



Effects of Financial Innovation on Growth in Sub-Saharan Africa: *An Analysis of The Role of Financial Inclusion*

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Abstract

The objective of this article is to determine whether financial inclusion plays a role in the relationship between financial innovation and economic growth in sub-Saharan African (SSA) countries. The study covers a sample of 35 sub-Saharan African countries. The study period spans from 2000 to 2017. To achieve this objective, our methodology relies on the construction of two indices: a financial innovation index and a financial inclusion index. We use Multiple Factor Analysis (MFA), which allows us to best summarize the information contained in the entire dataset into a small number of elements. We also employ various econometric techniques, namely simple panel estimation and the Generalized Method of Moments (GMM) system to mitigate endogeneity bias. The results of the analysis show that the development of innovations in the banking sector promotes financial inclusion. Furthermore, financial innovations are essential for economic performance in sub-Saharan Africa (SSA), but their impact depends on financial inclusion. Based on the findings, it is clear that governments in SSA countries and financial sector actors can effectively leverage the proliferation of financial innovations to boost access to and use of financial products. Therefore, it is recommended that governments in SSA countries invest in appropriate technological infrastructure that the banking sector can use to provide banking services, a key element in promoting financial inclusion and thereby optimizing economic growth.

Keywords: Financial Innovations, Economic Growth, Financial Inclusion, Generalized Method of Moments, Sub-Saharan Africa.

Introduction

The financial system plays a crucial role in global economic development. Indeed, the development of the financial sector plays an important role in mobilizing economic resources that promote capital accumulation (Gul et al., [1]). In recent decades, the economic environment has been strongly influenced by the rapid development of innovations, particularly financial innovations

in the financial sector, both in quantity and value (Blach [2]). As the World Bank has noted (2020), Dynamic, technology-driven innovations have enabled the proliferation of new financial products, numerous delivery channels, and the emergence and development of new business models. In developing countries, such as those in sub-Saharan Africa, financial innovations represent

a major opportunity for the development of the financial sector (Domeher et al., [3]).

Financial innovation can be understood as a process encompassing a variety of new products, processes, and organizational structures capable of reducing transaction costs and providing better risk and information management tools in the financial sector. In other words, using the terminology of Frame and White [4] and Tufano [5], it refers to “the introduction or improvement of a product, service, or process that benefits at least one of the stakeholders in a financial activity.” “Beneficial” here refers to reduced risks, lower costs, increased profits, and improved well-being. However, it is difficult to discuss financial innovation without linking it to the current economic climate.

Financial innovations have become an essential element of economic growth in the modern world. They encompass a wide variety of tools, technologies, and methods that enable financial institutions to better meet consumer needs and stimulate the economy. This is made possible by its ability to foster greater inclusion of the population in formal financial market activities. A higher level of financial inclusion in the economy must therefore be a priority for every government, particularly in developing countries. The contribution of the financial sector to the economy depends on the quality and quantity of the services it offers.

In recent years, the financial system of sub-Saharan African countries has undergone major reforms due to several factors, the main ones being technological innovation, which has facilitated the development of mobile finance, and monetary policies, which have fostered significant progress in financial inclusion (Demirgüç-Kunt et al. 2017). Indeed, the number of alternative channels available for the delivery of financial services has increased considerably; traditional delivery methods have given way to new delivery technologies, including online banking products such as internet banking, mobile banking, and various automated teller machine (ATM) products (Domeher et al. [6]). These new alternative financial products have expanded the provision of credit and significantly bridged the gap between financial providers and financial consumers. For Ndung'u (2019), banks have quickly taken advantage of the evolution of digital financial platforms not only to manage micro-accounts, but also to extend financial services to the previously unbanked and underserved population. According to (Elhajouji and Mesk, 2024), the Fintech industry is capable of disrupting the hegemony of traditional players and establishing an alternative financial system that operates in parallel and in collaboration with the classic financial system. There is no doubt that the financial sector is at the heart of this vitality, because it plays an essential role in economic growth, monetary stability and the promotion of financial inclusion.

Financial inclusion can be broadly understood as the process of making a range of necessary financial services available, at a fair price, in the right place, in the right form, and at the right time, without any form of discrimination against all members of society (Sarma and Pais [7]). In a narrower sense, financial inclusion refers

to a set of mechanisms that ensure easy access to, availability of, and use of the formal financial system by all components of an economy (Leyshon and Thrift, 1995; Carbo, Gardener, and Molyneux, 2007; Conroy, 2005; World Bank, 2007; Bayot and Jérusalmy, 2011; Figuet and Pinos, 2014). Financial services include, among other things, a range of products such as savings, appropriately designed and tailored loans, insurance, credit, payments, money transfers, and so on.

Unfortunately, globally, approximately 2 billion adults still lack access to banking services, and one-fifth of those who do have a bank account leave it inactive (World Bank [8]). In Africa, less than a quarter of adults have a formal bank account (Demirgüç-Kunt & Klapper, [9]). Irina (2016) estimates that only 35% of people with an account at a financial institution in sub-Saharan Africa use it for both saving and payments. These statistics are concerning, given the argument by Ashraf et al. (2006) that financial inclusion makes individuals more productive, leading to greater economic growth. This could partly explain the low levels of productivity and economic progress in Africa. The IMF (2017) links the poor performance of sub-Saharan African economies to a lack of economic opportunities for most citizens. However, financial inclusion can help ensure equitable growth, sustain informal sector jobs, support a transition to the formal sector, and create an economic environment conducive to the development of the informal sector. Given the significant role of financial innovation and inclusion in promoting economic growth, it is important to explore their interrelationship to inform policy decisions. Certainly, some studies already exist on the link between financial innovation and economic growth.

In the literature, the emergence of new financial instruments and their impact on growth are the subject of several studies. The theoretical framework ranges from the relationship between finance and growth on the one hand, to finance and fragility on the other. For proponents of the finance-growth relationship (Faruk, 2013; Laeven et al., 2015; Nazir et al., 2021), the introduction of financial innovations in an economy contributes to economic growth by facilitating capital mobilization, financial intermediation, capital formation, and generally the overall development of the financial system.

However, for authors of the finance-fragility school of thought (Solow, 1957; Beck et al., [10]), the introduction of technological advances into the financial sector weakens the growth rate of an economy. They argue that financial innovations lead to high systemic risks, low and suboptimal savings, and overcompensation of economic capacity, or inefficient and high costs for the economy (Ductor and Grechyna, 2015). However, the two theoretical frameworks underpinning the debates on financial innovation and economic growth in monetary economics overlook the importance of financial inclusion. By transposing the first framework, innovation-growth, onto the innovation-financial inclusion approach, it is implied that financial innovations contribute significantly to financial inclusion. A similar transposition onto the second framework, innovation-fragility, leads to the analysis that financial innovations do not promote financial inclusion. The

potential impact of financial innovations on economic growth could be overlooked if they are not properly transmitted through the promotion of inclusion in formal financial markets. This underscores the possibility of an indirect effect of innovations on growth. This could explain why previous studies on the subject have yielded inconsistent results in sub-Saharan Africa.

Beyond the fact that the results of these studies are inconsistent and insufficient to draw conclusions about the link between financial innovations and economic growth, we note that very few of these studies focus on social solidarity economy (SSE). Similarly, few studies have explored the possible existence of an indirect relationship between financial innovations and growth. If innovations do indeed have an impact on economic growth, the natural driver of this impact could be the role of financial inclusion. We therefore enrich previous studies on this subject by examining not only the impact of financial innovations on economic growth, but also the role played by financial inclusion in SSA countries. This article therefore seeks to determine whether financial inclusion influences the impact of financial innovations on economic growth in sub-Saharan Africa (SSA). To achieve this, we first construct indices of financial innovation and financial inclusion, which are then used in a dynamic panel of 35 SSA countries over the period from 2000 to 2017. Given that this article addresses, from a macroeconomic perspective, how financial innovations affect economic growth in SSA, we then integrate financial inclusion to examine whether financial inclusion has an effect on how financial innovations impact economic growth.

The remainder of the article is organized as follows: section 2 is the literature review, the methodology and data are in section 3, and the results and discussion are in section 4. Section 5 concludes and provides the implications of financial innovations on economic growth and suggests future studies.

Literature Review

Review of theoretical literature

Financial innovations and economic growth

The theoretical literature dating back to Schumpeter [11] the theory argues that innovations in the financial sector involve the introduction of new products and techniques that lead to better financial systems. These systems are characterized by increased coverage of service provision, a greater variety of financial products and services, more efficient institutions, the availability of credit for investment, and improved resource mobilization channels. Furthermore, the theory asserts that financial innovation enables the essential financial intermediation that enhances borrowers' ability to mobilize savings for investment and, consequently, improves the overall performance of the economy. The literature on the link between financial innovations and economic growth divides economists. Two main schools of thought can be distinguished: one that asserts that financial innovations have a positive impact on growth, and the other that condemns financial innovations.

Optimists, such as King and Levine (1993) and Rajan and Zingales (1998), have rationalized the importance of financial innovation as having a role to play in achieving economic prosperity and sustained growth. According to King and Levine (1993). Financial services are essential for promoting financial activities, accelerating wealth generation, and stimulating financial development in an economy. Therefore, innovations in financial services are imperative for improving financial efficiency, which in turn leads to financial growth. Furthermore, new financial products not only increase resource mobilization through more efficient payment systems but also reduce investment risks and accelerate capital creation.

To explain the link between financial innovations and economic growth, the theory of financial intermediation becomes extremely fundamental. The theory suggests that financial innovations improve the mobilization and efficiency of fund allocation for entrepreneurial and economic activities (Allen & Santomero, 1998; Werner, 2016). Mishra (2007) addressed the issue of financial innovation as a whole, stating that the introduction of financial technologies improves capital productivity and reduces transaction costs, thereby increasing economic growth. In the modern view, Bayar and Gavriltea (2018) shows that the expansion of the financial sector accelerates trade between countries, wealth creation, and capital accumulation. Furthermore, Hunjra et al. (2018) argue that the expansion of the financial sector plays a central role in reducing the costs associated with information asymmetry and improving resource mobilization, thereby stimulating economic prosperity.

Similarly, Asongu et al. (2019) indicates that innovations stemming from the spread of ICTs reduce information asymmetry, thus lowering loan prices. Consequently, this increases the amount of loans that financial institutions can grant to their clients. Indeed, it has been observed that financial innovations through various channels, such as online banking, mobile banking, ATMs, branch banking, internet-only banking, agency banking, and the use of point-of-sale machines in remote areas, offer a lower-cost alternative to traditional branch banking. These modalities significantly increase the availability and accessibility of financial services across all segments of society by reducing intermediation and transaction costs, geographical/local constraints, and general information asymmetry (Ahn & Lee, 2019; Chen, 2020; Cull et al., 2018).

Skeptics, for their part, gained popularity following the 1997/1998 financial crisis, but especially the major crisis of 2007/2008. They argue that financial innovations lead to high systemic risks, low and suboptimal savings, and overcompensation of economic capacity, or high and inefficient costs for the economy (Ductor and Grechyna, 2015). From this perspective, the literature highlights the dark side of financial innovations, notably attributing the financial crisis of that crisis to risky financial innovations. Beck et al., [10], Allen [12], and Llewellyn [13] have stated that excessive or inefficient innovation can have serious consequences for the entire economy. They argue that this crisis was caused by financial innovations that were initially considered safe but were in fact very

risky (Bara et al., [14]). Similarly, Llewellyn [13]; Allen (2011); and Arnaboldi and Rossignoli (2013) can also be cited.

Financial inclusion and economic growth

According to theoretical literature, financial inclusion can contribute to economic growth in several ways. In most cases, it does so by enabling more efficient use of available funds and reducing hoarding behavior, particularly in the African context. Let us consider that an economy is composed of two spheres: the real sphere and the financial sphere, and that the interaction between these two spheres can contribute to economic growth. Indeed, the real sphere uses resources from the financial sphere, which also facilitates the mobility and interchangeability of resources between the various agents within the real sphere. Thus, the financial sphere is a function of access to and use of financial services. Considering these two aspects of the financial sphere determines the cost of using financial products, but above all, the financial sphere's capacity to facilitate the seizing of economic opportunities by economic agents in the real sphere. The gap between agents in the real sphere and agents in the financial sphere determines the speed with which the financial sphere will influence not only its own innovations, but also innovations in the real sphere of the economy.

Several authors emphasize that financial inclusion can enable and improve the process of mobilizing and accumulating savings and allocating resources to borrowers, thereby increasing productivity (Claessens 2006; Dabla-Norris et al. 2015; Sethi and Acharya 2018). This process occurs through the timely transfer of funds (Dabla-Norris et al. 2015; Dontsi 2021), low transaction costs (Nguling'wa 2019), and the availability of funds. According to Dabla-Norris et al. (2015), the timely transfer of funds increases their efficiency by minimizing resource distortions caused by financial frictions related to constraints in the penetration, access, and use of financial services. Nguling'wa (2019) shows that financial inclusion driven by technological development reduces transaction costs, leads to increased use of financial services, and consequently facilitates efficient allocation of funds across sectors, thereby reducing intermediation costs and stimulating investment. Easy access to financial services will make credit affordable for the least privileged and most vulnerable. These individuals will then be able to readily initiate productive and economic activities, leading to increased production of goods and services and contributing to growth.

Empirical literature review

A number of studies have been conducted to explore the interrelationships that exist between innovation and economic growth, financial inclusion and economic growth, and financial innovation and financial inclusion.

Financial Innovation and Economic Growth

Financial innovation is considered a driver of financial sector development and has become an important factor in stimulating economic activity. This is attributed to the ability of financial

innovations to increase savings, capital accumulation, and productivity levels, which, in turn, generates economic growth. There is empirical evidence about the relationship between financial innovation and economic growth. Qamruzzaman and Jianguo (2017) used ARDL (autoregressive distributed lag) cointegration tests and an error correction model (ECM) based on Granger causality to investigate the effect of financial innovation on Bangladesh's economic growth between 1980 and 2016. This study demonstrates that financial innovation within the financial system contributed to Bangladesh's economic growth between 1980 and 2016. Domestic credit to the private sector and the broad money supply ratio were used as indicators of financial innovation. Real GDP per capita was also used as an indicator of economic growth. The results revealed a long-term relationship between financial innovation and economic growth. This relationship was found to be positive and significant. This indicates that increased financial innovation within the financial system stimulates economic growth.

Qamruzzaman and Wei [15] studied the link between financial innovation, stock market development, and economic growth in Bangladesh using the ARDL model. The data cover the period from 1980 to 2016. The study revealed that the relationship between financial innovation and economic growth is positive and significant in both the short and long term. This is explained by the fact that financial innovation stimulates the money supply in the financial system, which, in turn, stimulates economic growth.

Adu-Asare Idun and Aboagye [16], in their study on financial innovation, banking competition, and economic growth in Ghana, found that financial innovation is negatively correlated with long-term economic growth. However, the correlation between the two is positive in the short term. The negative long-term impact observed in this study can be explained by the fact that technology can lead to unemployment, as machines replace humans in the production process. If the savings achieved through innovation are significantly lower than the associated cost of unemployment, this could result in weaker economic growth. Thus, while in the short term the increased efficiency and convenience offered by the deployment of innovations may stimulate economic growth, the long-term effect could be negative due to the rising cost of unemployment generated by increased reliance on technology.

Okereke (2016) used ordinary least squares to investigate the effect of automated teller machines (ATMs), point-of-sale (POS) terminals, transaction value, internet banking, and mobile banking on Nigeria's economic growth. The research findings showed that the relationship between ATMs, mobile banking, internet banking, and economic growth is insignificant. Only POS terminals showed a significant relationship with economic growth. Therefore, the empirical findings on this topic in the African context appear inconclusive. Studies that have established the absence of a significant relationship between innovations and growth should be re-examined, as there may be mediating variables in this relationship. Until such variables are identified and included in the analysis, related studies will fail to uncover the true nature of the relationship between the two variables.

Financial inclusion and economic growth

Atadouanla Segning et al. (2024) used a dynamic panel of 35 sub-Saharan African (SSA) countries from 2001 to 2016 to examine, from a macroeconomic perspective, how financial inclusion affects economic growth in SSA. The authors then segmented the continent into several socio-cultural groups, notably based on income level, most practiced religion, and official language, to determine whether cultural factors influence how financial inclusion impacts economic growth. The results of the analysis show that financial inclusion is a key driver of economic performance in SSA, but that its effect depends on the specific cultural, religious, political, institutional, and structural characteristics of the economies.

Adedokun and Aga [17] examine the impact of financial inclusion on growth in 36 sub-Saharan African countries over the period 2004-2017 and finds that financial inclusion has a positive influence on economic growth in these countries. Their results further show that there is a causal relationship between economic growth and financial inclusion in the short term. Using an ARDL approach, Bigirimana and Hongyi [18] find a long-term relationship between various indicators of financial inclusion and economic growth, and a short-term relationship between some financial inclusion indicators and economic growth in Rwanda. Similarly, Sethi and Acharya (2018) employ panel data models such as country fixed-effects, random-effects, and time-fixed-effects regressions, panel cointegration, and panel causality tests to examine the link between financial inclusion and economic growth in 31 developed and developing countries. The results reveal a positive long-term relationship and bidirectional causality between financial inclusion and economic growth in these countries. Sharma (2016) also investigated the indicators of the link between financial inclusion and economic growth in the emerging Indian economy. The main research questions were tested using vector autoregressive (VAR) models and the Granger causality test. The study highlighted a positive relationship between economic growth and the three dimensions of financial inclusion: bank penetration, availability, and use of financial institution services. Similarly, using the VAR technique, Gretta (2017) analyzes the relationship between certain components of financial inclusion and economic growth in the MENA (Middle East and North Africa) region and in the BRICS countries, attempting to identify the transmission channels between financial education, financial intermediaries, and growth. He concludes that financial inclusion is important for economic growth.

Gul et al. [1] conducted an empirical study on the relationship between financial inclusion and economic growth: a global perspective. Indicators of financial inclusion were bank accounts, bank branches, ATMs, and life insurance premiums. Economic growth was measured by gross domestic product per capita. A panel dataset from 185 countries covering the period 1996-2015 was used. The results revealed a positive relationship between financial inclusion and economic growth, indicating that financial inclusion is a key driver of economic growth.

Nguling'wa [19] found a positive effect of the financial inclusion index, constructed from three of its components (i.e., financial penetration, financial access, and financial utilization), on economic growth in 25 sub-Saharan African countries. Van et al. [20] used data from a large panel of 152 countries to analyze the relationship between financial inclusion, as captured by a multidimensional financial inclusion index, and economic growth at the international level. Using the GMM method, they found a positive link between the two variables, with a stronger relationship in low-income countries with low levels of financial inclusion.

Financial innovation and financial inclusion

Domeher et al. [3] used data from 26 sub-Saharan African countries, covering the period 2004-2017, to determine whether financial inclusion mediates the relationship between financial innovation and economic growth. These data were analyzed using the generalized method of moments (GMM). The results show that investments in banking sector innovations promote financial inclusion. Furthermore, financial inclusion fully mediates the relationship between innovation and economic growth.

Affandi, and Malik [21] used measures from a dataset on low- and lower-middle-income economies over a sampled period from 2010 to 2017 to examine the effect of financial innovation on economic growth mediated by financial inclusion. The results of this study show that financial innovation creates opportunities for financially excluded segments of society, resulting in financial inclusion that leads to economic growth in low- and lower-middle-income economies.

Qamruzzaman and Wei [22] used a distributed lag autoregressive model on panel data to investigate the relationship between financial innovation and financial inclusion. The researchers incorporated financial development and remittance flows into this relationship. Monthly data covering the period 1990-2018 were collected from six South Asian countries. The results revealed a positive relationship between financial innovation and financial inclusion, both in the short and long term. According to Andrianaivo and Kpodar (2012), there is a significant positive relationship between mobile phone penetration rates and financial inclusion. The spread of mobile phones has the potential to improve financial inclusion by making affordable financial products and services available to poor populations. Access to mobile banking, mobile payment innovations, and ATMs has thus demonstrated a significant and positive impact on financial inclusion. Cull et al. (2013) emphasize the importance of technological and product innovation in improving financial inclusion. Karmakar et al. (2011), in assessing financial inclusion in India, begin by highlighting the importance of expanding the reach of formal financial institutions, such as banks, as a channel for accessing a range of financial services. Similarly, the role of technological innovation in reducing the costs of service delivery is again emphasized, as is the need for financial advice. Indeed, the demand-side behavioral aspects of financial inclusion deserve as much attention as the supply-side technological approaches.

Methodological Approach

Sample

The analysis sample consists of 35 sub-Saharan African countries. The time horizon covers the period 2000-2017. The choice of the analysis sample and time horizon is contingent upon data availability. The data are drawn from the World Bank's World Development Indicators database (2019) and the Financial Development and Structure Database (2020). The data focus on key variables of interest selected based on the literature and data availability. Table 1 provides details of the selected variables and how they were measured in this study.

Specification of the econometric model

In order to model the role of financial inclusion in the relationship between financial innovation and economic growth, a functional shape model is structured as follows:

$$Y_{it} = (INNOVFI_{it}, INCLU_{it}, X_{it}) Y_{it} = (INNOVFI_{it}, INCLU_{it}, X_{it}) \quad (1)$$

Or

Y: Growth in gross domestic product per capita; INNOVFI: financial innovation index; INCLU: financial inclusion index; X: indicators of control variables; the index t represents the particular period, for each country i,

Following Aghion, Howitt, and Mayer-Foulkes [23]; Laeven, Levine, and Michalopoulos [24], we examine the role of financial inclusion in the relationship between financial innovation and economic growth using a standard endogenous growth model. The model is presented as follows:

$$y_{it} = \phi_1 Y_{it-1} + (2) \phi_2 INNOV_{it} + \phi_3 X_{it} + \delta_i + \varepsilon_{it} \quad (2)$$

This is a dynamic panel data model, with temporal and individual dimensions and a lagged variable. This equation takes into account country-specific effects and the dynamic aspect. The variables are defined as follows: the annual GDP growth rate, the financial innovation index, which we calculated;

This study follows the methodological approach of Brambor et al, [25]. This methodological approach is based on Multiplicative interaction models are the most common in quantitative literature. According to these models, interaction terms are introduced into a model when it has conditional assumptions.

The first is that the relationship between the dependent variable (economic growth) and the independent variable (financial innovation) must be significant. The objective of the first step is to be able to verify whether the evolution of economic growth rates in the countries of sub-Saharan Africa is due to the development of financial innovations.

This relationship is represented by the equation below:

$$y_{it} = \phi_1 INNOV_{it} + \phi_2 X_{it} + \delta_i + \varepsilon_{it} \quad (3)$$

The second condition is that the independent variable (financial innovation) must be significantly related to the variable (financial inclusion). The equation is the mathematical representation of this condition. In this case, there should be a significant relationship between financial innovation and financial inclusion.

$$INCLU_{it} = \phi_1 INNOV_{it} + \phi_2 Z_{it} + \delta_i + \varepsilon_{it} \quad (4)$$

Or financial inclusion index, which we calculated.

Thirdly, the variable that acts as a transmission channel (financial inclusion) must also be significantly related to the dependent variable (economic growth). This is represented by the equation below.

$$y_{it} = \phi_1 INCLU_{it} + \phi_2 P_{it} + \delta_i + \varepsilon_{it} \quad (5)$$

The final condition is to verify the role of financial inclusion in the relationship between the independent variable (financial innovation) and the dependent variable (economic growth). This step involves considering the multiplicative interaction between financial innovation and financial inclusion. Its aim is to demonstrate the effect of financial innovation on economic growth when financial inclusion is taken into account. This step allows us to show how financial inclusion can either strengthen or reduce the effects of financial innovation on economic growth. Therefore, to test whether financial inclusion is a channel through which financial innovation influences economic growth, an interaction variable is added to the equation.

$$y_{it} = \phi_1 INNOV_{it} + \phi_1 INCLU_{it} + \phi_2 X_{it} + \phi_3 (INNOVFI_{it} * INCLU_{it}) + \phi_4 After2008 + \delta_i + \varepsilon_{it} \quad (6)$$

The interactive effect can be observed from the coefficient relating to indicators of financial innovation crossed with the indicator of financial inclusion. The variable represents the cross-variable of financial inclusion and financial innovation. It highlights the interaction effect of financial innovation and financial inclusion on economic growth.

Estimation Method

Given that this study highlights the dynamic nature of the relationship between financial innovation and economic growth, and to account for the heterogeneity of countries and address the potential endogeneity issues arising from the dual causality between financial innovation and economic growth, we use the System GMM estimator of Blundell and Bond [26] to estimate the preceding equation. This estimator was developed by Blundell and Bond [26] to resolve problems associated with predetermined and endogenous variables. The choice of this estimator is justified by its superior performance compared to the difference GMM estimator of Arellano and Bond [27] when the autoregressive coefficient is relatively high and the number of periods is small (Andrinaivo and Kpodar 2011).

Table 1: Description of variables and data sources.

Variables Definition		Sources
INNOVFI	Financial Innovation Index	Author
INCLUDED	Financial Inclusion Index	Author
INST	Institutional Quality Index	Author
CDSP	Domestic bank credit to the private sector as a percentage of GDP	World Development Indicator 2020
CSP	Growth rate of credit to the private sector	World Development Indicator 2020
GDP	real GDP per capita	World Development Indicator 2020
GDPR-1	Log of initial real GDP per capita (beginning of period)	/
EDU	Secondary school enrollment rate (% gross): share of the population enrolled in secondary school within the population of secondary school age	World Development Indicator 2020
INF	Rate of change in the consumer price index	World Development Indicator 2020
GOV	Government final consumption expenditure including current spending on goods and services (as a percentage of GDP)	World Development Indicator 2020
TRADE	The value of the sum of imports and exports of goods and services (as a percentage of GDP)	World Development Indicator 2020
INVEST	Gross fixed capital formation as a percentage of GDP	World Development Indicator 2020
IDE	Net inflows of foreign direct investment	World Development Indicator 2020
KAOPEN	Capital account, degree of financial openness	Chin and Ito
ATMS	ATMs	WDI
CONKBANK	Number of bank branches	WDI
Internet	life insurance premium volume relative to GDP	WDI
(MCS)	Mobile Banking	ITU
M2/M1	Ratio of broad currency to broad currency	World Development Indicator 2016
DEPO	deposit accounts at commercial banks per 1000 adults	Financial Access Survey
LOANS	Loans	Financial Access Survey
BORR	Commercial bank loans per 1000 adults	Financial Access Survey
OUT	Outstanding loans to commercial banks: including SMEs (% of GDP)	Financial Access Survey

Methodology for constructing the composite index of financial innovation and financial inclusion

The inertia method was developed through the work of several authors, including: Benzecri et al (1975), Caillez and Pagès (1976). This approach is based on so-called factor analysis techniques, which may include Principal Component Analysis (PCA), Correspondence Analysis (CA), Multiple Correspondence Analysis (MCA), and Multiple Factor Analysis (MFA), etc. The principle of MFA used is that described by Escofier and Pages (2008), which relies on the analysis of several groups of variables. (represented by the years, from 2000 to 2017, in the case of this study). This method makes it possible to represent the information provided by all the tables in a common reference frame, used to describe the characteristics of individuals, variables and groups of variables in relation to the different axes of interpretation. In order to perform Multiple Factor Analysis, we have selected five aspects of financial innovation for

the construction of this index.: Growth of bank credit to the private sector, the ratio of broad money to narrow money, Mobile Banking/ Mobile money, the number of ATMs, the number of bank branches. Similarly, since the concept of financial inclusion refers to the processes aimed at determining the number of individuals and businesses using financial services, it is important to have statistics on the use of financial services, such as account penetration, savings, credit, insurance, etc. (World Bank, 2013; Van der Werff et al., 2014; Demirguç-Kunt and Klapper, 2012). We focus on three aspects of financial inclusion for the construction of this index: banking penetration, measured by the number of bank accounts per 1,000 inhabitants; the use of financial services, measured by bank deposits or savings; and the availability of financial services, measured by the number of branches per 10,000 inhabitants [28-30].

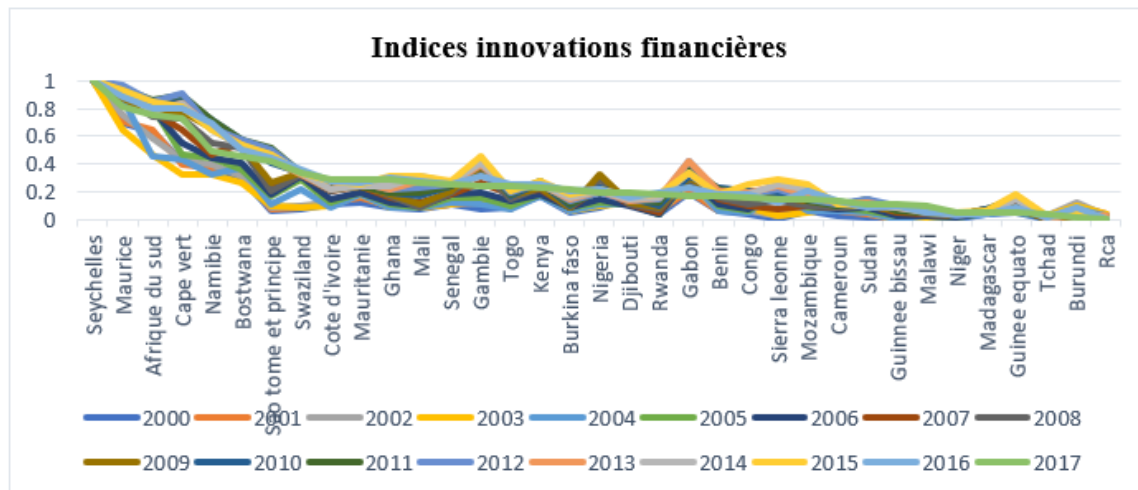


Figure 1: Evolution of the composite index of financial innovation in Sub-Saharan African countries.

According to this graph, financial innovation in sub-Saharan Africa has been quite sluggish in recent years. Figure 1 highlights a lack of financial innovation in sub-Saharan African countries during the period 2000-2017. The curves are almost identical. The differences between them are small, representing the year-to-year variations in financial innovation; this confirms the slow annual growth of financial innovations in these countries. Innovation in the selected African countries did not fundamentally change between 2000 and 2017. This also means that, as of the end of 2017, it cannot

be concluded that there was no real innovation over the past ten years. These countries would then be very unproductive in applied research to economics and creativity in the financial sector [31,32].

The peaks in Figure 1 correspond to countries with a relatively high level of financial innovation. Ultimately, the Seychelles occupy first place in terms of financial innovations, along with Mauritius and South Africa. Most Central African countries, and in particular Chad, occupy the last ranks over the period 2000-2017.

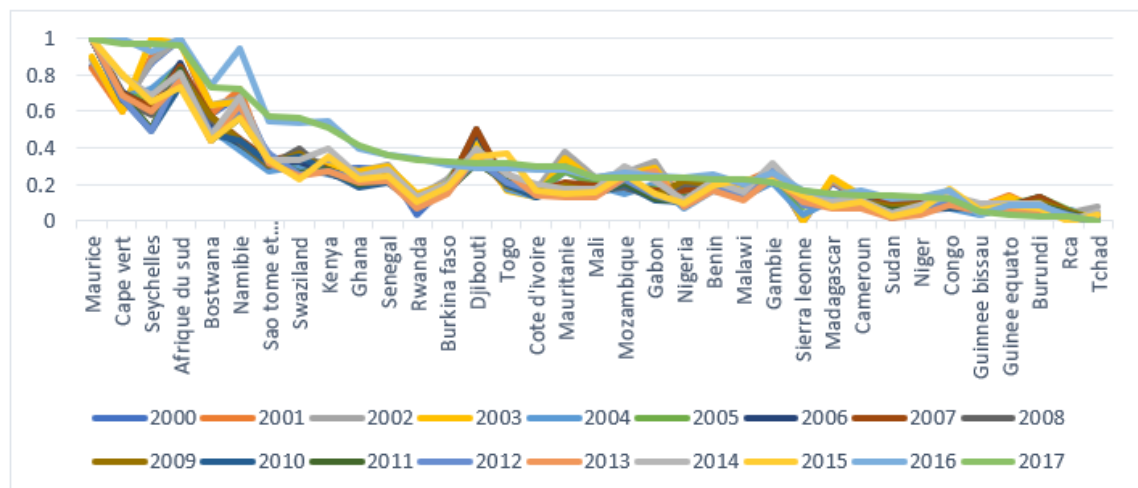


Figure 2: Evolution of the financial inclusion index in Sub-Saharan African countries.

Among the 35 SSA countries studied, Mauritius, Cape Verde, Seychelles, South Africa, and Botswana rank first (the top five) with the highest level of financial inclusion according to the constructed financial inclusion index. These countries are shown in Figure 2. In

the lower part of the sample, Chad, the Central African Republic, Burundi, and Equatorial Guinea are the least inclusive countries. For the East African Community (EAC) region (comprising Burundi, Kenya, Rwanda, Tanzania, and Uganda), Kenya is the most

financially inclusive country, followed by Rwanda and Burundi, respectively. Furthermore, a substantial increase in the use of formal, non-bank, technology-related financial services is notable in middle-income countries such as Mauritius and South Africa. Furthermore, significant results in terms of access to financial services are notable in middle-income countries such as Seychelles, Mauritius, South Africa, Botswana and Cape Verde [33].

Results and Implications

Statistical description of variables

Summary statistics for the variables used in this research are presented in Table 2. The two main components of descriptive statistics are central tendency (mean and median) and variability (standard deviation, maximum, minimum) [34].

Table 2: statistical description of variables.

Variable	Dimension	Average	Standard deviation	Minimum	Maximum
GDPR_	overall	2631.68	3550.51	214.14	20512.94
	between		3501.37	229.51	14701.16
	within		823.33	-6511.51	8443.46
TCPOP	overall	2.41	0.84	-2.63	5.60
	between		0.76	0.41	3.75
	within		0.39	-1.20	5.35
KAOPEN	overall	-0.58	1.17	-1.90	2.37
	between		1.09	-1.59	2.03
	within		0.48	-3.34	1.29
TCHOM	overall	10.05	7.00	0.29	37.60
	between		6.84	1.12	25.54
	within		1.86	-8.10	22.21
GOV	overall	15.46	6.32	2.74	47.19
	between		5.76	6.22	32.31
	within		2.78	4.19	30.34
INF	overall	6.67	6.49	-8.97	37.39
	between		4.36	1.98	15.97
	within		4.86	-6.18	37.35
IDE	overall	5.16	7.42	-4.85	64.38
	between		4.19	0.58	15.07
	within		6.17	-14.56	58.22
TRADE	overall	74.96	44.59	0.00	351.11
	between		40.07	0.00	188.65
	within		20.64	-21.08	237.42
INNOVFI	overall	0.24	0.25	0.00	1.00
	between		0.24	0.01	1.00
	within		0.08	-0.09	0.48

Source: the author

Table 3: Correlation matrix of the variables in the analysis.

	Variable	1	2	3	4	5	6	7	8	9	10	11
1	LnPIB ha	1										
2	INVEST	0.34*	1									
3	TCPOP	-0.54*	0.04	1								
4	EDU	0.65*	0.12*	-0.65*	1							
5	IDE	0.10*	0.49*	0.01	0.01	1						

6	GOV	0.24*	0.03	-0.32*	0.30*	0.09*	1					
7	INF	-0.12*	-0.11*	-0.01	-0.02	0.07	-0.18*	1				
8	TRADE	0.56*	0.57*	-0.23*	0.21*	0.36*	0.17*	-0.09*	1			
9	INCLU	0.59*	0.13*	-0.68*	0.84*	0.01	0.46*	-0.09*	0.24*	1		
10	INNOVFI	0.68*	0.20*	-0.64*	0.86*	0.09*	0.44*	-0.09*	0.35*	0.87*	1	
11	INNOVFI*INCLU	0.61*	0.15*	-0.65*	0.81*	0.02	0.39*	-0.10*	0.30*	0.92*	0.94*	1

Source: author

Table 4: Direct effects of financial innovations on growth in sub-Saharan Africa.

Explained	D.LnGDPG		LnGDPG			
Special feature	Random effect panel (model 1)	fixed effect panel (model 2)	IDE exo expli (model 3)	IDE exo iv (model 4)	without exercise iv (model 5)	GOV exo iv (model 6)
Variable	Coef(tstat)^signif					
LnGDPG(L1)			0.8554 (21.57)***	0.9251 (24.11)***	0.9099 (34.12)***	0.9232 (43.2)***
TCPOP	-0.0003 (-0.09)	0.0064 (1.27)	-0.0067 (-0.26)	-0.0416 (-1.06)	-0.0404 (-1.58)	-0.059 (-2.89)**
KAOPEN	-0.0014 (-0.63)	-0.0112 (-2.88)**	0.0189 (0.45)	-0.0361 (-1.09)		
TCHOM	0.00003 (0.08)	0.0002 (0.23)	-0.0118 (-1.41)	-0.0102 (-1.21)		
IDE	0.0012 (4.04)	0.0009 (2.86)**	-0.0005 (-0.24)			
GOV	-0.0015 (-3.52)	-0.0036 (-5.19)***	0.0053 (1.14)	-0.0037 (-0.89)	0.0019 (0.34)	-0.007 (-5.76)***
INF	-0.00025 (-0.74)	-0.0008 (-2.17)*	-0.0004 (-0.26)	-0.00094 (-0.73)	-0.0026 (-1.83)	-0.0031 (-2.45)*
TRADE	0.00020 (3.15)	0.0006 (6.17)***	0.0043 (4.44)***	0.0018 (2.51)*	0.0016 (2.13)*	0.0011 (2.57)*
INNOVFI	0.00011 (0.72)	0.0004 (1.17)	0.0025 (2.47)*	0.0014 (1.36)	0.0038 (3.78)**	0.0029 (5.5)***
After 2008	-0.01381 (-3.36)	-0.0143 (-3.09)**			-0.0311 (-3.31)**	-0.0281 (-4.06)***
_cons	0.0281 (1.96)	0.0044 (0.2)	0.7557 (2.89)**	0.6336 (2.04)*	0.5544 (2.13)*	0.7008 (5.13)***
Instruments for first-difference equations			L(1/4).EDU; L(2/17).lnGDPer- cap	IDE; L(1/4). EDU; L(2/17). lnGDPerCap	L(2/17).lnGDPerCap; L(1/4).EDU;	GOV; L(1/4).EDU; L(2/17).lnGDPerCap
Instruments for level equations			constant; D.EDU; DL.lnGDPerCap	constant D.IDE ; D.EDU; DL.lnG- DPerCap	constant; D.EDU; DL.lnGDPerCap	constant D.GOV; D.EDU; DL.lnGDPer- cap

Note: Estimates are obtained using simple and dynamic panel data with the Bond-Blundell System (GMM) generalized method of moments. Student's t-statistics are presented in parentheses. The symbols *, **, and *** refer to significance levels at 10%, 5%, and 1%, respectively. For interpretation, it should be noted that innovation was expressed as a percentage in the direct effects models.

The first part of Table 4 presents the results of the simple panel estimation of the direct effects of financial innovations on growth for a sample of 35 sub-Saharan African (SSA) countries over the period 2000-2017, represented by models (1) and (2). The results of model 2 show that the financial innovation index does not have a significant effect on the growth rate of SSA countries. However, the estimated coefficient is positive. Regarding the control variables-financial openness, foreign direct investment, government spending, inflation, and trade openness-these variables are statistically significant with expected signs. These results are consistent with the theory [35-37].

The second part of Table 4 presents the results of the estimation of the effects of financial innovations on growth in dynamic panel using the generalized method of moments GMM in System, represented through models (3), (4), (5) and (6). The results of Model 3 shows that the lagged variable is positively and significantly correlated with the dependent variable. In economic terms, the growth of GDP per capita in the current year (t) depends on that of the previous year (t-1). The effect of initial GDP per capita is positive and significant at the 1% level. The financial innovation index has a positive but weakly significant effect on growth in sub-Saharan Africa. Indeed, a 100% increase in the financial innovation index leads to a 0.25% increase in the GDP growth rate. These results corroborate the empirical findings of other researchers (Bara and Mudzingiri, 2016; Bara et al., 2016; Qamruzzaman and Wei, 2017) [38-40]. In model (4), the FDI variable was used as an exogenous instrumental variable (uncorrelated with the explanatory variable lagged by one period). The effect on initial GDP per capita is positive and significant at the 1% level. In this

model, the financial innovation index does not have a significant effect on growth. However, the sign of the estimated coefficient is positive. Regarding the control variables, only the trade openness variable (TRADE) has a positive and significant effect on growth. In the model in column (5), which does not use an exogenous instrumental variable, the effect on initial GDP per capita is positive and significant at the 1% level. Financial innovation has a positive and significant effect on growth in SSA at the 5% level. Indeed, a 100% increase in the financial innovation index leads to GDP per capita growth of 0.38 [40,41].

Finally, in model (6) which takes into account the variable Using government spending as an exogenous instrumental variable, the results show that the effect of initial GDP per capita is positive and significant at 1%. The financial innovation index has a positive but weakly significant effect on growth. Indeed, a 100% increase in the financial innovation index leads to GDP growth of 0.29. This result is consistent with the results of Ajide (2013), Jianguo and Qamruzzaman (2017), Laeven et al. (2013), and Michalopoulos et al. (2009) found a significant and positive relationship between innovation and growth. However, this is not consistent with the findings of Idun and Aboagye (2014) and Bara et al. (2016b), who found a negative relationship between financial innovation and growth [42-46].

At the end of the various dynamic panel estimations, we retain model (6) which appears to be the best model which allows us to conclude that financial innovation has a direct positive and weakly significant impact on the economic growth of the countries of SSA [47,48].

Relationships between financial innovation and growth, and financial inclusion and growth

Table 5: Results of estimations of the simple relationship between financial innovation-growth and financial inclusion-economic growth.

Variables	Model (1)	Model (2)
L.lnPIBha	0.868 (28.95)**	0.916 (17.78)**
GOV	-0.008 (3.50)**	-0.002 (0.59)
INF	-0.003 (2.35)*	-0.001 (0.59)
TRADE	0.001 (3.47)**	0.003 (1.92)
TCPOP	0.003 (0.1)	0.003 (0.1)
INVEST	0.002 (0.59)	0.006 (2.14)*
INNOVFI	0.003 (4.55)**	
INCL		0.006 (3.13)**

After 2008	-0.02	-0.01
	(2.44)*	(0.91)
cons	0.835	0.191
	(4.78)**	(0.47)
Number of observations	594	594
AR Test(1)	0.013	0.09
AR Test(2)	0.102	0.094
Sargan Test	0.550	.0496

, * : significance at the 10%, 5% and 1% levels AR (1): Arellano-Bond statistic of the autocorrelation test of first-order errors, and AR (2): Arellano-Bond statistic of the autocorrelation test of second-order errors, with probabilities in parentheses.

The results in Table 5 The above shows that our variables of interest, financial innovation and financial inclusion, have positive and significant coefficients, which is consistent with theoretical

expectations. Regarding the control variables, their coefficients meet theoretical expectations, except for the price index, which has a positive sign [48-50].

Relationships of the interaction between financial innovation and financial inclusion on growth

Table 6: Analysis Combined effects of financial innovations and financial inclusion on the growth of SSA countries.

Explained	LnPIB ha
Special feature	Model (1)
Variable	Coeff(tstat)^signif
LnPIB ha (L1)	0.9555(50.62)***
TCPOP	-0.0707(-3.03)**
GOV	-0.0054(-5.87)***
INF	-0.0008(-0.76)
TRADE	0.0011(2.58)*
INVEST	
INNOVFI*INCLU	0.1855(3.33)**
after2008	-0.0105(-1.8)
_cons	0.5018(3.77)***
Instruments for first-difference equations	GOV; L(1/4).EDU; L(2/17).lnGDPercap
Instruments for level equations	constant D.GOV; D.EDU; DL.lnGDPercap

Regarding the interaction between the financial innovation index and financial inclusion, the result shows a positive and statistically significant effect on growth at the threshold of 5%. In the case of perfect financial inclusion, a 1% increase in financial innovation leads to growth in 0.1855% of GDP per capita compared to the previous year. The interaction term (INNOVFI * INCLUS) suggests that the effect of financial innovations on economic growth is greater when financial inclusion is a reality, and vice versa. Indeed, this result shows that there has been improvement in terms of new financial products/services and financial inclusion within the banking systems of sub-Saharan Africa. The implication of this result is essentially that financial inclusion should be accompanied

by the development of financial innovations to have a positive impact on economic growth. Consequently, financial policies that promote both financial inclusion and the development of financial innovations are valid in light of this finding. Financial innovation and financial inclusion foster positive externalities from the financial sector on economic growth. This finding is consistent with expected signs and aligns with the conclusions of Beck et al. (2015) and Domeher et al. (2022), who demonstrate that investments in banking sector innovations promote financial inclusion. Furthermore, financial inclusion plays a comprehensive mediating role in the relationship between innovation and economic growth [50-52].

Regarding the control variables, the trade openness rate significantly improves growth, particularly through capital accumulation. A 1% increase in this variable translates into a corresponding rise in the GDP per capita growth rate.0.0011% at the 10% threshold [53].

Conclusion And Implications

The importance of this study stems from the fact that past work has not sufficiently emphasized the role of financial inclusion as a channel for transmitting financial innovations towards growth. Indeed, it is established that the financial sector plays a fundamental role in economic development. Many arguments have led us to hypothesize that financial innovations ensure better growth, depending on the economy's ability to provide economic opportunities on the one hand, and on financial inclusion which plays a mediating role [54-56].

This study aimed to analyze the role of financial inclusion in the relationship between financial innovation and economic growth in sub-Saharan Africa. To this end, three models were tested. First, a weakly significant relationship was established between growth (dependent variable) and financial innovation (independent variable). Second, the interaction relationship between financial innovation and financial inclusion (interaction variable) was also significant. Third, the analysis also revealed a positive relationship between financial inclusion and economic growth. All these results confirmed the existence of a transmission channel in the innovation-economic growth relationship. To verify this transmission channel, a fourth test was conducted by introducing the interaction variable into the innovation-growth model. The results confirmed that inclusion plays a role as a transmission channel in this relationship [58-62].

An econometric analysis using the generalized method of moments on a dynamic panel applied to data from a sample of 35 SSA countries over the period from 2000 to 2017 allowed us to highlight the role of financial inclusion in the relationship between financial innovations and economic growth [63,64].

This study contributes to the debate on financial innovation and growth by analyzing the role of financial inclusion as a transmission channel in this relationship. This aspect has been the subject of very little empirical research. Indeed, as long as financial innovations introduced into the financial sector do not lead to greater inclusion, their potential to stimulate economic growth remains ignored. Thus, financial innovations are of little importance if they do not promote greater availability and easier access to financial services, as well as increased use of these services. This study helps to explain the mixed results of previous studies on this topic.

In light of the current situation, the need to critically rethink the political issues related to the effects of government action on generating economic prosperity by harnessing the potential of technological innovations in financing Sub-Saharan African economies is emphasized. It appears that reforms must prioritize and target specific obstacles to support the development and strengthening of the financial sectors. While these reforms must be

adapted to the specific challenges of each country, it is essential to take action in priority areas. The goal for governments in the sub-region is to create an enabling environment that allows financial institutions to leverage technology in the delivery of their services. Therefore, particular attention should be paid to the high rate of illiteracy in the sub-region is one such obstacle. Improving literacy would promote the adoption of innovations, financial inclusion, and consequently, economic growth in sub-Saharan Africa [65-68].

The study also confirms that financial inclusion has a positive impact on economic growth. To promote financial inclusion, sub-Saharan African countries should invest in establishing institutional structures that empower consumers and leverage the benefits of technological innovations through the use of mobile banking services. Financial policies that foster both financial inclusion and the development of financial innovation are desirable. Policymakers should make the financial sector more focused on financial innovation in order to provide financial services to a greater number of households [69-71].

This study is limited, as we did not consider other variables that could moderate the relationship between financial innovation and growth, nor did we extend the study over a longer period with more recent data. It is therefore recommended that future work in this area test the potential influence of certain key economic variables on the relationship studied.

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