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Digital Technologies and Financial Inclusion in Sub-Saharan Africa

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Abstract

The study investigates the digital technology-financial inclusion nexus in 43 Sub-Saharan African countries between 2004 and 2019. The methodologies are the Generalized Method of Moment (GMM) to take care of double causality and country heterogeneity and IV-Tobit to take into account the limited range in the dependent variables. At all levels, digital technology measured by ICT indicators of the subscription rate of fixed and mobile telephone users, fixed broadband, internet users and a composite indicator of digitalization have positive significant effects on financial inclusion. A further robustness check is conducted by computing a composite indicator of financial inclusion to determine how it is affected by digital technology. The findings indicate that the rate of financial inclusion in Sub Saharan Africa rises with increasing digital technologies. There should be more investments in terms of promoting financial and technological infrastructures and also in the human capital sector since financial literacy can play an important part in promoting financial stability and inclusive finance in Africa.

Keywords: Digital Technologies; Financial inclusion; Sub Saharan Africa

1. Introduction

Digital technologies have been found to facilitate the access to more financial services by individuals who reside in local areas and cannot afford a bank account which made them financially exclusive (Anarfo et al., 2018). Besides, digital technologies have been argued as an asset for the inclusion of the financial system and for achieving sustainable development (Asongu et al., 2021; Nchofoung and Asongu, 2022 a). This is the point of departure of this study with focus on sub-Saharan Africa. Firstly, the growth in the number of accounts owners in Africa is a sign of financial development, but a question is raised; does digital technology makes the African financial sector vulnerable to attacks (instability) or does it contribute to financial development that helps ameliorate the livelihood of individuals since they have access to financial services? Though, the rate of poverty in some economies has been so high making it difficult to afford financial services, making life miserable. Sustainable development goals are aimed at ensuring the inclusion of all in the sustainable development plans (Adeleye and Eboagu, 2019).Secondly, Digital technologies can ensure the accessibility of financial services by ensuring its provision at affordable prices to the less privileged. Stability though is not assured with growth in technology and increased competition between financial institutions which made many to question the modulating effects of digitalization on financial system stability.

The assumption of financial inclusion being significantly influenced by growth in digitalization is a topic of debate among contemporary researchers. Financial inclusion in Sub Saharan Africa has risen over the years because of mobile money penetration (Asongu et al., 2021; Zins and Weill, 2016). The growth in financial inclusion is yet to be determined if the rate is generated by growth in digital technologies. This is yet to be translated to the amelioration of the average living standard and life expectancy which can be reduced through poverty alleviation and equitable distribution of wealth. Information and communication technologies have contributed to the development of the African economy specifically in the financial department, aimed at reaching the goal of inclusive sustainable development (Asongu et al., 2021; Nchofoung and Asongu, 2022 b). Many African countries have achieved growth rates in their gross national products over the past decades and aspire to adapt to the global structural transformation dominated by growth in digital technologies. According to De Koker and Jentzsch (2012), financial inclusion does not only refer to provision of access and affordable

financial services but making sure that these services reach the large segments of the vulnerable groups. Financial inclusion at the level of the African continent where many people do not have access to financial services has to include services to low-income groups with access to formal financial services such as credit for daily transactions, savings and insurance opportunities.

Digital technologies include communication device, cellular phones, internet penetration, computers, hardware and software networks and satellite systems etc. Technological growth has facilitated financial services transactions through the transformation of information, automation of processes and rapid flow of financial transactions in the World financial market in general and different banking sectors in Africa (Anarfo et al. 2018). ICT growth has been complimented for the world structural changes and increased financial globalization that has been a major factor in shaping the new global world which produces rapid changes with dynamic and accessible communication patterns and multi-national engagements (Friedline, 2017). Growth in digital technologies presents the bedrock for financial development and inclusive growth in Africa. Relative to the growth in other countries where the rate financial inclusion is so high, the African economy has realized an increase in the provision of financial services but relatively very low as compared to European countries. In Africa, more than half of the population is excluded from financial services because of poverty and income inequality. Most African countries have registered successes in the use of digital technologies especially in the domain of mobile money transfers which helps in financing transactional purchases with a reducing cost of funds management at a reduced transaction cost (Asongu et al., 2021; Evans, 2018). The adoption of digital technologies in Africa is yet to be fully harnessed for sustainable growth, due to a very high rate of illiteracy and the cost outlay of technological infrastructures and services. The majority of the population are uneducated and do not have the knowledge to exploit the opportunities presented by digital technologies.

There is too much speculation and optimism concerning the role of digital technologies on financial inclusion. Most research works documented have demonstrated positive digital technology effects on financial development but a lot is yet to be determined in the African continent and specifically in Sub Saharan Africa (Friedline, 2017; Lenka and Barik, 2018). The statement of Friedline (2017) on the relevance of digital technology on financial systems where he said: *"Financial inclusion in the 21st century economy depends on affordable, reliable*

Internet". The pre-occupation of the effects of digital technologies on financial inclusion in Africa is the issue at stake. The rate of financial inclusion is very low in Africa despite the growth in digital technologies till presently, though with the majority of the population judged to not having access to internet access. Low levels of technological and financial literacy in Africa have been a great determining factor of financial exclusion (Evans, 2018). Most services provided for the purchase of financial services have still not been well exploited and that is the reason why education for all has been an established target by all countries and part of sustainable development goals.

ICT has played an important role in uplifting social and economic hurdles faced in most African countries. Affordable financial services obtained via the help of digitalization have helped in poverty alleviation and improved the wellbeing of the citizens. Evans (2018) documented that developed countries have higher access to finance than developing countries solely because of advanced technology which plays a considerable role in reducing financial exclusion. Digitalization also contributes in reaching out to the poor on time and provides access to less expensive information and better connectivity through mobile-banking, internet banking and mobile automated teller machine services (Mushtaq, 2019). Warren (2007) documented that the population who benefit from the modulating effect of digitalization through mobile phone penetration are the underprivileged in rural populations which help in poverty alleviation and societal inclusion. The rate of financial inclusion in African countries is very low as compared to that of the developed economies (Kadjie et al., 2022). Inclusive finance in developed countries is highly attributed to high human capital (Stein and Yannelis, 2020), ICT (Asongu et al., 2021) and foreign direct investments (Odugbesan et al., 2020). The rate of financial inclusion in Africa has been increasing at a very slow rate and it is in this aspect that the study seeks to determine if the level of inclusive finance in Africa can be enhanced by digital technologies. The findings of the study will be imperative to policy makers of the African countries on how the financial sector can be enhanced through information and communication technologies.

The financial system in Africa contributes to the continents' economic sustainability. Banking sectors in Sub Saharan Africa have undergone some substantial changes in recent years. In the mid 1900's before the 21st century, most financial institutions were state-owned institutions, but the system has been transformed considerably into competitive sectors with

many commercial and private institutions (Evans, 2016). However, the banking sectors have developed considerably due to digital technologies and increase competition in the market which has prompted the discovery of ICT strategic mobile banking and internet banking. Financial integration and globalization has reduced trade restrictions and barriers which have paved a way for foreign banks to enter the African economy and has led to an integrated outlook to banking in most banking sectors in Africa (Beck and Cull, 2014). Despite all these digital technologies, the formal financial sector in most parts of Africa is still very exclusive (Beck et al., 2015; Edoh et al., 2021).Equally, Morgan and Pontines (2014), and Asuming et al. (2018) documented that the rate of financial inclusion between adults in low-income countries is very low. In developing countries, larger segments of the population have no access to the formal financial system. According to the findings of Chaia et al. (2013) 80% of adult population is without formal financial system relative to 8% of the adult population in OECD economies. According to Arun and Kamath (2015), 45% of the number of adults who have an account poses also a mobile account.

The contributing effects of ICT to development and financial inclusion are higher in the developed world than in the developing countries. In the same vein, output elasticities of digital technologies are slightly higher in western world than in African countries. Though, the rate of growth of some developing countries considered of recent as emerging economies have been outstanding (Demirgüç-Kunt and Singer, 2017). The world has been so competitive at the international market caused by technological progress. Competitiveness is an important factor that determines the success of each country at the international level and has been taken as a base to be actively involved in the global economy. The African economy has faced lot of challenges posed by globalization which requires well formulated policies to react to the growing need of the continent. The penetration of digital technologies has been deemed to be of great importance to financial development but poses some threats to the World's financial systems. The potential penetration of ICT in developed countries has reached saturated levels whereas the rate has been very high in Sub Saharan Africa which explains why the region has developed over the years (Tchamyou et al., 2019). The objective of this study is therefore to empirically verify the effect of digital technology on financial inclusion in Sub-Saharan Africa

The study has contributed to the field of research on several fronts. Firstly, from the best of our knowledge, this is still the first study to be conducted on the effect of digital technologies on financial inclusion by adopting all ICT indicators and developing a composite indicator that encompassed all the individual variables of ICT specifically in Africa. The closest study to this is that of Asongu et al. (2021) who examined the impact of technology on financial inclusion but based only on mobile cellular subscription and neglected the other ICT indicators such as fixed broadband and internet users. This study employs all ICT indicators used in literature with its composite indicator. Secondly, the study has gone further to analyze both the demand and the supply sides indicators of financial inclusion with a composite indicator, and also to determine how these aspects are affected by technology which is not the case with the previous studies such as the works of Odugbesan et al. (2020), Bansal (2014), Adrianaivo, Lenka and Barik (2018) and Kpador (2011) who limited the number of measures of financial inclusion.

The rest of the paper is further organized in 5 sections. Section 2 presents some stylized facts on digital technologies and financial inclusion in Sub Saharan Africa, section 3 discusses the relevant theoretical literature and empirical findings on digital technologies-financial inclusion nexus. Section 4 presents the data and methodology. In section 5, we present and discuss the results and Section 6 presents the conclusion and policy implications with the research perspective.

2. Stylized facts on digital technologies and financial inclusion

Digitalization has influenced the structure of the World's financial systems. Before the 21st century, financial institutions in Africa have frequently provided services to their customers, but these services have considerably taken a new dimension with penetration of mobile banking via the help of digitalization. The creation of mobile banking has changed the lives of many, especially those living in rural areas. Nearly all Sub-Saharan African countries have undergone extensive financial sector reforms in recent years; their financial sectors remain under-developed, even relative to the levels of other developing countries especially the Asian countries (Allen, 2014).
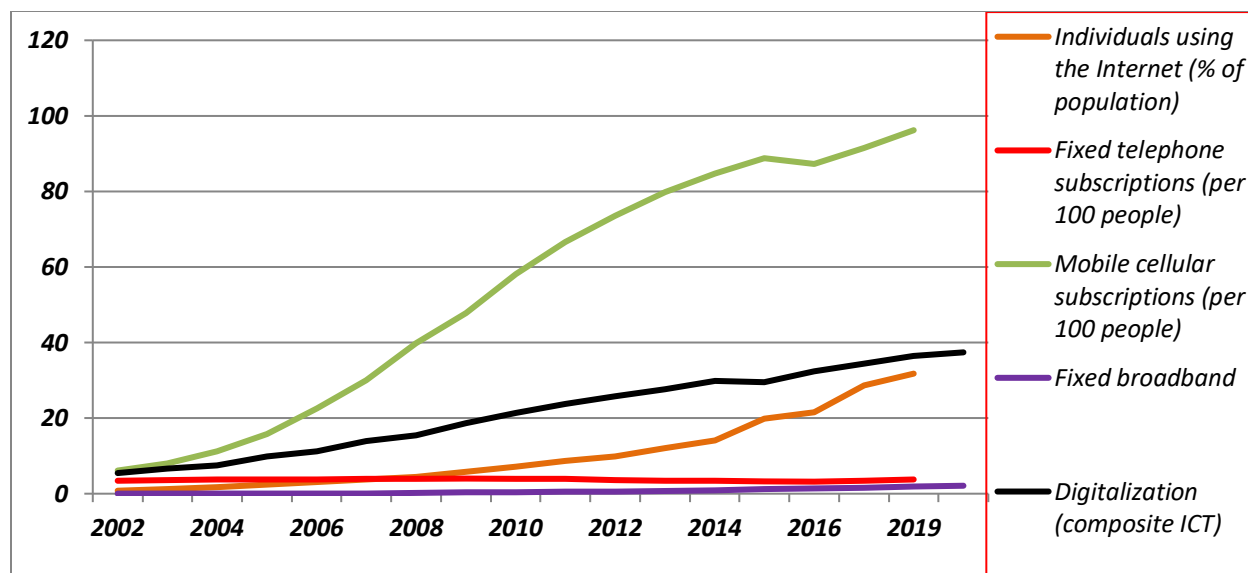
Figure 1: _**The average evolution of digital technology in Sub Saharan Africa**_/ Source: _**Authors' construction**_

Digital technologies in Sub Saharan Africa have been increasing over the years as shown by the evolution of ICT indicators in Figure 1. All ICT indicators of individuals using internet, fixed telephone subscription, mobile cellular subscription, fixed broadband and a composite indicator of digitalization have all shown increasing trends between the period of the study. The number of internet users rises from 0.7900273 in 2002 to 31.77885 in 2019 with a big difference of 30.988. The number of fixed telephone subscribers per 100 people increases from 3.468884 in 2002 to 3.767255 in 2019. The number of cellular subscribers per 100 people increases from 6.124509 in 2002 to 96.2048 in 2019. The number of fixed broadband subscribers per 100 people increases by 1.864998 between 2002 and 2019. As a measure of digitalization, we adopt a composite indicator of all these indicators which also show an increasing trend between 2002 and 2019. The increasing trend of all these indicators show a rise in digital technologies.Though, the increasing trends is dominated by a large technological gap between the region and other parts of the world which requires more investments in this sector to cover the technological frontiers.
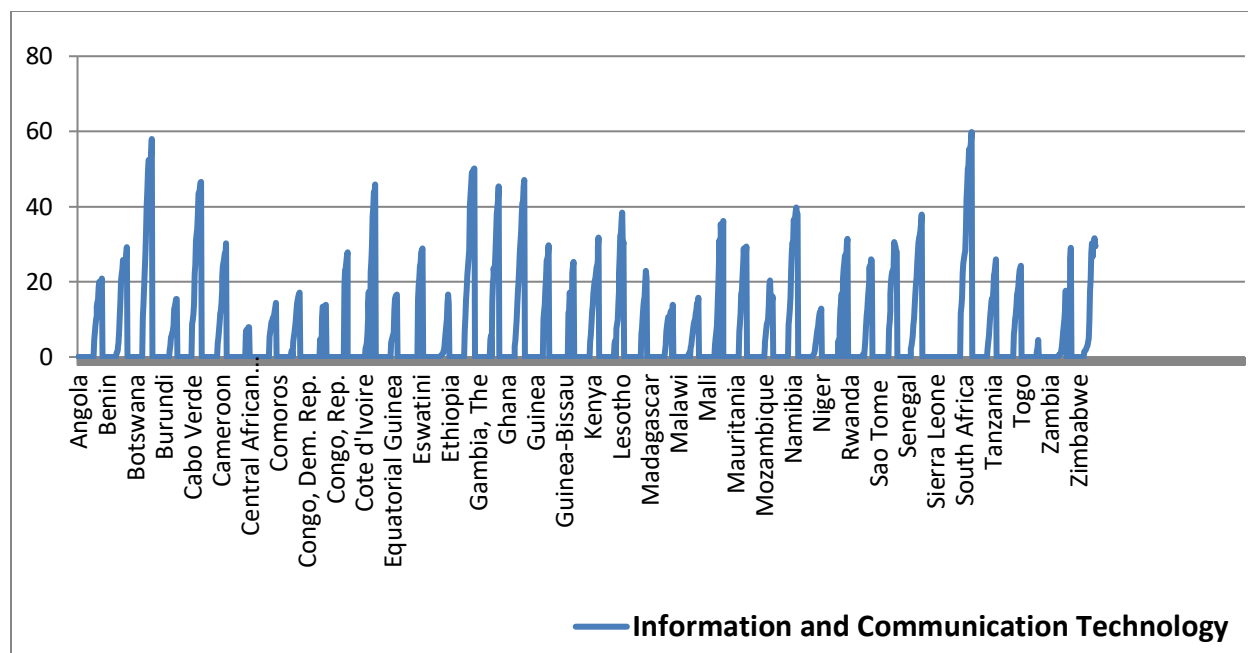
Figure 2: *Digitalization in Sub Saharan Africa* /Source: *Authors' construction*

Figure 2 shows that South Africa, Ghana, Nigeria, Botswana, Kenya, Nigeria and Gambia have a high digitalization rate and ICT growth between 2002 and 2019 in Sub Saharan Africa. Countries such as Central African Republic, Niger, Burundi and Chad have the lowest growth in digital technologies in the last two decades. South Africa has the highest which is demonstrated by how the country has evolved over the years in terms of infrastructural development which made them to be considered among the newly industrialized countries with a first-tier emerging economy demonstrated by her inclusion into the BRICS countries (Brazil, Russia, India, China and South Africa). The average trend of financial inclusion indicators in Sub Saharan Africa between 2004 and 2019 is presented in Figure 3.

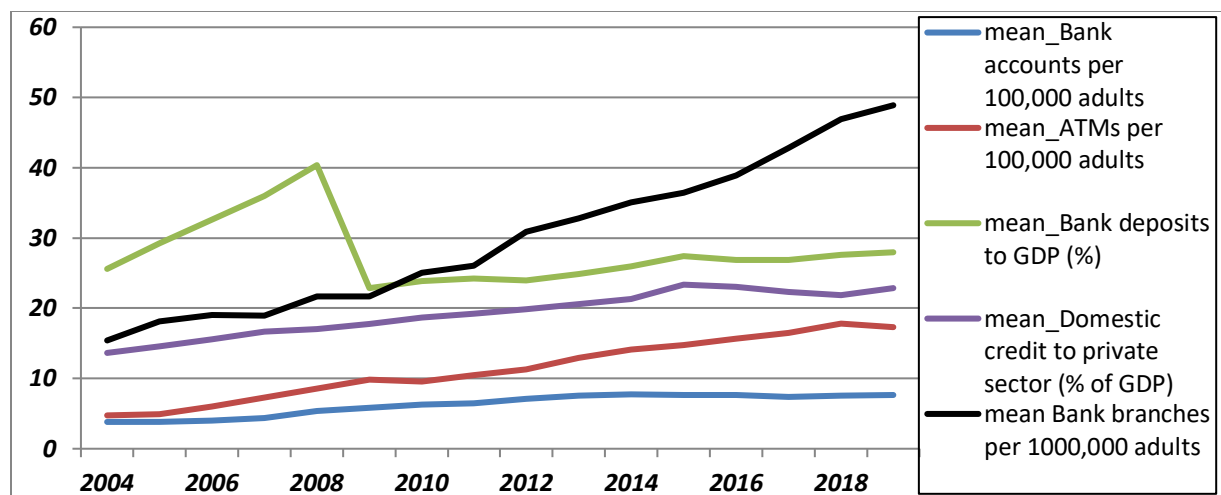Figure 3: *Financial inclusion in Sub Saharan Africa* /Source: *Author's construction*

Financial inclusion has shown increasing trends between 2004 and 2019. The number of bank accounts per 100,000 people has risen from 154.1196 in 2004 to 488.9809 in 2019 which is considered to be increasing due to increased digitalization. The number of financial institutions has increased in the last decades making the regions bank branches per 100,000 adults to increase from 3.81462 in 2004 to 7.656842 in 2019. The amount of deposits to financial institutions has risen which is due to increased economic activities though hindered in the last three years by the Covid-19 pandemic. This increase in economic activities has resulted to an increase in bank deposit (% GDP) to rise from 25.58594 in 2004 to 27.95869 in 2019. The increasing number of domestic credit to private sector investment has demonstrated how the rate of financial inclusion has risen over the last two decades. Though as confirmed by Evans (2016) and Anarfo et al. (2018), these increasing trends of financial inclusion pose the problem of instability in the banking system. Boyd and De nicolo (2009) documented that an increase in these indicators increases the level of banking competition in the banking sector. Financial development is marked by increasing trends in financial inclusion in Sub Saharan Africa which still has many adults without a bank account. A notable increase in financial inclusion is also demonstrated by the progress in financial access in the last two decades (Asuming et al., 2018) though, more than half of the population do not have access to financial services and as a result remain excluded from the horizon of economic and financial development.

3. Literature Review

This section begins with a theoretical base. In this respect, several studies have made an attempt in providing the theoretical foundation for financial inclusion. The public goods approach of financial inclusion has argued that the provision of formal financial services should be treated as public goods and should be provided to everyone for the benefit of all. This gives the government the responsibility for promoting financial inclusion (Ozili, 2020). Also, another approach is through the financial literacy approach which argues that awareness on the availability of basic fincial services should be created within the economy instead of investing public funds (Staschen and Nelson, 2013; Ozili, 2020). In this regard, the use of digital technology in the financial sector can be an appropriate measure in creating awareness.

On the empirical front, a lot of research has been carried in the banking sectors of most African countries with much attention on financial development, financial inclusion, financial intermediation and banking competition but less has been done on mobile and digital banking. Financial inclusion has gained much attention in recent years because of its ability to promote inclusive growth and financial sector development (Anafor et al., 2019). At the same time, it helps to foster greater income equality and ensure inclusive growth. According to Diamond (1984), Anafor et al. (2019), Hanning and Jansen (2010), the importance of inclusive finance is basically for its ability to enhance economic growth and poverty alleviation. It is argued in the public good theory of financial inclusion that the delivery of formal financial services to the financially excluded population while ensuring the treatment of the unrestricted access to finance for everyone should be considered as a public good to be provided by the states. In the dissatisfaction theory of financial inclusion, it is often argued that inclusive finance activities should first be targeted to reach all the people who were not enjoying formal financial services but left the formal financial sector because they were not satisfied. Also, this is similar to the community echelon theory's idea of ensuring the inclusivity of the formerly financially-excluded population through their leaders.

Financially excluded individuals often transport their money themselves or before the massive creation of financial institutions, many usually carry money themselves. With high insecurity, financial institutions are deemed as safer and cheaper means of storing and transferring money from one person to another, which is assured by the integrity of the transport

mechanism. The world financial systems have ensured the establishment of some prudential norms to be followed so as to ensure the effectiveness of banking sectors (Siddik and Chitokwindo, 2014). Digital banking through increased digitalization has been a key to increasing financial development and financial inclusion in recent years particularly through mobile money and e-banking. The telecommunications and information platforms are subject to specific regulations which arises due to consumer protection and policy implications (Klen and Mayer, 2011).

Studies on digital technologies and financial inclusion have not been well exploited. Some studies on digital technologies and development indicators have been mostly concentrated in the economic and environmental domain and have neglected how growth in technologies affects financial inclusion and deepening. In attempts to study the determinants of financial inclusion, Chai et al. (2018) findings reveal that digital technologies significantly influence and increase the possibility of individuals participating in the financial market. The authors further state that ICT increases financial inclusion in both the informal and the formal sectors. As an influence of digital banking, Siddik et al. (2017) found out that digitalization through internet banking have increased financial inclusion and boost the level of bank's performance in Bangladesh. Lenka and Barik (2018) in their verification of the financial inclusion-growth nexus documented that digitalization through mobile phone and internet services penetration affects positively the degree of inclusion in financial services which contributes to inclusive growth. Also, the authors revealed a linear causal flow in the degree of digital technologies and expanded financial inclusion. Sassi and Goaied (2013) in their study reported that the rate of financial inclusion is ameliorated by the level of human capital via increases in digitalization. In the same empirical findings, the authors posited a positive significant role of information and communication technologies on financial infrastructure which help to boost the rate of financial inclusion. Mushtaq (2019) conducted a study to determine the effect of ICT diffusion on poverty reduction through financial inclusion in 62 developing countries between 2001 and 2012. His findings show a positive association of ICT with the interaction of financial inclusion indicators on poverty reduction. The author determined financial inclusion as a channel through which ICT affects poverty and inequality. Triki and Faye (2013) researched on the nexus between digital technology especially on the aspect of mobile technology effects on financial inclusion in Africa and arrived at the conclusion that mobile technologies facilitate financial services transactions in

the financial sector and makes many unbanked persons to be included in the financial sector and to have access to financially affordable financial services. Digital technology like internet banking offers a potential solution for many people in emerging markets making financial services accessible and at an affordable rate (CGAP, 2006).

Another strand of literature demonstrated that digitalization can have other side effects to financial development. Siddik et al. (2014) demonstrated in his work on factors that hinder the involvement of individuals in the digital banking, since they were already accustomed with traditional branch based banking system. According to these authors, people are less inclined to change in adopting a new technology banking system especially in developing countries where the rate of digital banking is considerably low. The concept of digital finance and financial inclusion can be well linked by the diffusion research theory that has examined the adoption and uses of information technology from a diffusion of innovation in the market economy precisely by firms such as financial institutions. Siddik et al. (2014) found out that digital technology does not necessarily lead to financial inclusion but instead reduces financial inclusion because of the cost of purchasing a device and the fear of insecurity in the system. Klein and Colin (2011) demonstrated that though digital technologies bring about financial inclusion, they have other repercussions in the exposure of those who are financially illiterate on how digital banking operates due to the risk of discouragement caused by complicated technology. Empirical studies carried in this field have the following short comings. Elhadj and Elouaourti (2021) conducted a study on mobile banking and financial inclusion. His findings show that the rate of financial inclusion in Morocco is constant over the years despite the growth in digital banking in the African subsector. Empirical studies have focused only on mobile phone technology and financial inclusions as in the works of Klein and Mayer (2011), Mago and Chitokwindo (2014) and neglected other indicators like fixed broadband and fixed telephone subscriptions. Most studies carried on financial inclusion have not employed both the supply and demand financial inclusion indicators with a composite that encompasses various financial inclusion indicators (Arun and Kamath, 2015; Bansal, 2014; Klein and Mayer, 2011; Evans, 2016). Some studies carried on financial inclusion and digital finance has only focused on demonstrating the positive side of financial inclusion without studying the other extreme.

4. Data and Methodology

4.1. Data

The study employs secondary data on 43[1] Sub Saharan African countries between 2004-2019 obtained from the World Bank development indicators and international financial statistics (2021). The sample size of 43 Sub Saharan countries adopted in the study and the period of study is due to the data constraints on other periods and countries such as Somalia, Liberia, Burkina Faso and Eritrea.

Variables and justification

Dependent variable

The dependent variable is financial inclusion measured by the number of bank accounts per 100,000 adults, the number of bank branches and the number of ATMs subscribers per 100,000 adults. The study also employs a composite indicator of financial inclusion that encompasses all the indicators of financial inclusion employed in the study by using the PCA analysis. These variables are all normalized to range between 0-1 in accordance with Ngouhouo and Nchofoung (2022). Many indicators have been computed to measure financial inclusion but we employed those that are widely used in literature for the following reasons. The number of bank accounts captures the increasing number of individuals who involve themselves in the financial sector and also the demand side of financial inclusion. The number of bank branches indicates how financial services are geographically distributed and also determines the concentration ratio of the banking sector. The amount of deposits and credit to the banking sector captures how the provision of financial services influences the level of economic activities in the economy. Among authors who adopted these measures are Sha'ban et al. (2019), Menyelim et al. (2019), Evans (2016), Turvey and Xiong (2016), Shen et al. (2018) and Abor et al., (2019). The variables are defined in the appendices.

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[1]Angola, Benin, Botswana, Burundi, Cabo Verde, Cameroon, Central African Republic (CAR), Chad, Comoros, Congo, Democratic Republic of the Congo, Cote d'Ivoire, Equatorial Guinea, Eritrea, Eswatini, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, South Africa, Tanzania, Togo, Uganda, Zambia, Zimbabwe.

The composite indicator obtained by the PCA analysis with its factors can be specified as

$$FIndex_{it} = Z_{j1}X_1 + Z_{j2}X_2 + Z_{j3}X_3 + Z_{j4}X_4 + \dots + Z_{jp}X_p \quad \dots \text{ (1)}$$

Findex represents financial inclusion index, Z_j signifies the weight of the parameter of the factor score while X represents the values of the respective components; p represents the number of variables used in the analysis. The computation of this index using the PCA analysis is inspired by the work of Anarfo (2018)

$$FIndex_{it} = \beta_0 Bank\ accounts + \beta_1 Bank\ branches + \beta_2 ATM + \beta_3 Deposit + \beta_4 Domestic\ credit + \beta_5 Bank\ loans \quad \dots \text{ (2)}$$

Variables of interest

The main independent variable is digital technology measured by four indicators. The number of individuals using internet, the number of fixed broadband subscribers, the number of fixed phone and mobile cellular phone subscribers and a composite indictor that encompasses all the indicators. All these indicators have been employed so as to have good policy implications on all aspects of digital technologies. Among authors who have employed this indicators are Abor et al. (2018), Sha'ban et al. (2019) and Evans (2016, 2018). These indicators are expected to have positive effect on financial inclusion since technology is viewed by many as a means toward attaining financial development and inclusive finance.
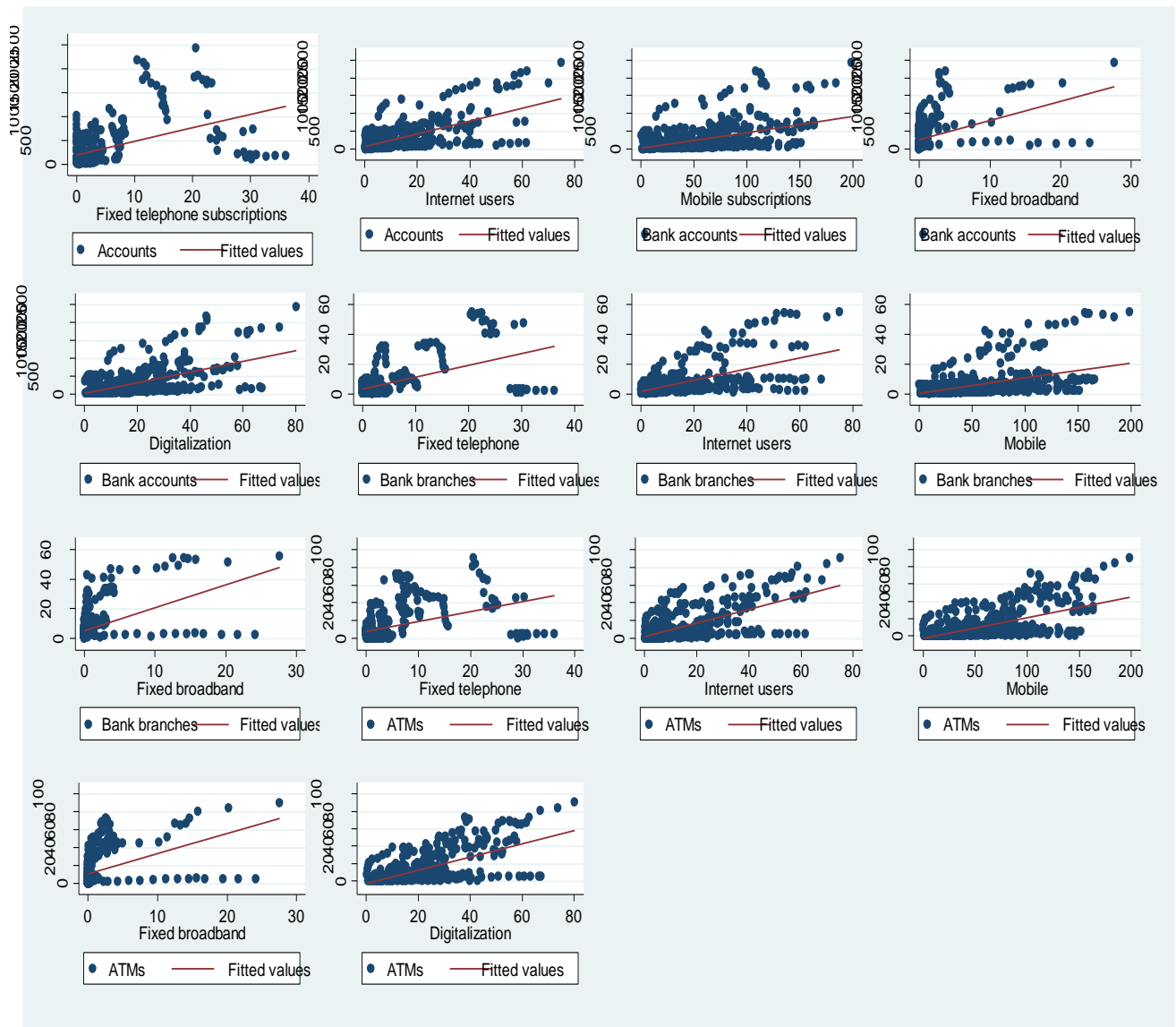
Figure 4: *The correlation between digital technologies and financial inclusion in Sub Saharan Africa*

Figure 4 shows a correlation between digital technology indicators and financial inclusion in Sub Saharan Africa within the period of study. The numbers of internet users, fixed broadband, fixed telephone and mobile cellular subscribers all have positive relationships with financial inclusion indicators of the number of bank accounts per 100,000 populations, the number of branches, mobile money subscribers. The correlation analysis indicates a positive effect of ICT growth on the rate of financial inclusion.

Control variables

We controlled other variables that could influence financial inclusion in Sub Saharan Africa as gross domestic product, the rate of domestic savings, government expenditures, foreign direct investments and trade. These variables have been widely employed in literature as determinants of financial inclusions. Foreign direct investment as a determinant of financial inclusion is inspired from the works of Odugbesan et al. (2020), where it is presumed to have a positive effect on financial inclusion. Economic growth as a determinant of financial inclusion is also inspired from the works of Odugbesan et al. (2020) and Allen (2014) whose influence on financial inclusion is expected to be positive. Financial inclusion is expected to be negatively influenced by the level of consumer price changes (Allen, 2014). The use of inflation as a determinant of financial inclusion is encouraged by the works of Sha'ban et al. (2019) and Allen (2014). The study employs trade as an indicator of financial inclusion inspired from the works of Lenka and Sharma (2017) and Chinoda (2020). The use of government final consumption as a determinant of financial inclusion is inspired from the works of Makina and Walle (2019), and Turegano and Herrero (2018). Domestic savings as a determinant of financial inclusion is inspired from the works of Rillo (2016). Table 1 presents the summary statistics for these variables considered.

Table 1: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Bank accounts	465	0.1230687	0.1606324	0	1
Automatic tellers machines	552	0.1308216	0.1868366	0	1
Bank branches	609	0.1105879	0.1644148	0	1
Financial inclusion index	350	0.5467605	0.1659115	0	1
Fixed telephones	665	3.152	6.113	0	36.128
Internet users	643	12.573	14.806	.031	75
Fixed broadband	574	0.9260429	2.965389	0	27.59799
mobile	673	58.652	41.454	.21	198.152
Digitalization	538	20.79387	14.89285	0.2543311	80.33443
Foreign direct investments	688	4.978	8.649	-11.199	103.337
GDP per capita	688	4.523	4.693	-36.392	37.999
Consumption	607	14.567	6.6	2.047	43.484
Savings	618	15.422	17.138	-38.835	83.287
Inflation	688	8.347	20.024	-21.165	440.83
Trade	629	72.773	34.04	20.722	225.023

Source: Authors' computation

Table 1 shows that our dependent variables vary between 0 and 1 with very standard deviation

values. Equally, the ICT indicators show that mobile phone subscription has dominated. Fixed broadband and fixed telephone subscriptions have been the least in terms of development. Fixed telephone subscription has actually been on a decrease globally since the advent of mobile phones.

4.2. Methodology

The study employs the IV-TOBIT regression to address the limited range of the financial inclusion variables and also to address the concern of potential endogeneity (Nchofoung and Asongu, 2021 a). The study further applies the GMM techniques due to the weaknesses of the IV-TOBIT regression of not addressing the problems of unobserved heterogeneity by accounting fortime-invariant omitted variables and the concern of reverse causality. The main GMM technique is applied to address these issues of estimation. The study spans from 2004 to 2019 and focuses on 43 African countries fulfilling the main condition of adopting the GMM strategy which requires the number of individuals to be greater than the time series (Nchofoung et al., 2022; Nchofoung and Asongu, 2022 b). The study also fulfills the condition of adopting the GMM when it concerns panel data analysis. Also, the correlations between financial inclusion indicators at level and their first lag values are 0.9935, 0.9869 and 0.9946 which are all higher than the threshold of 0.800 which is considered as an established rule of thumb for the assessment of persistence in an economic indicator (Asongu and Odhiambo, 2019). The system GMM technique adopted in the study is summarized with the following equations in levels (1) and in first difference (2):

$$FI_{it} = \beta_0 + \beta_1 FI_{i\,(t-1)} + \beta_2 Tech_{it} + \sum_{h=1}^{k} \delta_h\, Z_{h\,i(t-\tau)} + \mu_i + \gamma_t + \varepsilon_{it} \quad \ldots\ldots\ldots \quad (3)$$

$$FI_{it} - FI_{i(t-\tau)} = \beta_1(FI_{i(t-\tau)} - FI_{i(t-2\tau)}) + \beta_2(Tech_{it} - \beta_2 Tech_{i(t-\tau)} +$$
$$\sum_{h=1}^{k} \delta_h\, (Z_{h\,i(t-\tau)} + Z_{h\,i(t-2\tau)}) + (\gamma_t - \gamma_{(t-\tau)}) + (\varepsilon_{it} - \varepsilon_{i(t-\tau)}) \qquad \ldots\ldots \quad (4)$$

FI signifies financial inclusion which is measured by the number of bank accounts, the number of bank branches and the ATM users. Tech represents digital technologies proxied by ICT indicators of internet users, fixed broadband, fixed and mobile cellular phone users. In equations(2) and (3), Z signifies the vector of control variables (Foreign direct investments,

GDP, Savings, government spending, trade and inflation. μi represents the country specific effect in panel analysis whileγt is the time-specific constant, εit is the error term and $\tau$the lagging coefficient.

The main problem usually associated with the GMM framework is that of identifications, simultaneity and exclusion restrictions. To overcome these problems, all our explanatory are treated as exogenous in accordance with related literature (Asongu and Acha-anyi, 2019; Tchamyou and Asongu, 2017; Tchamyou et al., 2019 a, b; Tchamyou, 2019; Nchofoung et al., 2022; Nchofoung and Asongu, 2022 b). Besides, the time fixed effects are used as instruments in both the difference and level equations, while adopting the forward orthogonal deviation to limit instrument proliferations.

Equally, the instrumental Tobit regression has been applied. Given that the first condition for the application of this variable to be feasible is that the dependent variable should have a limited range, our dependent variable was linearized using the min-max technique (Ngouhouo and Nchofoung, 2022). In the computation process of the IV-Tobit, internal instruments were used in accordance to attendant literature (Nchofoung et al., 2021 a; Nchofoung and Asongu, 2022). In this case, the explanatory variables suspected of endogeneity are regressed with their first period lags and the residues extracted and used as instruments.

5. Results and discussions

The study employs the GMM and the IV-TOBIT as techniques of estimation. The results began with the baseline results of the IV-TOBIT regression which addresses the limited range of the study variables. The baseline results are presented in three different tables representing 3 different indicators of financial inclusion. The first table measures the effects of ICT indicators on the number of bank accounts per 100,000 people. The second table measures how ICT indicators influence the number of bank branches per 100,000 people in Sub Saharan Africa. Table 4 shows the IV-TOBIT estimates how automated teller machines users per 100,000 population is influenced by digital technology indicators of individuals using internet, fixed broadband, fixed and mobile phones subscribers per 100,000 people in Sub Saharan Africa.

Table 2: ***The effect of digital technology on financial inclusion in Sub Saharan Africa***

[2]VARIABLES	(1)	(2)	(3)	(4)	(5)
			Dependent variable: Bank Account		
Fixed telephone	0.0450***				
	(0.0100)				
Internet users		0.0413***			
		(0.00368)			
Mobile phone			0.0137***		
			(0.00142)		
Broadband				0.0504***	
				(0.0179)	
Digitalization					0.0407***
					(0.00438)
FDI	0.0111	0.0236**	0.0233**	0.0105	0.0275**
	(0.0117)	(0.0109)	(0.0109)	(0.0136)	(0.0129)
GDP per capita	-0.0117	-0.00458	-0.00714	-0.00909	-0.00190
	(0.0120)	(0.0109)	(0.0111)	(0.0145)	(0.0134)
Consumption	-0.0118	-0.0227**	-0.0266***	-0.0151	-0.0234**
	(0.0102)	(0.00920)	(0.00935)	(0.0110)	(0.0101)
Savings	0.0146***	0.00830**	0.00528	0.0131***	0.00234
	(0.00388)	(0.00367)	(0.00374)	(0.00428)	(0.00417)
Inflation	0.00226	0.00217	0.00239	0.00277	0.00271
	(0.00211)	(0.00191)	(0.00194)	(0.00213)	(0.00198)
Trade	0.00590**	0.00359*	0.00531**	0.00989***	0.00326
	(0.00257)	(0.00213)	(0.00210)	(0.00258)	(0.00238)
Constant	4.495***	4.401***	4.063***	4.431***	4.192***
	(0.159)	(0.142)	(0.143)	(0.174)	(0.164)
Observations	396	364	395	342	312
chi2_exog	6.135	0.109	2.398	1.266	1.289
Tobitul	7.793	7.793	7.793	7.793	7.793

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; FDI stands for foreign direct investment, GDP signifies gross domestic product, consumption
Source: Authors' computation

The IV-TOBIT results presented in Table 2 shows a positive statistically significant effect of digital technologies on the number of bank accounts at 1%. The results presented on the table will be confirmed and interpreted in Table 5 of the GMM estimates.

Table 3: ***The effect of digital technology on financial inclusion in Sub Saharan Africa***

VARIABLE	(1)	(2)	(3)	(4)	(5)
	Dependent variable: Bank branches				
Fixed telephones	0.460***				
	(0.0566)				
Internet users		0.279***			
		(0.0211)			
Mobile phone			0.0684***		
			(0.00844)		
Fixed broadband				0.900***	
				(0.117)	
Digitalization					0.245***
					(0.0273)
Foreign direct investment	0.214***	0.238***	0.204***	0.187***	0.235***
	(0.0588)	(0.0549)	(0.0582)	(0.0669)	(0.0679)
GDP per capita	-0.0703	0.0146	-0.0565	-0.0316	0.0244
	(0.0748)	(0.0697)	(0.0744)	(0.0929)	(0.0935)
Consumption	0.0427	-0.117**	-0.106*	0.0292	-0.117*
	(0.0600)	(0.0558)	(0.0605)	(0.0691)	(0.0685)
Savings	0.0606***	0.0256	0.0245	0.0685***	0.0266
	(0.0225)	(0.0214)	(0.0230)	(0.0257)	(0.0263)
Inflation	0.000792	-0.00450	-0.00387	0.00120	-0.00203
	(0.0136)	(0.0126)	(0.0136)	(0.0145)	(0.0145)
Trade	0.0892***	0.102***	0.128***	0.114***	0.116***
	(0.0143)	(0.0120)	(0.0125)	(0.0155)	(0.0150)
Constant	-3.883***	-4.464***	-6.572***	-4.641***	-6.906***
	(0.963)	(0.881)	(0.943)	(1.126)	(1.156)
Observations	495	468	495	415	386
chi2_exog	11.19	3.749	0.0800	0.507	0.0167
chi2	429.2***	534.4***	433.9***	411.8***	372.6***
Tobitul	55.07	55.07	55.07	55.07	55.07

Notes: Standard errors in parentheses; *** $p<0.01$, ** $p<0.05$, * $p<0.1$; GDP is gross domestic product.
Source: Authors' computation

Table 3 shows a positive effect of digital technology indicators on the number of bank branches per 100,000 adults in Sub Saharan Africa. The results indicate that the number of branches per 100,000 adults increases with increasing digital technologies. The results of ICT-bank branches

causal relations are further presented in Table 6.

Table 4: ***The effect of digital technology on financial inclusion in Sub Saharan Africa***

VARIABLES	(1)	(2)	(3)	(4)	(5)
	Dependent variable: ATMs per hundred thousand adults				
Fixed telephones	0.957***				
	(0.131)				
Internet users		0.703***			
		(0.0478)			
Mobile			0.222***		
			(0.0188)		
Fixed broadband				1.836***	
				(0.273)	
Digitalization					0.734***
					(0.0615)
Foreign direct investment	0.217	0.329***	0.228*	0.0966	0.276*
	(0.138)	(0.124)	(0.126)	(0.156)	(0.147)
GDP per capita	-0.433**	-0.172	-0.311*	-0.572**	-0.312
	(0.176)	(0.159)	(0.162)	(0.223)	(0.209)
Consumption	0.802***	0.410***	0.365***	0.849***	0.464***
	(0.140)	(0.126)	(0.131)	(0.162)	(0.150)
Savings	0.245***	0.175***	0.138***	0.268***	0.164***
	(0.0534)	(0.0488)	(0.0498)	(0.0611)	(0.0577)
Inflation	0.00642	0.00130	0.00750	0.00465	0.00660
	(0.0309)	(0.0275)	(0.0287)	(0.0334)	(0.0311)
Trade	-0.0316	-0.0114	0.0308	-0.00400	-0.0272
	(0.0343)	(0.0274)	(0.0273)	(0.0371)	(0.0330)
Constant	-3.201	-5.584***	-11.46***	-2.746	-10.37***
	(2.280)	(2.017)	(2.071)	(2.678)	(2.568)
Observations	457	429	460	390	360
chi2_exog	15.55	0.122	0.287	1.062	0.00150
chi2	192.5***	383.9***	308.9***	157.7***	260.4***
Rank	8	8	8	8	8
Tobitul	89.99	89.99	89.99	89.99	89.99

Note: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1, GDP is gross domestic product, ATM is automatic teller machine
Source: Authors' computation

Table 4 findings show a positive effect of digital technologies on the number of automated teller machines per 100,000 adults in Sub Saharan Africa. These results will be further tested in a more consistent system GMM estimates presented in Table 7.

Table 5: ***The effect of digital technology on financial inclusion in Sub Saharan Africa (GMM)***

Variables	(1)	(2)	(3)	(4)	(5)
	Dependent variable: Bank account
L. Bank account	0.944***	0.938***	0.938***	0.960***	0.937***
	(0.0102)	(0.0122)	(0.00941)	(0.00755)	(0.00672)
Fixed telephone	0.205***				
	(0.0330)				
Internet users		0.0413***			
		(0.00235)			
Mobile phone			0.0147***		
			(0.00125)		
Fixed broadband				0.0554***	
				(0.0137)	
Digitalization					0.0431***
					(0.00317)
Foreign direct investment	-0.00950**	0.00215	0.00545	-0.0120	0.00594
	(0.00381)	(0.00288)	(0.00511)	(0.00767)	(0.00531)
GDP per capita	-0.0265***	-0.0180***	-0.0251***	-0.0392***	-0.0301***
	(0.00453)	(0.00477)	(0.00526)	(0.00931)	(0.00245)
consumption	-0.0566***	-0.0487***	-0.0546***	0.0436	-0.0479***
	(0.0188)	(0.00895)	(0.00993)	(0.0258)	(0.0109)
Savings	0.0128**	0.00763*	0.00364	0.0737***	-0.00103
	(0.00544)	(0.00385)	(0.00448)	(0.0166)	(0.00332)
Inflation	0.00180***	-5.61e-05	0.00108**	0.00274***	0.000763
	(0.000517)	(0.000714)	(0.000453)	(0.000450)	(0.000484)
Trade	0.0302***	0.00603***	0.00895***	0.00311**	0.00925***
	(0.00462)	(0.00105)	(0.00195)	(0.00134)	(0.00155)
Constant	1.458***	4.842***	4.256***	3.395***	4.218***
	(0.526)	(0.234)	(0.265)	(0.487)	(0.251)
Observations	266	253	308	267	236
Number of id	33	30	33	32	29
Prop>AR1	0.297	0.879	0.773	0.0611	0.499
Prop>AR2	0.600	0.201	0.588	0.378	0.288
Instruments	24	25	25	24	25
Prob > hansen	0.138	0.136	0.137	0.315	0.135

Notes: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; GDP is Gross domestic product
Source: Authors' computation

Table 6: ***The effect of digital technology on financial inclusion in Sub Saharan Africa (GMM)***

VARIABLES	(1)	(2)	(3)	(4)	(5)
	Dependent variable: Bank branches				
L.Bank branches	0.986***	1.003***	0.995***	0.988***	0.998***
	(0.00287)	(0.00206)	(0.00215)	(0.00173)	(0.00230)
Fixed telephones	0.510***				
	(0.0649)				
Internet users		0.218***			
		(0.0228)			
mobile			0.0420***		
			(0.00778)		
Fixed broadband				0.800***	
				(0.0175)	
Digitalization					0.229***
					(0.0109)
FDI	0.0147	0.0883***	0.135***	0.0282*	0.104**
	(0.0191)	(0.0269)	(0.0232)	(0.0162)	(0.0413)
GDP per capita	-0.140***	-0.0656**	-0.0372	-0.124***	-0.0664**
	(0.0195)	(0.0276)	(0.0245)	(0.0295)	(0.0307)
Consumption	0.0262	-0.174***	-0.0691	-0.111*	-0.869***
	(0.0774)	(0.0633)	(0.0779)	(0.0612)	(0.106)
Savings	0.0558**	0.0230	-0.0170	0.0554*	-0.194***
	(0.0232)	(0.0161)	(0.0277)	(0.0324)	(0.0497)
Inflation	-0.00661***	-0.0167***	-0.00181	-0.0103***	-0.0377***
	(0.00191)	(0.00184)	(0.00253)	(0.00189)	(0.00389)
Trade	0.129***	0.107***	0.124***	0.154***	0.222***
	(0.0104)	(0.0267)	(0.0207)	(0.0115)	(0.0206)
Time fixed effect	yes	yes	Yes	yes	yes
Constant	-4.412***	-1.622	-4.884***	-3.448***	1.582
	(1.012)	(1.840)	(1.139)	(1.162)	(1.828)
Observations	313	283	312	267	243
Number of id	34	32	34	33	31
Prop>AR1	0.116	0.466	0.228	0.598	0.256
Prop>AR2	0.697	0.616	0.112	0.614	0.959
Instruments	25	25	25	25	25
Prob > hansen	0.141	0.197	0.515	0.170	0.172

Notes: Standard errors in parentheses, *** $p<0.01$, ** $p<0.05$, * $p<0.1$, FDI stands for foreign direct investment, and GDP signifies gross domestic product.
Source: Authors' computation

Table 7: ***The effect of digital technology on financial inclusion in Sub Saharan Africa (GMM)***

VARIABLES	(1)	(2)	(3)	(4)	(5)
	Dependent variable: ATMs per hundred thousand adults				
L.ATM	1.031***	1.050***	1.043***	1.036***	1.045***
	(0.00333)	(0.00389)	(0.00197)	(0.00259)	(0.00139)
Fixed telephone	1.210***				
	(0.134)				
Internet users		0.639***			
		(0.0311)			
Mobile phone			0.175***		
			(0.0323)		
Fixed broad				1.783***	
				(0.191)	
Digitalization					0.730***
					(0.0625)
Foreign direct investment	-0.0509	0.172**	0.162***	-0.200***	0.153*
	(0.0541)	(0.0737)	(0.0483)	(0.0521)	(0.0904)
GDP per capita	-0.254*	0.0492	-0.00306	-0.499***	-0.108***
	(0.144)	(0.0304)	(0.0440)	(0.136)	(0.0336)
Consumption	0.681***	0.531***	0.227	0.804***	0.481***
	(0.182)	(0.118)	(0.175)	(0.180)	(0.167)
Savings	0.208**	0.173***	0.0420	0.326***	0.155**
	(0.0825)	(0.0434)	(0.0625)	(0.0690)	(0.0684)
Inflation	0.00632	-0.00828**	0.00970	-0.00288	-0.000788
	(0.00694)	(0.00365)	(0.00655)	(0.00453)	(0.00554)
Trade	-0.00329	0.0423*	0.0720***	0.0639**	-0.00201
	(0.0300)	(0.0220)	(0.0183)	(0.0289)	(0.0143)
Constant	-3.920	-10.88***	-11.79***	-8.199***	-13.82***
	(2.657)	(1.532)	(2.501)	(2.537)	(2.817)
Time fixed effect	yes	yes	Yes	yes	yes
Observations	361	336	366	307	278
Number of id	37	36	37	36	34
Prop>AR1	0.168	0.0501	0.0900	0.653	0.0474
Prop>AR2	0.0736	0.133	0.0437	0.801	0.0596
Instruments	25	25	25	25	25
Prob > hansen	0.110	0.236	0.257	0.0827	0.166

Notes: Standard errors in parentheses; *** $p<0.01$, ** $p<0.05$, * $p<0.1$; ATM is Automatic teller machine, GDP is gross domestic product
Source: Authors' computation

The GMM results indicate some efficiency in its estimates demonstrated by the conditions of its adoption since the number of individuals (43) is greater than the period of the study (19 years) which is enough to adopt the GMM technique. Also, the GMM results are efficient since the

correlation of the dependent variables and their first lags are all greater than 0.800 which respects the role of thump for ensuring stability in economic indicators. The GMM results are also decided at the level of Hansen probabilities in all equations which is consistently greater than 0.10. The GMM result represents the main results to be interpreted and outline policy recommendations due to the credibility of its methodological backings. From the findings of the study in Table 5, the number of individuals using internet increases the number of bank account per 100,000 adults in SSA. This indicates that internet penetration in this region increases inclusivity in the financial sector which is justified by the presence of internet that has also facilitated the so called E-banking. The number of bank accounts increases also with an increasing number of fixed phone subscriptions at a 1% statistically significant effect. Similarly, the number of bank accounts also increases with an increasing mobile phone subscribers in Sub Saharan Africa. The number of fixed broadband also has a positive statistically significant effect on the number of bank accounts in Sub Saharan Africa. Adopting the number of bank accounts per 100,000 adults as a proxy of financial inclusion, can lead to the conclusion that digital technology increases financial inclusion in the African banking sector. Among researchers who adopted this measure are Anarfo et al., (2018).

Table 6 shows a positive relationship between the number of bank branches and all ICT indicators at 1% statistically significant level. The number of telephones subscription (fixed and mobile cellular) has a statistically significant effect at 1% level on the number of bank branches in Sub Saharan Africa. This indicates that bank branches increase with and increasing phone subscription. As indicators of internet penetration, the number of individuals and fixed broadband influence positively the number of bank branches per 100,000 adults in Sub Saharan Africa. Internet penetration has led to the inclusion of many individuals in the financial sector indicated by increasing number of individuals using internet and the number of fixed broadband subscribers per 100,000 adults. This indicates that digital technology increases the rate of financial inclusion in Sub Saharan Africa. The digitalization composite indicator indicates a positive statistically significant effect on financial inclusion measured by the number of bank branches. Table 7 presents the results where financial inclusion is measured by ATM users per 100,000 adults. The results show a positive effect of internet subscribers, fixed broadband, fixed telephone users, mobile cellular subscription and ICT composite indicator on the number of automated teller machines per 100,000 adults. The results indicate that the number of ATM users

increases with increase in digital technologies which corroborates the findings of Sha'ban et al. (2019) who concluded that digital technology has brought about some benefits to the financial sector development through an increasing rate of financial inclusion where people have more access to financial services than before. The positive effects of digitalization on financial inclusion corroborates to the findings of Sha'ban et al. (2019), Turvey and Xiong (2016), Menyelim et al. (2019), and Evans (2016).

Foreign direct investments have a positive statistically significant effect on the number of bank branches but appear to have a negative significant effect on some equations of bank account which indicates that financial development affects differently various indicators of financial inclusion in Sub Saharan Africa. The positive effect of FDI on bank branches is justified by the fact that investments in the financial sectors increases the number of banks with its branches to areas not formerly occupied by a financial institution. This finding corroborates to that of Odugbesan et al. (2020). The findings on the effect of GDP and inflation are mixed and vary with different measures of financial inclusion. A negative effect of GDP per on the number of bank accounts, bank branches and the ATM users indicates that GDP growth in SSA increases with a decreasing number of individuals involved in financial services. It could be possible if a high rate of inclusive finance causes an increase in lending rate due to high demands for funds which can have long term negative effects on businesses since much capital will not be demanded. In the other side, a negative effect of inflation on financial inclusion is understandable since a rise in prices can hinder financial activities. These results corroborate to the findings of Mushtaq (2019), Lenka and Sharma (2017). Trade has a positive and statistically significant effect on financial inclusion index which indicates that financial inclusion in Sub Saharan Africa increases with an increasing trade in goods and services, the finding is in conformity with that of Chinoda (2020), Lenka and Sharma (2017). Government final consumption has a negative effect on financial inclusion which is justified by the fact that the spending does not consider the most part of the population. This is consistent with the findings of Makina and Walle (2019). Domestic savings has a positive influence on the rate of financial inclusion in Sub Saharan Africa which confirms the findings of Rillo (2016).

Robustness analysis

To ensure the robustness of the study's findings, we computed a composite indicator that encompasses financial inclusion indicators used in literature by applying the principle component analysis. These indicators are the number of bank accounts per 100,000 adults, the number of ATMs per 100,000 adults, bank branches per 100,000 adults, commercial bank branches per 100,000 adults, borrowed amount from commercial banks per 100,000 adults and deposits with commercial banks per 100,000 adults. After computing this composite index of financial inclusion, we obtained the same results as in the other individual indicators. All indicators of digital technologies have positive effects on financial inclusion in Sub Saharan African countries. The computation of this composite index with the inclusive finance indicators employed is inspired from the works of Anarfo (2018) who also employed PCA to compute a composite indicator of financial inclusion.

Table 8: The effect of digital technologies on financial inclusion case in Sub Saharan Africa

VARIABLES	(1)	(2)	(3)	(4)	(5)
	Dependent variable: [3]Financial inclusion index				
Financial inclusion index(-1)	0.944***	1.006***	0.977***	0.946***	0.945***
	(0.0152)	(0.00952)	(0.00855)	(0.0109)	(0.00903)
Fixed telephone	0.0371***				
	(0.00856)				
Internet users		0.0305***			
		(0.00266)			
Mobile phone			0.00975***		
			(0.00126)		
Fixed broadband				0.106***	
				(0.00339)	
Digitalization					0.0447***
					(0.00129)
Foreign direct investment	-0.0214***	-0.00151	-0.00240*	-0.0184***	0.00271
	(0.00223)	(0.00344)	(0.00133)	(0.00140)	(0.00535)
GDP per capita	-0.0302***	-0.00692***	-0.00741**	-0.0309***	-0.0374***
	(0.00212)	(0.00215)	(0.00333)	(0.00282)	(0.00496)
Consumption	-0.00755	-0.0100	-0.00541	0.0135	-0.136***
	(0.00699)	(0.00671)	(0.00774)	(0.00874)	(0.00900)
Savings	0.0147***	0.0175***	0.00522**	0.0205***	-0.0268***
	(0.00243)	(0.00172)	(0.00200)	(0.00171)	(0.00589)
inflation	-0.00157***	-0.00186***	-0.000923***	-0.00141***	-0.00583***
	(0.000236)	(0.000233)	(0.000286)	(0.000203)	(0.000545)
Trade	0.0161***	0.0121***	0.0139***	0.0114***	0.0244***
	(0.00165)	(0.000966)	(0.00122)	(0.000840)	(0.000979)
Time fixed effect	yes	yes	Yes	yes	yes
Constant	-1.069***	-1.323***	-1.624***	-1.164***	-0.161
	(0.107)	(0.0812)	(0.0988)	(0.134)	(0.139)
Observations	216	192	216	193	206
Number of id	31	28	31	30	28
Prop>AR1	0.232	0.108	0.0497	0.0750	0.249
Prop>AR2	0.320	0.344	0.311	0.721	0.347
Instruments	25	25	25	25	25
Prob > hansen	0.349	0.268	0.342	0.261	0.136

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; GDP is gross domestic product.
Source: Authors' computation

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[3]The study has employed PCA to construct a financial inclusion index named as Findex which is computed by using six selected measures of financial inclusion. These indicators are the number of bank accounts per 100,000 adults, the number of bank branches, the number of ATMs subscribers per 100,000 adults, the amount deposited, borrowed and the domestic credit to private sectors.

6. Conclusion and Policy recommendations

The study investigated the effect of digital technology on financial inclusion in 43 Sub Saharan Africa countries between the periods of 2004 to 2019. The study employed four ICT indicators of individuals using internet, fixed telephone subscription, mobile cellular subscription, fixed broadband with a composite indicator of digitalization that encompasses all these indicators. Financial inclusion was measured by financial development variables: number of bank accounts per 100,000 adults, the number of bank branches, the number of ATM users per 100,000 adults, domestic credit to private businesses, amount deposit and the amount of money borrowed with a composite indicator that encompasses all the variables computed via the PCA analysis. Other variables such as GDP, Inflation, and FDI were judged from literature to be determinants of financial inclusion. The IV-Tobit and the GMM strategies were adopted to address different estimation issues. IV-Tobit was employed to take care of the limited range of financial inclusion variables after normalization while the GMM approach was adopted to address the potential endogeneity and reverse causality in our results. The findings show that digital technology at all levels had significant effects on financial inclusion in Sub Saharan Africa. The results further explained how significant ICT is in ensuring inclusive finance in a region where more than half of the population does not have access to financial services. The results obtained were inconformity with those of Sha'ban et al. (2019), Turvey and Xiong (2016) and Menyelim et al. (2019).

From the findings of the study, we recommend policy makers to invest in information and digital technologies so as to ensure the inclusiveness of the population to the financial sector. Also, as shown by the literature on the absence of financial institutions in rural areas, states are encouraged to invest more to infrastructures that transmit knowledge about technology so as to ensure access to banking activities like e-banking that can help ameliorate the living conditions of the citizens. As a future perspective, studies should be carried to investigate the modulating effects of mobile banking as a dimension of digital technology on financial inclusion. A further perspective is suggested to be carried on digital banking-financial stability nexus. Besides, informal finance which characterizes this study region could be integrated in future studies.

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Appendices

Appendix 1. Matrix of correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
(1) ATM	1.000														
(2) bank account	0.878	1.000													
(3) Findex	0.961	0.827	1.000												
(4) Digitalization	0.707	0.619	0.670	1.000											
(5) fixed telephone	0.624	0.574	0.619	0.672	1.000										
(6) Internet users	0.715	0.704	0.661	0.901	0.645	1.000									
(7) Mobile	0.615	0.500	0.582	0.965	0.507	0.784	1.000								
(8) fixed broadband	0.635	0.581	0.632	0.704	0.836	0.686	0.555	1.000							
(9) Bank branches	0.822	0.829	0.808	0.656	0.742	0.696	0.516	0.747	1.000						
(10) FDI	0.315	0.270	0.355	0.225	0.393	0.206	0.156	0.366	0.488	1.000					
(11) GDP per capita	-0.124	-0.108	-0.118	-0.116	-0.045	-0.123	-0.113	-0.061	-0.025	0.018	1.000				
(12) Consumption	0.333	0.191	0.310	0.390	0.342	0.393	0.347	0.250	0.336	0.186	-0.031	1.000			
(13) Savings	0.213	0.219	0.206	0.182	0.196	0.127	0.173	0.142	0.186	0.192	0.110	-0.281	1.000		
(14) Inflation	-0.071	-0.089	-0.060	-0.216	-0.085	-0.169	-0.235	-0.106	-0.068	0.030	0.144	-0.065	-0.072	1.000	
(15) Trade	0.573	0.474	0.568	0.624	0.723	0.576	0.525	0.660	0.714	0.522	-0.049	0.623	0.087	-0.030	1.000

Note: Findex is financial inclusion index, FDI is foreign direct investments, GDP is gross domestic product, and ATM is automatic teller machine.

Appendix 2: **Data, source and description of variables**

Variables	Definition	source
-Financial inclusion	-The number of bank accounts per 100,000 adults -The number of bank branches per hundred thousand adults -ATMs per hundred thousand adults (100,000) ***A financial inclusion indicator that encompasses all indicators**	IFS (2021)
Digital technologies	Measured by four different indicators with a composite indicator	
Fixed telephone subscription	- Fixed telephone subscriptions refers to "the sum of active number of analogue fixed telephone lines, voice-over-IP subscriptions, fixed wireless local loop subscriptions, ISDN voice-channel equivalents and fixed public payphones".	FDI (2021)
-Mobile cellular subscription	Mobile cellular telephone subscriptions are subscriptions to a public mobile telephone service that provide access to the PSTN using cellular technology. It includes the number of postpaid subscriptions, and the number of active prepaid accounts.	
-*Individuals using internet*	The World Bank defines this indicator as "Individuals who have used the Internet (from any location) in the last 3 months. The Internet can be used via a computer, mobile phone, personal digital assistant, games machine, digital TV."	
-Fixed broadband subscription	According to the World Bank, Fixed broadband subscriptions refers to "fixed subscriptions to high-speed access to the public Internet (a TCP/IP connection), at downstream speeds equal to, or greater than, 256 kbit/s, which encompasses cable modem, fiber-to-the-home/building, other fixed (wired)-broadband subscriptions, satellite broadband and terrestrial fixed wireless broadband. It should include fixed WiMAX and any other fixed wireless technologies."	
-Consumption expenditure	"Final consumption expenditure is the sum of household final consumption expenditure (private consumption) and general government final consumption expenditure (general government consumption)."	WDI (2021)
-GDP per capita	GDP per capita (constant 2015 US$) is GDP per capita is gross domestic product divided by midyear population.	WDI (2021)
-Foreign direct investment	Foreign direct investments are the net inflows of an enterprise operating in a foreign economy. According to the World Bank, foreign direct investment is "the sum of equity capital, reinvestment of earnings, other long-term capital, and short-term capital".	WDI (2021)
-Gross domestic savings	Gross domestic savings are determined as the part of GDP that does not belong to the final consumption expenditure.	WDI (2021)
-Inflation	Inflation as measured by the consumer price index which reflects the annual percentage change in the cost to the average consumer of acquiring a basket of goods and service.	WDI (2021)

WDI: World Development Indicators of the World Bank., FDI : Financial development indicators. IFS : International financial statistics.