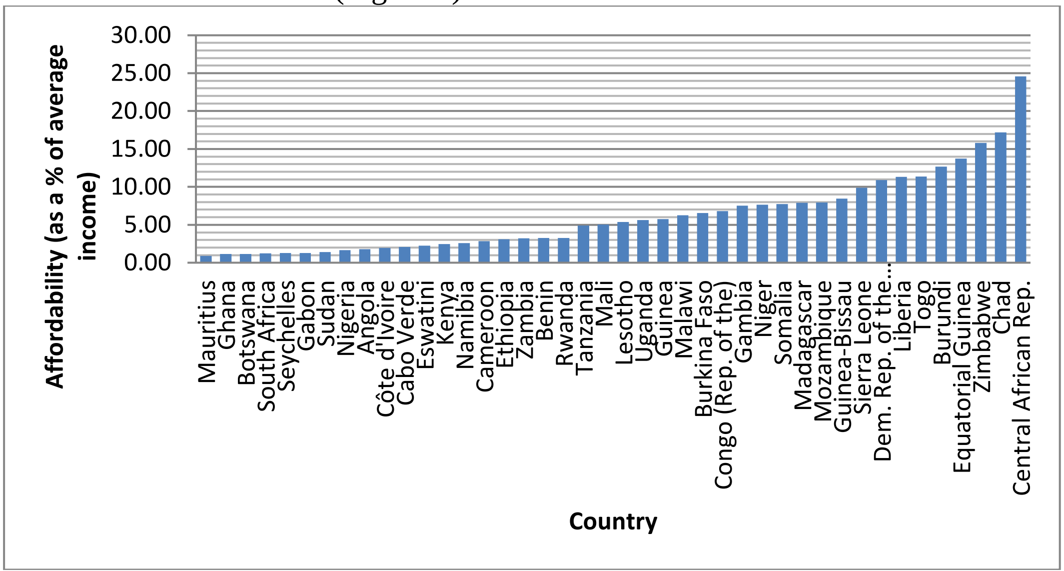

Figure 5: Affordability of 1GB of Broadband Data –GNI per capita 2021 (in USD)
<u>Source</u>: Data constructed from Alliance for Affordable Internet, 2022.

Generally, and following criteria set by the United Nations (UN), internet access is considered affordable when the cost of 1GB is less than 2% of the monthly income per capita. In fact, by using that criteria only 10 of the 42 SSA countries included in the ranking have affordable internet access (Figure 5).

The cost of handsets is also a significant barrier to mobile internet adoption and use. Almost 2.5 billion people in low and middle-income countries live in countries where the most affordable smartphone costs more than a quarter of the average monthly income. The average cost of an entry-level smartphone in Africa still exceeds more than 60% of the monthly income, making smartphones largely inaccessible to a large proportion of the population. For example, the cost of the cheapest internet-enabled device was 26.5% of the monthly GDP per capita in 2020, having decreased from 39.2% in 2016 (GSMA, 2021a).

2.2.2 Consumer Digital Capabilities and Readiness

Digital literacy by definition is "the ability to use information and communication technologies to find, evaluate, create, and communicate information, requiring both cognitive and technical skills" (Clark & Visser, 2011, p. 38). In other words, one can say digital literacy correlates with digital inclusion by which people are able to use and access information and communication technologies; and, also are able to do administrative procedures online via e-government services, and make payments and financial services using technology. It affects consumer readiness for the uptake of digital services.

The available literature suggests that lack of skills is one of the most commonly cited reasons for non-use of the internet (Schmidt and Stork, 2008). Besides, some studies have revealed differences in the endowment or acquisition of skills often result in a digital divide (Ndulu et al., 2020). In addition, affordability and low levels of digital literacy pose further challenges that prevent users from exploring fully the potential of the Internet in their daily lives. A GSMA Intelligence Consumer Survey (2018) showed that among those consumers who were aware of the mobile internet, 34% reported a lack of literacy and digital skills as the main barriers to its adoption in SSA —the reason for not coming online. As Stork & Schmidt (2009) note, the absence of necessary skills marginalizes even those who can access and afford to use ICT services. Implicitly, individuals must develop certain skills, such as the ability to understand, use, modify, and create Internet content and services, to fully benefit from using the Internet on a computer or mobile phone. Broader literacy skills can help individuals to develop internet skills, such as the ability to modify internet content, which is required to experience the full benefits and make optimal use of ICTs. However, evidence shows that 27% of the world's illiterate people live in SSA (UNESCO, 2017); and, 17 countries in Africa still have 50% to very low literacy rates. Even more significant, the average literacy rate for adults (ages 15 and above) in SSA was estimated to be around 67.27% in 2020.[1] This implies poor literacy rates would continue to drag internet adoption in SSA.

3. Methodology

3.1 Conceptual Framework

The conceptual framework we use here has been adopted from a model developed by Gao et al. (2004). It considers an aggregation of consumers (internet users), each contemplating whether or not to use wireless digital internet services but actually making a choice to use the internet, conditional on several supply and demand-side shifters. The choice made by the consumer is at the earliest stage of the decision tree, that is, whether to use the internet or not – abstracting from second-order choices of types of internet services.

It is assumed that the representative consumer has a separable utility function for internet services and other goods (U(x,q)) which is embedded with the budget constraint such that:

$$U(x,q) = C(x) + W(q) = C(I - pq) + W(q) \tag{1}$$

Where x is the consumption of the outside good (or, identically, income minus spending on digital service); q is the consumption of internet service; I is the decision period compatible income; and p is the per-unit-of-time price of internet service connection.

By assumption, the representative consumer maximizes the utility function conditional on four other supply-side constraints, (i) access to a broadband network (at least 3G network coverage); (ii) access to a smartphone; (iii) digital readiness (capability of using the internet --– skill-wise, and so on); and, (iv) access to electricity (whether on or off-grid), specifically, absence power outages. On the demand (users') side, the factors that influence internet use

[1] There are significant variations across countries. For example, Seychelles, Mauritius, and South Africa have relatively higher literacy rates, above 90%, while countries like Chad, Niger, and Guinea have a literacy rate of below 40%.

include internet affordability (in turn dependent on price and income) as well as consumer readiness, which measures the capability of using the internet gainfully.

A reduced form equation from the model represented by equation (1) is a quantity equation, tracing actual internet use represented at points of intersection between demand and supply. We are aware of the potential identification problems in using an approach that includes both supply and demand-side factors in the reduced form equation and, therefore, do not use prices in the quantity equation we estimate. Alternatively, we could, as others have done, use an instrument for price to deal with that challenge.

In applying the model empirically, we use a reduced form equation for determinants of internet adoption. Specifically, we use cross-country panel data to estimate the relative influence of the determinants of diversity of internet adoption across the SSA countries (Estache et al., 2002; Caselli and Coleman 2001). The actual data points of internet adoption is at the intersection of the aggregated supply and demand curves for internet, and are influenced by the host of supply and demand-side shifters.

For the purpose of this study, internet users (% population) correspond to the proportion of individuals using the internet, based on national households' surveys. Adult literacy is measured as the percentage of people aged 15 years and above who can both read and write a short simple statement on their everyday life. However, the proportion of the population covered by at least a 3G mobile network refers to the percentage of inhabitants that are within range of at least a 3G mobile-cellular signal, irrespective of whether or not they are subscribers. Moreover, access to electricity is measured as the percentage of population with access to electricity. It refers to the percentage of people in a given area that have relatively simple, stable access to electricity. We also used GNI per capita, based on purchasing power parity (PPP), as a measure of real income in constant prices (measured in USD in 2017 prices).[2] Also we used mobile ownership as a measure of the number of unique individuals who have regular access to a mobile phone (features, smartphones), even if they do not personally own one, as a percentage of the total population.

3.2 Data sources and its reliability

The study is based on a panel data set of 35 SSA countries for the period 2014–2021 (See Annex I). The data were collected from various secondary sources. The data on internet use (measured by the percentage of the population using the internet) were obtained from ITU (various years). The data on GNI per capita and adult literacy rate (used as a measure of skills) were obtained from the World Development Indicators of the World Bank. Data on internet coverage (measured by the percentage of the population covered by 3G networks), the percentage of the population with access to electricity (as a measure of enabling infrastructure), consumer readiness (as a measure of the capacity to access the internet), and handset prices (as a measure of a cost of the cheapest internet-enabled device) were obtained from the GSMA Mobile Connectivity Index scores. The data used is very reliable and, therefore, credible for making good policy inference from the results: the World Development Indicators (WDI), which also uses data from International Telecommunication Society (ITU) and GSMA for internet and related information, is a credible internationally recognised source of data used by the economists and other social scientists throughout the world.

[2] PPP GNI is gross national income (GNI) converted to international dollars using PPP rates. An international dollar has the same purchasing power over GNI as a U.S. dollar has in the United States. GNI is the sum of value added by all resident producers plus any product taxes (less subsidies) not included in the valuation of output plus net receipts of primary income (compensation of employees and property income) from abroad. Data are in constant 2017 international dollars.

The descriptive statistics-- mean, standard deviation, minimum and maximum of the variables used in the analysis are as presented in Table 1.

Table 1: Summary Statistics for 35 SSA Countries, 2014 - 2021

Variable	Abr.	Observation	Mean	Std. Dev.	Min	Max
Internet Use	IU	280	26.17	16.29	1.2	70
GNI per capita	y^{pc}	280	4787.97	4730.32	931.78	25501.10
Literacy	LT	280	65.50	20.47	19	95.02
Mobile ownership	MO	280	53.23	11.67	27.82	80.33
Access to electricity	AE	280	47.85	23.41	7.7	100
3G coverage	IC	280	67.66	24.54	10	99.87

The results in Table 1 show that the mean for internet use for the SSA during the period is 26.17%, where the highest rate is 70% and the lowest rate is 1.2%. The high value of standard deviation (16.3%) suggests existence of substantial unevenness in internet use among the population of SSA countries. The internet coverage rates are substantial or high: the mean is 67.7%and its standard deviation is 24.5%. The GNI per capita (I^{pc}), based on income measured by using the PPP, also reflects existence of significant variation in income levels in SSA countries: range from a high of USD 25,501 to a low of USD 932. Other variables are as shown in Table 1.

Table 2: Correlation Matrix

	IU	lny^{pc}	$lnMO$	$lnAE$	$lnIC$	$lnLT$
IU	1					
lny^{pc}	0.72	1				
$lnMO$	0.84	0.76	1			
$lnAE$	0.79	0.77	0.77	1		
$lnIC$	0.75	0.42	0.56	0.58	1	
$lnLT$	0.54	0.60	0.53	0.62	0.49	1

The correlation coefficients of the variables (transformed by applying natural logarithms) used in estimation presented in Table 2 suggests possible existence of multicollinearity problem in the estimation of the model: some of the pairs of variables are highly correlated. Notable, $lnMO$ is highly correlated with $\mathrm{lnI}^{\mathrm{pc}}$ and $lnAE$. The high correlation between some of the variables is tolerated as is explainable: the level of per capita income influences affordability, and hence ownership of the mobile phones.

3.3 Estimation Strategy

A fixed effect model is used to establish importance of each of the enabler in explaining broadband penetration or internet use in SSA. The model has been preferred because it allows control of unobserved time-invariant characteristics within an entity, a country is our case.[3] The model reads as:

[3] Nonetheless, suffice it to note that the fixed effects procedure has one drawback: the within transformation does not allow one to include time-invariant independent variables in the regression, because they get eliminated similarly to the fixed unobserved component. In addition, parameter estimates are likely to be imprecise if the time series dimension is limited.

$$Y_{it} = \beta_0 + \beta_1 X_{it} + \beta_2 Z_i + \mu_{it} \quad (2)$$

where Y_{it} is internet use, variable, X_{it} is a vector of determinants of internet use, Z_i are unobserved time-invariant heterogeneities across the entities $i = 1,2, \ldots .N$, t = time, and μ_{it} is error term. We aim to estimate β_1, the effect on Y_i of a change in X_i holding constant Z_i.

By defining $\alpha_i = \beta_0 + \beta_2 Z_i$, Equ. (2) reads as:

$$Y_{it} = \alpha_i + \beta_1 X_{it} + \mu_{it} \quad (3)$$

Where α_i $(i = 1,2, \ldots N)$ is a vector of unknown intercepts for each entity (n entity-specific intercepts).

More explicitly Equ. (3) can be presented to read as follows:

$$lnIU_{it} = \beta_1 lny_{it}^{pc} + \beta_2 lnLT_{it} + \beta_3 lnIC_{it} + \beta_4 lnMO_{it} + \beta_5 lnAE_{it} + \alpha_i + \varepsilon_i \quad (4)$$

whereas $lnIU$ stands for the proportion of internet users in the total population; $lnLT$ is log of literacy rate as a measure of basic skills; lny^{pc} is a log of GNI per capita, PPP as a measure of income; $lnIC$ is a log of internet coverage as a measure of the percentage of population covered by the 3G network; $lnAE$ is log of access to electricity as a measure of the percentage of the population with access to electricity; and $lnMO$ is log of mobile ownership as a measure of the percentage of the population owning a mobile phone.

Following Andres et al. (2007) and the reduced form of a Gompertz model of technology diffusion with a constant speed of adjustment used successfully by Estache et al. (2002), a lagged value of internet use (IU) is added in the estimation of Equ. (4) in order to test for networking effects and habitual inertia to change once a consumer is using the internet platform. Granted, the revised estimation model reads as:

$$lnIU_{it} = \beta_1 lny_{it}^{pc} + \beta_2 lnLT_{it} + \beta_3 lnIC_{it} + \beta_4 lnMO_{it} + \beta_5 lnAE_{it} + \beta_6 lnIU_{it-1} + \alpha_i + \varepsilon_i.. \quad (5)$$

From theory, we expect a positive income effect on internet use and a positive effect of literacy rate on internet use: implying people with basic literacy skills (reading and writing abilities) are more likely to use the internet than their counterparts. Also, of infrastructure, such as 3G coverage (IC), access to electricity (AE), and mobile ownership (MO), are expected to have positive effects on the internet use in SSA where most of the internet connections are through mobile phones.

4. Empirical Results and Discussion

A priori, estimation of the basic model was preceded by a test of goodness of fit, and therefore appropriateness, of the fixed effect model relative to a random effect model. We used the Hausman test where the null hypothesis tested is that the preferred model is the random effects model; and, the alternative hypothesis tested is that the preferred model is fixed effects model. We rejected the null hypothesis 193.31 (Prob>chi2 = 0.00) and, therefore, concluded that the fixed effects model is the preferred model.

Estimation results revealed the estimated fixed effect model is sufficiently robust in the sense that small variations in the sample size (or in the time period under analysis) do not provoke changes in the value and significance of the parameters of the model. We also tested for heteroskedasticity under a null hypothesis of constant variance. The modified Wald Test for group-wise heteroskedasticity in a fixed effect regression model showed a chi2 (35) = 3937.03 (Prob>chi2 = 0.00) and, therefore, we rejected the null hypothesis confirming the presence of a heteroskedasticity. To deal with heteroskedasticity, we used robust standard errors adjusted for 35 clusters. We also performed the Wooldridge (2002) test for autocorrelation in panel data (H0: no first-order autocorrelation) and the result shows that F(1, 34) = 23.032 (Prob > F = 0.00). Therefore, we rejected the null hypothesis and concluded that there is first order autocorrelation.

Table 3 presents the estimated reduced form equations for the determinants of internet use in SSA by using panel data with 280 observations (covering 35 SSA countries for eight years). The R^2 suggested the enablers included in the estimation model explained over 80% of the internet use in SSA. The results reveal the estimated coefficients for connectivity (network coverage, mobile phone ownership, and access to electricity) are statistically significant determinant of internet use in SSA. The coefficients are robust and positive: the estimated elasticities are 0.25 for network coverage; 3.7 for mobile phone ownership; and 0.28 for access to electricity (Column 1). Therefore, we are reasonably convinced that connectivity enablers (3G network coverage, access to electricity, and ownership of a mobile phone) are robust and significant determinants of internet use.

Table 3: Model results – Determinants of Internet Use in SSA

Variable	(1)	(2)	(3)	(4)
lny^{pc}	0.26		0.56**	-0.04
	(0.29)		(0.27)	(0.16)
$lnMO$	3.70***	3.65***	3.97***	2.26***
	(0.47)	(0.47)	(0.55)	(0.45)
$lnAE$	0.28*	0.33**	0.21	0.16
	(0.16)	(0.16)	(0.18)	(0.16)
$lnIC$	0.25**	0.25**	0.27***	-0.04
	(0.10)	(0.10)	(0.10)	(0.06)
$lnLT$	0.70**	0.76***		0.23*
	(0.29)	(0.28)		(0.13)
$lnIU(-1)$				0.50***
				(0.08)
$Constant$	-18.61***	-16.75***	-19.06***	-8.39***
	(2.62)	(1.66)	(2.84)	(2.63)
Observations	280	280	280	245
R-squared	0.84	0.84	0.83	0.88
Number of country1	35	35	35	35

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Source: Own computation.

On the user's side, the per capita income (I^{pc}) and adult literacy rate (AE) are positive and statistically significant determinants of internet use in SSA. As expected, per capita income is a key determinant of internet use. With the income elasticity for internet use of 0.5, points to a conclusion that internet use, as a service, fits the category of a normal good, with use increasing as per capita income increases. Using a simple model and global cross-country data from 2000, Goel et al. (2006) found the income elasticities were unity and in some cases higher, suggesting that internet services (at that time) were not deemed a necessity. The positive and statistically significant coefficient of the adult literacy rate calls for upskilling consumers to benefit from digital transformation in SSA.

The estimation results with a lagged dependent variable to capture the network effects and the possibility of habitual response to internet use once consumers are on board with the service, show the adult literacy rate and mobile ownership are still robust and significant determinants of internet use in SSA (Table 3, Column 4). The adjustment coefficient is positive and significant, signifying the role played by network effect on internet use.

5. Conclusion

The study used panel data containing information on a set of 35 SSA countries for the period 2014–2021. A fixed effect model was estimated and the results confirmed connectivity enablers (3G network coverage complemented by access to electricity) are robust and significant determinants of internet use in SSA. Thus, network coverage requires investment in the right of way, switching and transmission and network equipment. On the user's side the results confirmed affordability of digital services (via income effects) is a strong and robust determinant of internet use in SSA. Therefore, a predominance of low incomes in the region is a key influence on low internet use.

Moreover, the results revealed ownership of mobile phone has the largest elasticity on internet use in SSA. As the ultimate connectivity platform for internet users, mobile phone ownership is an essential condition for the use of digital services by most consumers in the region who depend on mobile broadband. The government should therefore institute an affirmative fiscal action targeted to increase ownership of smart or feature mobile phones as that will raise potential internet use in SSA. The fiscal policy measures should complement business models that make smartphones and digital services available at lower costs to ensure that people living in poverty can afford such life-changing services; cease classification of smartphones as luxury items; and suspend Value Added Tax (VAT) on low-end smartphones (for example feature phones) in order to render them affordable by low-income earners; subsidization by the government of subsidies the cost of devices purchased by the poor; abolish of taxation and duties imposed on smartphones. Alternatively, the government should offer fiscal incentive attractive to private investment in domestic production of affordable smartphones as that would increase internet use by a majority of the population, especially the poor, in SSA. Noteworthy, the increase in the use from the increase in ownership of smartphones will also increase government revenue from increase in demand for airtime and data bundles in each country.

References

Andres, L., Diouf, M. Cuberes, D. & Serebrisky, T. (2007). *Diffusion of Internet: A cross-Country Analysis*, in *Telecommunications Policy*, December.

Ali, A., Raza, A. A., & Qazi, I. A. (2023). Validated Digital Literacy Measures for Populations with Low Levels of Internet Experiences. *Development Engineering*, *8*, 100107.

Birba, O., & Diagne, A. (2012). Determinants of adoption of Internet in Africa: Case of 17 sub-Saharan countries. *Structural change and economic dynamics*, 23(4), 463-472.

Caselli, F., & Coleman, W.J. (2001). Cross-country technology diffusion: The case of computers. *American Economic Review*, 91(2), 328-335.

Cisco Systems (2020) *Remote Working in South Africa 2020*. Retrieved from: http://www.worldwideworx.com/wp-content/uploads/2020/08/Remote-Working-in-SA-2020.pdf

Clark, L., & Visser, M. (2011). Digital Literacy Takes Center Stage. *Library Technology Reports*, *47*(6), 38-42.

Estache, A., Manacorda, M., Valletti, T. M., Galetovic, A., & Mueller, B. (2002). Telecommunications Reform, Sccess Regulation, and Internet Adoption in Latin America. *Economia*, *2*(2), 153-217.

Gao, M., Hyytien, A., & Toivanen, O. (2004). *Demand for Mobile Internet: Evidence from a Real World Pricing Experience (No. 964). ETLA Discussion Papers.*

Goel R., Hsieh, E., Nelson M., & Ram R. (2006). Demand Elasticities for Internet Services, in *Applied Economics*, vol 38(9) pp 975-980.

GSMA (2021a). *The State of Mobile Internet Connectivity Report 2021*. Connected Society programme. Retrieved from: https://www.gsma.com/r/somic-2021/

GSMA (2021b), "The state of mobile internet connectivity in Sub-Saharan Africa: why addressing the barriers to mobile internet use matters now more than ever", https://www.gsma.com/mobilefordevelopment/blog/, October.

GSMA (2022), *The State of Mobile Internet Connectivity Report 2022*. Retrieved from: https://data.gsmaintelligence.com/research/research/research-2022/the-state-of-mobile-internet-connectivity-2022.

International Telecommunication Union. (2021). *Digital Trends in Africa 2021*. Geneva, Switzerland: ITU.

International Telecommunication Union. (2022). Measuring Digital Development: Facts and Figures 2022**.** Geneva: ITU.

Khera, P., Ng, S., Ogawa, S. & Sahay, R. (2021), "Is Digital Financial Inclusion Unlocking Growth?", IMF Working Paper WP/21/167, June.

Leandro, T., & Gomes, V. (2019). Estimating the Demand for Broadband Services in Brazil: Analysis by a Discrete-Choice Model. *Revista De Economia Contemporânea*, *23*(2).

Makwakwa, O. (2020). AfricaCom Interview: Onica Makwakwa on Closing the Digital Gender Gap by AfricaCom Perspectives 10/22/2020.

Mwamba, O., & Qutieshat, A. (2021). The Future of Formal Retail in Sub-Saharan Africa: Brief Review and Opinion. *Open Journal of Business and Management*, *9*(4), 1563-1571.

Myovella, G., Karacuka, M., & Haucap, J. (2021). Determinants of Digitalization and Digital Divide in Sub-Saharan African Economies: A Spatial Durbin analysis. *Telecommunications Policy*, 45(10), 1-14.

Ndulu, B., Joseph, C. and Tryphone, K. (2021). Fiscal Regimes and Digital Transformation in Sub-Saharan Africa. Digital Pathways Paper Series, Paper 11, March 2021DOI: https://doi.org/10.35489/BSG-DP-WP_2021/01Digital.

Ndulu, B., Ngwenya, N. & Setlhalogile, M. (2020). *The Digital Divide in South Africa: Insights from the Covid-19 Experience and Beyond*, University of Witwatersrand.

Neira, M. A., Jiménez, F. J., & Ania, A. R. (2008). Determinants of the Internet Use in Africa. Spanish Economy, JEL Classification O, 30, L69.

Niyazbekova, S. U., Moldashbayeva, L. P., Zhumatayeva, B. A., Mezentseva, T. M., & Shirshova, L. V. (2021). Digital Economy Development as an Important Factor for the Country's Economic Growth. *Socio-economic Systems: Paradigms for the Future*, 361-366.

Oliveira, A. R., & Coutinho, P. C. (2010). Broadband Expansion in Brazil: An Empirical Study. In *manusc.» In: Proceedings of the 4th ACORN-REDECOM Conference Brasilia, DF*, May.

Penard, T., Poussing, N., Mukoko, B., & Tamokwe, G. B. (2013). Internet Adoption and Usage Patterns in Africa: Evidence from Cameroon. (Working Papers; No. 2013-22). CEPS/INSTEAD.

Pénard, T., Poussing, N., Zomo Yebe, G., & Ella, N. (2012). Comparing the determinants of internet and cell phone use in Africa: Evidence from Gabon. *Communications & Strategies*, (86), 65-83.

Schmidt, J. P., & Stork, C. (2008). e-Skills. *Towards Evidence-based ICT Policy and Regulation policy paper series; 2008, v. 1, no. 3*.

Stork, C., & Schmidt, J.P. (2009).Towards Evidence-Based ICT Policy and Regulation: E-skills (Vol.1, Policy Paper 3). Johannesburg, South Africa: Research ICT Africa.

Wooldridge, J.M. (2002). *Econometric Analysis of Cross Section and Panel Data*. The MIT Press. ISBN 978-0-262-23258-0.

World Bank (2016). *World Development Report 2016: Digital Dividends*. Washington, DC: World Bank. Retrieved from: http://www.worldbank.org/en/publication/wdr2016.

Appendix

List of Countries used in Analysis

	Country				
1	Angola	13	Gambia	25	Nigeria
2	Benin	14	Ghana	26	Rwanda
3	Botswana	15	Guinea	27	Senegal
4	Burkina Faso	16	Guinea-Bissau	28	Sierra Leone
5	Cabo Verde	17	Kenya	29	South Africa
6	Cameroon	18	Lesotho	30	Sudan
7	Chad	19	Madagascar	31	Tanzania
8	Congo, Democratic Republic	20	Mali	32	Togo
9	Cote d'Ivoire	21	Mauritius	33	Uganda
10	Eswatini	22	Mozambique	34	Zambia
11	Ethiopia	23	Namibia	35	Zimbabwe
12	Gabon	24	Niger		