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BANKING & FINANCE | RESEARCH ARTICLE

Financial innovations and economic growth: Does financial inclusion play a mediating role?

Daniel Domeher^{1*}, Emmanuel Konadu-Yiadom¹ and Godfred Aawaar¹

Abstract: Innovations in the financial sector play a critical role in promoting economic growth. Studies that have sought to investigate this linkage in sub-Saharan Africa have produced mixed results. None of the existing studies have attempted to examine the possible mediating role of financial inclusion in explaining the relationship between innovations and growth. This paper thus sought to establish if financial inclusion mediates the relationship between innovation and growth. Secondary data from (26 selected SSA countries over the period 2004 to 2017) were used. The data were analysed using the GMM estimation technique. It was found amongst other things that investments in innovations in the banking sector promote financial inclusion. In addition, financial inclusion fully mediates the relationship between innovation and economic growth. It is thus recommended that governments in the sub-region invest in the appropriate technological infrastructure that the banking sector can leverage on in the provision of banking services as the key to promoting financial inclusion and economic growth.

Subjects: Economics; Finance; Business, Management and Accounting

Keywords: economic growth; financial inclusion; financial innovation; mediation analysis; Sub Saharan Africa

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PUBLIC INTEREST STATEMENT

The revolution in technology has led to a wave of innovations across the financial services industry globally. These financial innovations have the potential to spur economic development. Whether or not the innovations will eventually lead to economic growth will depend to a large extent on the transmission mechanisms available. This study investigates the channel through which innovations may impact economic prosperity of the nations in Sub-Saharan Africa (SSA). It was established that the benefits of innovation in the financial sector only translates into a positive effect on economic development when there is an improvement in the number of people with access to financial services. Hence, if people remain excluded from the formal financial system, the potential economic development effect of innovations will be missed. Governments should thus pursue policies that will drastically reduce the number of people who do not have access to basic financial services so that we can take advantage of the rising use of technology to promote economic prosperity.

1. Introduction

Financial institutions play a critical role in the economic development process globally. They provide an effective payment system that promotes trade and businesses. Through a range of innovative activities, the financial system enhances financial inclusion that encourages optimal savings and consumption decisions and promotes the productive use of funds by business and individuals. Financial innovation involves the creation of new financial products, enhanced processes and well-organized systems within the financial system to meet the emerging needs of stakeholders (Tufano, 2003). It involves finding new mechanisms to deliver financial services that address the ever-changing socio-economic and cultural needs of the populace.

In recent times, there has been a significant increase in the number of alternative channels available for the delivery of financial services; traditional delivery methods have given way to new delivery technologies that include e-banking products such as internet banking, mobile banking and various Automated Teller Machine (ATM) products (Domeher et al., 2014). Innovations in the financial services sector give firms a competitive advantage that is central to their survival. Indeed, Damanpour et al. (2009) confirms that innovation affects a firm's performance positively. The extent to which the financial sector can make contributions to the economy depends on the quality and quantity of the services it offers. Whilst financial institutions enjoy the cost reduction and market expansion benefits of innovation, clients relish the wide range of services and the enhanced convenience associated with such innovations. With the combination of the risk and transaction cost reduction benefits, financial innovations promote broader financial development that spirals into economic growth through its positive impact on saving, investment, and output.

Financial innovation is thus such a critical deriving factor of growth. This is made possible by its ability to promote greater inclusiveness of the populace in formal financial market activities. Higher levels of financial inclusion in the economy must thus be the priority of every government especially in developing countries. Unfortunately, globally, about 2 billion adults remain unbanked and a fifth of those who have accounts were reported to have kept these accounts dormant (World Bank, 2014). In Africa, less than a quarter of adults have a formal bank account (Demirgüç-Kunt & Klapper, 2012). Irina, A. (2016) estimates that only 35% of those who have formal accounts at a financial institution in Sub-Saharan Africa use their accounts for both savings and payments. These statistics are worrying given the argument of Ashraf et al. (2006) that with financial inclusion, people become more productive leading to improved economic growth. This may partially explain the low levels of productivity and economic progress in Africa. Given the significant role of financial innovations and inclusion in promoting economic growth, there is a need to explore their interrelationship in order to inform policy decisions.

Admittedly, there are some existing studies on the financial innovation and economic growth linkage. Other studies have also considered the linkage between financial inclusion and economic growth (Gul et al., 2018). The findings of these studies have been mixed in Africa. On the financial innovation-economic growth relationship, some studies concluded that innovation and growth have a positive association (Qamruzzaman & Jianguo, 2017). Other studies however found an inverse link between the two in the long-run but positive relation in the short-run (Adu-Asare Idun & Aboagye, 2014; Okereke, 2016). The potential impact of innovations on the economy might be missed if not properly transmitted through the promotion of inclusiveness in formal financial markets. This points to the possibility of an indirect effect of innovations on growth. This could possibly explain why prior studies so far on the subject matter have produced inconsistent results in sub-Saharan Africa. Currently, there is no known study that has attempted to explore the possibility that an indirect relationship may exist between innovations and growth. If innovations do indeed have an impact on economic growth the natural medium through which this could happen is through the promotion of financial inclusion. Innovations enhance efficiency in the provision of financial services. The associated convenience and cost reduction benefits work together to draw people into the formal financial system. As the level of financial inclusion increases, it stimulates capital formation and hence economic growth.

The paper thus specifically seeks to contribute to the debate on this subject by investigating the transmission mechanism through which innovations affect growth in the economies of Sub-Saharan Africa. According to Baron and Kenny (1986) a mediation analysis is most suitable for a study of this nature. The findings of this paper could help explain the inconsistencies in previous studies on this subject and set the stage for further studies that would explore the range of factors that could act as media for transmitting innovations into growth. The rest of the paper is structured as follows. Section 2 considers the relevant literature. In Section 3, the methodology adopted for the study is outlined. Sections 4 and 5 present the results and conclusions and policy recommendations, respectively.

2. Literature review

Financial inclusion as defined by Aduda and Kalunda (2012) is making a range of financial services accessible without discriminating against any member of the society. These financial services are provided at a reasonable cost and in a translucent manner. In the view of World Bank (2014), financial inclusion occurs when individuals who are inadequately provided with financial services in a society and are excluded financially get access to an array of obtainable financial services devoid of partiality. Financial inclusion has three main dimensions namely: access to financial services, usage of financial services and banking penetration.

The use of the traditional approach to banking which relies heavily on branch networks could effectively limit the number of people who may be able to access banking services. Innovations in technology that makes it easier and less costly to access and use various financial services thus have the potential to enhance financial inclusion in any given economy. The origin of financial innovation dates back to thousands of years. Goetzmann and Rouwenhorst (2005), for instance, observe that some financial markets exhibited traits of important financial innovation in the seventeenth century. However, it was in the 1970s and 1980s that innovations in financial markets gained a lot of grounds. The seminal works of Schumpeter (1961), Marx, [1894] 1959 and Kuznets (1972) provided sufficient insights into the critical role innovations play in economic development. There abound both theoretical and empirical literature on financial innovations, inclusion and economic growth.

There are a number of theories that attempt to explain the reasons why Financial Institutions pursue innovations. In the traditional theory of financial innovation, Sundbo (1997), identifies technological development as the most important part of the innovation process. Indeed, the growth in information and communication technology amongst others have made it easier for financial institutions to address the needs of clients in a more convenient and cost-effective manner. Sundbo further notes that the entrepreneurial acts of market players also tend to drive financial innovations. This is to say that the profit making opportunities associated with innovations tend to motivate Financial Institutions to look for better ways of serving their clients. Once this is achieved, institutions that innovate gain a competitive advantage over those that fail to innovate. As a result, many enterprises invest heavily in technology in order to be effective and efficient in their operations so that they can maintain their competitiveness.

Schumpeter (1950) argues in the financial constraints theory that institutions must innovate to address the constraints and inconveniences caused by market imperfections, regulations, taxes and operation cost. These constraints can limit the earning capacity of financial institutions. To optimize the return on capital employed therefore, these constraints must be lessened. Hence, financial innovations are driven by constraints in the financial markets. Innovations provide an escape route for institutions from these constraints, allowing them to lower borrowing cost and other expenses and improve investment options (Tufano, 2003). In an apparent support of this argument, Miller (1991) asserts that financial innovation is a reaction to the increasing volatility in the financial markets.

2.1. Empirical literature

A number of studies have been conducted in an attempt to explore the interrelations that exist between innovations and economic growth, financial inclusion and economic growth as well as financial innovations and inclusion.

2.2. Financial innovation and economic growth

Financial innovation is considered as one of the fundamental pillars of financial-sector development and has become a significant causal factor in spawning economic activities. This is attributed to the ability of innovations to enhance savings, capital accumulation and productivity levels that consequently brings about economic growth.

Qamruzzaman and Jianguo (2017) used autoregressive distributed lag (ARDL) bound testing and Granger causality-based Error Correction Model (ECM) to investigate the effect of financial innovation on economic growth in Bangladesh spanning from 1980 to 2016. This study provides evidence that financial innovation in the financial system resulted in the economic growth of Bangladesh from 1980 to 2016. Domestic Credit to the Private Sector and Broad-to-Narrow Money were used as proxies for financial innovation. Real Gross Domestic Product per Capita was also used as an indicator for economic growth. The findings revealed a long-run relationship between financial innovation and economic growth. The relationship was found to be positive and significant. This indicates that increase in financial innovations in the financial system boosts economic growth.

Qamruzzaman and Wei (2018) investigated the nexus between financial innovation, stock market development and economic growth of Bangladesh using ARDL Model. The data set covered a 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 run and the long run. The reason is that financial innovation kindles the supply of money in the financial system, which in turn boosts economic growth.

Adu-Asare Idun and Aboagye (2014) in their study on financial innovation, bank competition and economic growth in Ghana revealed that, financial innovation negatively correlates with economic growth in the long term. However, the correlation between the two is positive in the short term. The long-run negative impact as reported by this study may be explained by the fact that technology may lead to unemployment as machines replace humans in the production process. If the cost saving benefits of innovation falls far below the cost of associated unemployment, then this could be translated into lower economic growth. So whilst in the short term the enhanced efficiency and convenience enjoyed via the deployment of innovations could spur economic growth. The long-run effect may be negative due to the rising cost of unemployment generated by increasing reliance on technology. Okereke (2016) used ordinary least square to investigate the effect of Automated Teller Machine (ATM), point of sales terminal, transaction value, Internet banking and mobile banking transaction on economic growth of Nigeria. The findings of the research showed that the relationship between automated teller machine (ATM), mobile banking, Internet banking and economic growth is insignificant. Only point of sales terminal has a significant relationship to economic growth. Empirical findings on the subject matter within the African context thus appear inconclusive. The studies that have established that no significant relationship exists between innovations and growth need to be looked at again in that, there may exist some mediating variables in this relationship. Until such variables are identified and factored into the analysis-related studies will fail to unearth the true nature of the relationship between the two variables.

2.3. Financial inclusion and economic growth

Gul et al. (2018) conducted an empirical study on the relationship between financial inclusion and economic growth: A global perspective. Financial inclusion indicators were bank accounts, bank branches, automated teller machines and life insurance premium. Economic growth was measured by gross domestic product per capita. A panel data set of 185 countries spanning over 1996–2015

were used. The findings revealed a positive relationship between financial inclusion and economic growth, indicating that financial inclusion is one of the essential factors for economic growth.

Inoue and Hamori (2016) used data on 37 countries in sub-Saharan Africa countries from 2004 to 2012 to examine the effect of financial access on economic growth. The findings of the research clearly indicated that access to financial services has a robust and statistically significant effect on the economic growth of sub-Saharan Africa economies. The study furthermore investigated whether financial access has contributed to economic growth. From the estimated results, the relationship between the number of commercial bank branches and real gross domestic product per capita is positive. The relationship between financial deepening and economic growth in sub-Saharan Africa is significantly positive.

Nkwede (2015) also examined the consequence of financial inclusion on the growth of African economies, using Nigeria as a case study. The researcher used ordinary least square to estimate the regression coefficients. The research revealed that financial inclusion has a negative but significant relationship with the growth of the Nigerian economy. According to the researcher, high level of financial exclusion in Nigeria accounted for the negative relationship because all-inclusive financial system promotes economic growth.

Most of the studies in Africa on the relationship between financial inclusion and economic growth show a significantly positive relationship and thus confirm the *a priori* expectations.

We would expect financial inclusion to promote economic growth because first inclusion will ensure optimal saving and consumption decision and enhance capital formation and second inclusion leads to more productive use of funds. These working together tend to promote economic growth.

Sharma (2016) also researched into the indexes of the financial inclusion-economic growth nexus in the emerging Indian economy. The main research questions were tested using vector auto-regression (VAR) models and Granger causality test. The study found a positive relationship between economic growth and the three dimensions of financial inclusion, which are banking penetration, availability and usage of financial institutions services.

2.4. Financial innovation and financial inclusion

Qamruzzaman and Wei (2019) employed panel autoregressive distributed lagged model to investigate the relationship between financial innovation and financial inclusion. The researchers incorporated financial development and inflows of remittance in the relationship.

Monthly data covering from 1990 to 2018 was collected on six South Asian countries. The findings revealed a positive relationship between financial innovation and financial inclusion both in the long run and short-run.

According to Andrianaivo and Kpodar (2012), there is a significantly positive relationship between mobile phone penetration and financial inclusion. Diffusion of mobile phone has the capacity to enhance financial inclusion through the provision of cost-effective financial products and services to the poor. Access to mobile banking, mobile money innovations and automated teller machines has thus shown a significant and positive impact on financial inclusion.

3. Methodology

3.1. Data and data sources

This research used panel data for the fourteen-year period from 2004–2017. The data were obtained from the World Development Indicators (WDI) and Global Financial Development (GFD) databases. The data were collected on twenty-six (26) countries within sub-Saharan Africa (SSA). The countries are Angola, Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Chad,

Cosmoros, Congo, Republic of, Cote D' Ivoire, Equatorial Guinea, Ghana, Guinea, Guinea Bissau, Kenya, Lesotho, Madagascar, Niger, Nigeria, Rwanda, Senegal, Seychelles, Togo, Uganda, and Zimbabwe. Availability of data informed the selection of these countries and data period. The study was based on country level data collected over the above sample period. The data covered key variables of interest selected based on literature and data availability. Table 1 provides the details of selected variable and how they were measured in this study.

3.2. Model specification

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

$$Y_{it} = (FIN_{it}, FINC_{it}, GCF_{it}, GCEXP_{it}, GRATM_{it}, BOC_{it},) \quad (1)$$

Where

Y = Gross Domestic Product Per Capita Growth

FIN = Financial Innovation

FINC = Financial Inclusion

GCF = Gross Capital Formation

GCEXP = Government Consumption Expenditure

GRATM = Growth in Automated Teller Machine

BOC = Banks' Overhead Costs

Subscript t represents the particular period, for each country i ,

The standard growth model of Barro (1991) was modified to suit the aim of this research, which is to investigate the surrogating role of financial inclusion in the financial innovation-economic growth relationship. The model is presented below:

$$Y_{it} = \varphi_1 Y_{it-1} + \varphi_2 DCPS_{it} + \varphi_3 Z_{it} + \delta_i + \varepsilon_{it} \quad (2)$$

This is the dynamic panel model with temporal and individual dimensions. Where

Y = Gross Domestic Product per Capita Growth

DCPS = Domestic Credit to Private Sector

Z = Set of growth determinants other than domestic credit to private sector (Gross Capital Formation and Government Consumption Expenditure)

δ = Unobserved country-specific effects

ε = Idiosyncratic error term

$\varphi_1, \varphi_2, \varphi_3$ = Slope of coefficients

Subscript t represents the particular period, for each country i ,

Table 1. Variable description, units and sources

VARIABLES	PROXY	SYMBOL	A priori expectation
Dependent			
Economic growth	GDP Per Capita growth(Gul et al., 2018; Qamruzzaman & Wei, 2018)	GDPPC	
Independent			
Financial innovation	Domestic credit to the private sector as a percentage of GDP(Nazir et al., 2021; Qamruzzaman & Janguo, 2017)	DCPS	(+)
Mediator			
Financial inclusion	Index of Financial Inclusion(Sarma, 2015; Sarma & Pais 2011)	IFI	(+)
Controls			
Gross capital formationGovernment consumption expenditure	Gross capital formation (annual % growth) Government consumption expenditure (annual % growth)	DCPSGCEXP	(+)(+) or (-)
Automated teller machine	Growth in Automated teller machine per 100,000 adults	GRATM	(+)
Bank Overhead Cost	Bank Overhead Costs to Total Assets (%)	BOC	(+)

This study follows Baron and Kenny (1986) who asserted that in order to claim that mediation is occurring some conditions must be satisfied. The first condition is that the relationship between the dependent variable (economic growth) and the independent variable (financial innovation) must be significant. This relationship is represented in the equation below:

$$Y_{it} = \varphi_1 DCPS_{it} + \varphi_2 Z_{it} + \delta_i + \varepsilon_{it} \quad (3)$$

The second condition is that the independent variable (financial innovation) must be significantly related to the mediator variable (financial inclusion). Equation (4) is the mathematical representation of this condition. In this case, there should be a significant relationship between financial innovation and financial inclusion.

$$FINC_{it} = \varphi_1 DCPS_{it} + \varphi_2 J_{it} + \delta_i + \varepsilon_{it} \quad (4)$$

where

$FINC$ = Financial inclusion.

J = Financial inclusion determinants other than domestic credit to the private sector

Third, the mediator variable (financial inclusion) must also relate to the dependent variable (economic growth) significantly. This is represented in the equation below:

$$Y_{it} = \varphi_2 FINC_{it} + \varphi_2 P_{it} + \delta_i + \varepsilon_{it} \quad (5)$$

Where

$FINC$ = Financial Inclusion

P = Set of growth determinants other than financial inclusion (Inflation and Trade)

The last condition is that the relationship between the independent variable (financial innovation) and the dependent variable (economic growth) diminishes when the mediator is inserted into equation 3 in the case of partial mediation or the relationship becomes insignificant in the case of full mediation. Therefore, to test whether financial inclusion is a conduit through which financial innovation impacts economic growth, a variable for financial inclusion is added to the economic growth model (equation 3).

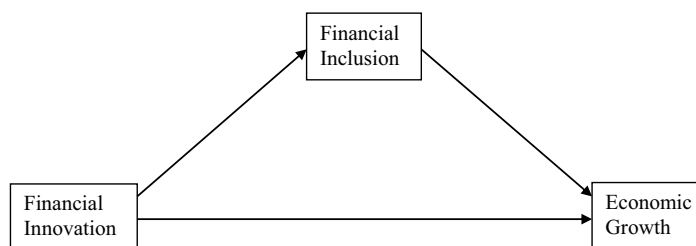
$$Y_{it} = \varphi_1 DCPS_{it} + \varphi_2 FINC_{it} + \varphi_3 Z_{it} + \delta_i + \varepsilon_{it} \quad (6)$$

Figure 1 is a pictorial representation of the mediation conditions as explained above

3.3. Estimation techniques

When the lag of the dependent variable is included in a model as one of the independent variables as can be seen from equation (1), it introduces endogeneity problem with respect to the variable. In view of this, the application of ordinary least square, (OLS) regression yields inconsistent estimates. The difference generalized method of moments and system method of moments estimators are adopted to deal with the endogeneity problem.

Figure 1. Simple mediation model.



To assess the mediating role of financial inclusion in the nexus between financial innovation and economics, Roodman (2009a, 2009b) which is the extension of Arellano and Bover (1995) was used. The reason for using Roodman (2009a, 2009b) is that it controls for cross-sectional dependence and also restricts the proliferation of instrument (Boateng et al., 2018; Tchamyou & Asongu, 2017). The two-step generalised method of moments was used because it is consistent with heteroscedasticity.

Alonso-Borrego and Arellano (1999) and Blundell and Bond (1998) revealed that the first difference generalised method of moments normally produce biased and inaccurate outcomes. However, Blundell and Bond (1998) recommended the use of the system generalised method of moments panel data estimation method instead of first-difference generalised method of moments. This study therefore used system-generalised method of moments because it incorporates generalised method of moments difference and level approaches.

Consistency of the generalised method of moments estimator depends on two assumptions. The first assumption is that the error term should not exhibit serial correlation and the second assumption is that the over-identifying restrictions are valid. To verify whether these two assumptions hold, Arellano and Bond (1991), Arellano and Bover (1995), and Blundell and Bond (1998) suggested two specification tests, that is, Sargan/Hansen test of over-identifying restrictions. This tests the overall validity of the instruments. The second test examines whether the second-order serial correlation is present.

3.4. Identification, simultaneity and exclusion restrictions

Below are the discussions of some key aspects of the Generalised Method of Moments (GMM) estimation technique. They include identification, simultaneity and exclusion restrictions.

The identification approach is in tandem with Tchamyou and Asongu (2017) and Tchamyou et al. (2018). Whereas Tchamyou and Asongu (2017) used years as strictly exogenous variable, Tchamyou et al. (2018) used Information and Communication Technology (independent variable) as strictly exogenous. This study used years as strictly exogenous variable. The predetermined or suspected endogenous variables represent the conduit through which financial innovations affect economic growth. The method used to treat the predetermined variables is *gmmstyle* whilst the *Fmethod* adopted to treat years is “iv(Years, eq(diff))”.

The lag of the explanatory variables are used as instruments to deal with the problem of simultaneity for forward-differenced indicators. Fixed effects that are correlated with the error term are removed by way of using the Helmert transformation that makes the estimation unbiased (Asongu & De Moor, 2017). The transformations represent the use of forward mean-variations, which means that the mean of future observations is subtracted from the preceding observations (Roodman, 2009b). These transformations guarantee orthogonal or parallel conditions between lagged observations and forward-differenced variables. Moreover, in order not to lose data, computations are made for all observations with exception of the last year in each country.

Concerning exclusion restrictions, the adopted strictly exogenous variables (Years) have an effect on Economic Growth (Dependent Variable) exclusively via Financial Inclusion (Predetermined or Suspected endogenous Variables). Difference in Hansen Test is used to investigate the statistical validity in relation to the exclusion restrictions for instrument exogeneity. According to Beck et al. (2003), when the null hypothesis of the Sargan Overidentifying Restrictions test is rejected, then the dependent variable (Economic Growth) is not exclusively explained by the instruments through the suspected endogenous variables.

The Difference in Hansen Test is the information criterion required to examine whether years is strictly exogenous with forward orthogonal deviations. Hence, for the assumption of strict exogeneity to hold, the null hypothesis of the Difference in Hansen connected to instrumental variable (Years, eq(diff)) is not rejected.

3.5. Robustness of the mediation analysis

Having used the GMM estimation technique to test for mediation in the relationship between financial innovation and economic growth, the robustness of the analysis was investigated in two main ways. First, an alternative measure of innovation (the independent variable) was used to re-estimate equation 6. We adopted bank concentration as used by Nagayasu (2012) and Dunne and Kasekende (2018) to measure innovation. This was used to test for the robustness of the mediation results in the first instance.

Second, further test for robustness was checked using the mediation analysis of structural equation modeling (MedSeM). MedSem performs a mediation study using Stata's structural equation modeling function to estimate a model. The techniques of "MedSem" are based on two methods. The first method is the well-known Baron and Kenny approach, which has been modified for use with structural equation modeling by Iacobucci et al. (2007). This strategy includes the use of the Sobel test to test for indirect effects. If the Sobel's z-test is significant and the relationship between the independent variable (financial innovations) and the dependent variable (economic growth) is not significant, then there is full mediation. Partial mediation occurs when both the Sobel's z-test and the relationship between the independent and dependent variables are significant. Alternatively, when the Sobel's z-test is not significant but the relationship between the independent and dependent variables is significant, then there is partial mediation. Furthermore, when neither Sobel's z-test nor the relationship between financial innovations and economic growth are significant, then there is partial mediation (Iacobucci et al., 2007).

The second approach is that of Zhao et al. (2010). This approach relies on the use of a Monte Carlo re-sampling-based approach to generate test results for the indirect effect. If the Monte Carlo z-test is significant and the relationship between the independent and dependent variables is not significant, then there is full mediation. However, when both the Monte Carlo z-test and the relationship between the independent and dependent variables are significant and their coefficients have the same sign, then there exist a complementary partial mediation. Alternatively, when both the Monte Carlo z-test and the relationship between the independent and dependent variables are significant and their coefficients point in opposite direction, then there is competitive partial mediation (Zhao et al., 2010).

3.6. Financial inclusion index (IFI)

The approach of Sarma and Pais (2011) and Sarma (2015) was adopted with modifications to construct the financial inclusion index. Three dimensions of financial inclusion were used to construct the index. These dimensions were banking penetration (measured by the number of deposit bank accounts per 1,000 adult), availability (measured by bank branches per 100,000 adults) and usage (measured by outstanding deposit as a percent of GDP). Equal weight of 1 was assigned to the three dimensions because they are equally considered to be important for the inclusive financial system. As indicated by Sarma (2015), when all the three dimensions are given equal weight, $w_i = 1$, then the ideal point is $W = (1, 1, 1)$ and the modified formula for the financial inclusion index (IFI) is

$$IFI = \frac{1}{2} \left[\sqrt{\frac{BP^2 + A^2 + U^2}{n}} + \left(1 - \frac{\sqrt{(1 - BP)^2 + (1 - A)^2 + (1 - U)^2}}{\sqrt{n}} \right) \right] \quad (7)$$

where

IFI = Financial inclusion index,

BP = Number of deposit bank accounts per 1,000 adults (Banking Penetration)

A = Number of bank branches per 100,000 adults (Availability)

U = Outstanding deposit as a percent of GDP (Usage)

n = Number of dimensions of financial inclusion

4. Results and discussion

4.1. Descriptive statistics

The summary statistics of the variables used in this research are reported in Table 2. The two main components of the descriptive statistics are the central tendency (mean and median) and variability (standard deviation, maximum, minimum).

Table 2. Descriptive statistics

	Mean	Median	S.D	Max.	Min.
GDPPC	2.076	1.965	4.632	32.169	-18.491
DCPS	16.354	13.797	11.408	65.742	1.248
GCF	7.443	5.640	22.672	218.754	-65.827
GCEXP	8.105	4.814	34.109	565.534	-55.348
GRATM	0.192	0.111	0.480	4.851	-1.206
BOC	5.597	5.245	3.375	42.639	0.001

Source: Author (2022)

GDP = Gross Domestic Product Per Capita; DCPS = Domestic Credit to Private Sector; IFI = Index of Financial Inclusion; GCF = Gross Capital Formation; GCEXP = Government Consumption Expenditure; GRATM = Growth in Automatic Teller Machine; BOC = Bank Overhead Costs to Total Assets (%);

Table 3 presents the pairwise correlation between the variables. This was done to find out whether multicollinearity exists among the projected variables for the study. The reason behind this was that when multicollinearity exists, the variance of the estimated coefficients and the standard errors become inflated (Simon, 2004). According to Kennedy (2008) when the correlation between two variables exceeds 0.80, multicollinearity exists. From Table 3, the estimated values of the coefficients of all the variables are below 0.80. It can therefore be concluded that the model for the study is free of multicollinearity.

Table 3. Correlation matrix, pairwise correlation between the variables

	GDPPC	DCPS	IFI	GCF	GCEXP	GRATM	BOC
GDPPC	1.000						
DCPS	-0.018	1.000					
IFI	-0.087	-0.290	1.000				
GCF	0.426	-0.048	0.015	1.000			
GCEXP	0.181	-0.137	0.088	0.203	1.000		
GRATM	0.151	-0.202	0.043	0.063	0.008	1.000	
BOC	0.136	-0.261	0.076	-0.080	0.131	0.048	1.000

Source: Author (2022)

4.2. Relationship between financial innovation and economic growth

In an attempt to determine the mediating role of financial inclusion in the innovation-growth nexus, some conditions must be met. The first condition is that there must be a significant relationship between economic growth and financial innovations. The results for this first condition are presented in Table 4. The results show that there is a significant and positive relationship between financial innovation and economic growth. What this means is that, as financial institutions become more innovative in their service delivery activities, the rate of growth in the economy is enhanced. More specifically, the results show that for every dollar increase in the credit to the private sector, economic growth increases by 0.045 units. This confirms the a-priori expectations. The introduction of various innovations is expected to generate risk and cost reduction benefits for financial institutions that could promote financial-sector development and economic growth. The above thus confirms the findings of Qamruzzaman and Wei (2018), Qamruzzaman & Jianguo (2017), which also revealed a positive relationship between financial innovation and growth. On the contrary, a study by Okereke (2016) concluded that a negative

relationship existed between the two variables. The findings of Adu-Asare Idun and Aboagye (2014) also revealed a negative relationship between financial innovations and economic growth in the long term but a positive relationship in the short term. This contradictory result is possible where innovations lead to a situation where machines replace human beings in the execution of tasks. In this case, the unintended consequence of unemployment could cause economic growth to slow down. Otherwise, one would expect the relationship between innovation and growth to be positive as established by this paper.

Taking the control variables into consideration, gross capital formation as shown in Table 4 has a positive and significant relationship with economic growth. A dollar increase in capital formation propels the economy to grow by 0.08 points. Capital formation promotes private sector investments, leads to technological progress in an economy and economies of scale. Government consumption expenditure, also has a strong and positive association with economic growth. A dollar increase in government consumption expenditure creates a resultant 0.073 points increase in economic growth. This is because an increase government consumption expenditure stimulates aggregate demand. Firms respond to the rise in aggregate demand by expanding output. The natural consequence of this is the creation of jobs and economic growth. In SSA where the public sector is so huge, government expenditure becomes a key driver of economic growth. From Table 4 however, the biggest driver of growth is gross capital formation. Governments in the subregion should thus give close attention to policies that can stimulate household savings as a way promoting capital formation to enhance economic growth.

Table 4. Financial innovations on economic growth

Dependent Variable: Economic Growth (Gross Domestic Product Per Capita Growth)

	Coefficient	Standard Error	P-Value
Lag (GDPPC)	0.167	0.038	0.000***
Financial Innovation	0.045	0.015	0.003***
Gross Capital Formation	0.080	0.013	0.000***
Government Cons. Expenditure	0.073	0.015	0.000***
Cons	-0.235	0.405	0.562
AR(1)			0.001
AR(2)			0.814
Sargan OIR			0.421
Hansen OIR			0.566
DHT for instruments			
(a) GMM Instruments for levels			0.495
H excluding group			0.948
Dif(null, H = exogenous)			
(b) gmm (lagged values)			0.245
H excluding group			0.824
Dif(null, H = exogenous)			
(c) IV (years, eq (diff))			
H excluding group			0.520
Dif(null, H = exogenous)			0.512
Instruments			22
Countries			26
Observations			286
Wald Chi ²			0.000

** significant at 5%; *** significant at 1%.

Both the first order (AR1) and the second order (AR2) serial correlation fails to reject the null hypothesis of no autocorrelation. This guarantees the validity of the model. The Sargan and Hansen over identification restrictions (OIR) tests are not significant. This means that the instruments are valid or not correlated with the error terms. Though the Sargan OIR test is not robust but not weakened by instruments, the Hansen OIR is robust but weakened by instruments. In addition, to assess the validity of the Sargan and Hansen OIR results, Difference in Hansen Test (DHT) for exogeneity of instruments was employed. The results of the DHT test failed to reject the null hypothesis that the entire instruments as a group are exogenous. This confirms the results of both Sargan and Hansen OIR results. Taking the Wald chi-square test into consideration, the null hypothesis that the joint estimated coefficients except the constant term are zero is rejected which implies that the joint estimated coefficients are significant.

4.3. Relationship between financial innovation and financial inclusion

The relationship between innovations and financial inclusion must be significant as per the second condition required to establish mediation in the innovation-growth nexus. Table 5 displays the results of the relationship between financial innovation and financial inclusion. The results show that financial inclusion has a significantly positive relationship with financial innovation. This finding is in tandem with the findings of a study conducted by Qamruzzaman and Wei (2019) and Andrianaivo and Kpodar (2012). The implication is that innovations make financial services more accessible and usable and draws people into the financial system of an economy. The above results confirm the theoretical expectation. In that, the convenience and cost reducing benefits of innovations tend to draw many into the formal financial system. The test satisfies the second condition required to establish mediating role of financial inclusion between innovations and economic growth.

Table 5. Financial inclusions and financial innovation

Dependent Variable: Financial Inclusion			
	Coefficient	Standard Error	P-Value
Lag (Financial Inclusion)	0.8220	0.0390	0.0000***
Financial Innovation	0.0001	0.0000	0.0010***
ATM Growth	0.0086	0.0014	0.0000***
Bank Overhead Costs	0.0012	0.0002	0.0000***
Constant	0.1370	0.0333	0.0000***
AR(1)			0.089
AR(2)			0.303
Sargan OIR			0.426
Hansen OIR			0.408
DHT for instruments			
(a) GMM Instruments for levels			
H excluding group			0.402
Dif(null, H = exogenous)			0.311
(b) gmm (lagged values)			
H excluding group			0.580
Dif(null, H = exogenous)			0.277
(c) IV (years, eq (diff))			
H excluding group			0.619
Dif(null, H = exogenous)			0.269
Instruments			24
Countries			26
Observations			235
Wald Chi ²			0.000

** significant at 5%; *** significant at 1%.

From the control variable, banks' overhead cost, which measures the efficiency of the banking system, has a positive and significant relationship with financial inclusion. Improvement in efficiency allows banks to provide their core services at more affordable rates to majority of the populace. This in no small way may influence the decision of the populace to use such services. Growth in automated teller machine has a positive and significant relationship with financial inclusion. An automated teller machine (ATM) enhances account access and new methods of payment that meet consumer demands for convenience and ease.

Both the first order (AR1) and the second order (AR2) serial correlation fails to reject the null hypothesis of no autocorrelation. This guarantees the validity of the model. The Sargan and Hansen over identification restrictions (OIR) tests are not significant. This means that the instruments are valid or not correlated with the error terms. Though the Sargan OIR test is not robust but not weakened by instruments, the Hansen OIR is robust but weakened by instruments. In addition, to assess the validity of the Sargan and Hansen OIR results, Difference in Hansen Test (DHT) for exogeneity of instruments was employed. The results of the DHT test failed to reject the null hypothesis that the entire instruments as a group are exogenous. This confirms the results of both Sargan and Hansen OIR results. Taking the Wald chi-square test into consideration, the null hypothesis that the joint estimated coefficients except the constant term are zero is rejected. This means that the joint estimated coefficients are significant.

4.4. Relationship between financial inclusion and economic growth

To check for the third condition required to establish mediation amongst a set of variables, the relationship between financial inclusion and economic growth was tested. The results are also shown in Table 6.

Table 6. Financial inclusion and economic growth

Dependent Variable: Economic Growth (Gross Domestic Product Per Capita)			
	Coefficient	Standard Error	P-Value
Lag (GDPPC)	0.128	0.041	0.002***
Financial Inclusion	13.217	3.908	0.001***
Gross Capital Formation	0.105	0.006	0.000***
Government Cons. Expenditure	0.033	0.009	0.015***
Constant	-10.336	3.167	0.001***
AR(1)			0.001
AR(2)			0.805
Sargan OIR			0.073
HansenOIR			0.327
DHT for instruments			
(a) GMM Instruments for levels			0.271
H excluding group			0.846
Dif(null, H = exogenous)			
(b) gmm (lagged values)			
H excluding group			0.221
Dif(null, H = exogenous)			0.493
(c) IV (years, eq (diff))			
H excluding group			0.175
Dif(null, H = exogenous)			0.519
Instruments			23
Countries			26
Observations			301
WaldChi ²			0.000

** significant at 5%; *** significant at 1%.

From Table 6, the relationship between financial inclusion and economic growth is positive and significant. A unit increase in financial inclusion would lead to 13.217 units increase in economic growth. The explanation of this result is not far-fetched. Financial inclusion improves economic growth in the selected sub-Saharan Africa countries. Indeed, greater access to financial services is pivotal in helping firms mobilise the much-needed financial resources and the usage of such resources in productive activities spurs growth in the economy. The finding is in tandem with the findings of Gul et al. (2018) and Sharma (2016). These researchers revealed that the relationship between financial inclusion and economic growth is positive. On the contrary, Nkwede (2015) indicated that financial inclusion has a negative and significant relationship with economic growth. The control variables all show a significant and positive relation with economic growth.

Both the first order (AR1) and the second order (AR2) serial correlation fails to reject the null hypothesis of no autocorrelation. This guarantees the validity of the model. The Sargan and Hansen over identification restrictions (OIR) tests are not significant. This means that the instruments are valid or not correlated with the error terms. Though the Sargan OIR test is not robust but not weakened by instruments, the Hansen OIR is robust but weakened by instruments. In addition, to assess the validity of the Sargan and Hansen OIR results, Difference in Hansen Test (DHT) for exogeneity of instruments was employed. The results of the DHT test failed to reject the null hypothesis that the entire instruments as a group are exogenous. This confirms the results of both Sargan and Hansen OIR results. Taking the Wald chi-square test into consideration, the null hypothesis that the joint estimated coefficients except the constant term are zero is rejected. This means that the joint estimated coefficients are significant.

4.5. The mediating role of financial inclusion in the nexus between financial innovation and economic growth

The aim of this study is to investigate whether financial innovation indirectly influences economic growth through financial inclusion. To achieve this, the last condition for mediation as outlined by Baron and Kenny (1986) was tested. The results of the test for mediation are displayed in Table 7. In an earlier test conducted without the mediating variable, it was established that the financial innovation-economic growth nexus was significantly positive (see Table 4). To check whether financial inclusion is one of the paths through which financial innovation influences economic growth, the index of financial inclusion was introduced into the model. As can be seen from Table 7, the relationship between financial innovation and economic growth became insignificant after controlling for financial inclusion. Before the introduction of financial inclusion, the model in Table 4 indicated a significant relationship between innovation and growth. However, when the index of financial inclusion was introduced into the same model, the relationship between innovations and growth became insignificant (see, Table 7). This according to Baron and Kenny (1986) is an indication of complete or full mediation of financial inclusion in the innovation-growth nexus.

Table 7. The mediating role of financial inclusion in the financial innovation-economic growth nexus

Dependent Variable: Economic Growth (Gross Domestic Product Per Capita)

	Coefficient	StandardError	P-Value
Lag (GDPPC)	0.178	0.045	0.000***
Financial Innovation	0.049	0.030	0.109
Financial Inclusion	-0.376	13.164	0.977
Gross Capital Formation	0.082	0.014	0.000***
Government Cons. Expenditure	0.075	0.017	0.000***
Constant	-0.045	11.525	0.997

(Continued)

Table 7. (Continued)

Dependent Variable: Economic Growth (Gross Domestic Product Per Capita)			
AR(1)			0.001
AR(2)			0.806
Sargan OIR			0.372
Hansen OIR			0.494
DHT for instruments			
(a) GMM Instruments for levels			0.455
H excluding group			0.490
Dif(null, H = exogenous)			
(b) gmm (lagged values)			0.170
H excluding group			0.828
Dif(null, H = exogenous)			
(c) IV (years, eq (diff))			
H excluding group			0.628
Dif(null, H = exogenous)			0.381
Instruments			22
Countries			26
Observations			285
Wald Chi ²			0.000

** significant at 5%; *** significant at 1%.

Both the first order (AR1) and the second order (AR2) serial correlation fails to reject the null hypothesis of no autocorrelation. This guarantees the validity of the model. The Sargan and Hansen over identification restrictions (OIR) tests are not significant. This means that the instruments are valid or not correlated with the error terms. Though the Sargan OIR test is not robust but not weakened by instruments, the Hansen OIR is robust but weakened by instruments. In addition, to assess the validity of the Sargan and Hansen OIR results, Difference in Hansen Test (DHT) for exogeneity of instruments was employed. The results of the DHT test failed to reject the null hypothesis that the entire instruments as a group are exogenous. This confirms the results of both Sargan and Hansen OIR results. Taking the Wald chi-square test into consideration, the null hypothesis that the joint estimated coefficients except the constant term are zero is rejected. This means that the joint estimated coefficients are significant.

4.6. Robustness analysis of the mediation results

From the results of the adjusted Baron and Kenny's approach by Iacobucci et al. (2007) as shown in Table 8a and Table 8b, the effect of financial innovation on financial inclusion (Step 1), the effect of financial inclusion on economic growth (Step 2) as well as the Sobel z-test are all significant but the effect of financial innovation and economic growth (Step 3) is not significant. This shows that there is a full mediation. The results of the second approach by Zhao et al. (2010) as shown in Table 8b revealed that the Monte Carlo z-test is significant but the effect of financial innovation on economic growth (Step 1) is not significant. This also means that financial inclusion fully mediates the relation between financial innovations and economic growth. The two approaches used here have both yielded results that are consistent with the results obtained from the GMM estimation technique.

Table 8a. Structural equation model

	Coefficient	OIM Std. Err	P-Value
StructuralEconomic			
GrowthFinancial	−24.152	7.852	0.002
InclusionFinancial	−0.014	0.022	0.528
InnovationConstant	22.604	6.710	0.001
Financial			
InclusionFinancial	−0.0007	0.0001	0.0000
InnovationConstant	0.8529	0.0029	0.0000
Var (e. Economic Growth)	19.7731	1.5121	
Var (e. Financial Inclusion)	0.0009	0.0000	

Table 8b. Mediation analysis of structural equation model

Estimates	Delta	Sobel	Monte Carlo*
Indirect Effect	0.045	0.045	0.045
Standard Error	0.017	0.017	0.016
Z. Value	2.666	2.690	2.774
P. Value	0.008	0.007	0.006
Confidence Interval	0.012, 0.078	0.012, 0.077	0.017, 0.081

Adjusted Baron and Kenny approach to testing mediation

STEP 1—IFI: DCPS (X → M) with B = −0.263 and p = 0.000

STEP 2—GDPPC: IFI (M → Y) with B = −0.170 and p = 0.002

STEP 3—GDPPC: DCPS (X → Y) with B = −0.035 and p = 0.528

As step 1, step 2 and the Sobel's test above are significant and step 3 is not significant the mediation is complete

Zhao, Lynch & Chen's approach to testing mediation

STEP 1—GDPPC: DCPS (X → Y) with B = −0.035 and p = 0.528

As the Monte Carlo test above is significant and step 1 is not significant you have indirect-only mediation (full mediation).

Furthermore, when an alternative measure of innovations (bank concentration) was used to re estimated the mediation relationship, the results reported in [Table 8b](#), [Table 9](#) are still consistent (in relation to the variable of interest) with that reported in [Table 7](#). This thus confirms the existence of full mediation in the innovation growth nexus by financial inclusion. These results are thus robust and could be relied on for policy purposes in relation to the subject under study.

Table 9. The mediating role of financial inclusion in the financial innovation-economic growth nexus using bank concentration as a measure of financial innovation

Dependent Variable: Economic Growth (Gross Domestic Product Per Capita)

	Coefficient	StandardError	P-Value
Lag (GDPPC)	0.054	0.064	0.401
Financial InnovationFinancial Inclusion	−0.00131.566	0.0124.421	0.9050.000***
Gross Capital Formation	0.101	0.007	0.000***
Government Cons. Expenditure	0.016	0.014	0.274

(Continued)

Table 9. (Continued)

Constant	−25.488	3.623	0.000***
AR(1)			0.003
AR(2)			0.388
Sargan OIR			0.371
Hansen OIR			0.355
DHT for instruments			
(a) GMM Instruments for levels			0.323
H excluding group			0.473
Dif(null, H = exogenous)			
(b) gmm (lagged values)			0.284
H excluding group			0.437
Dif(null, H = exogenous)			
(c) IV (years, eq (diff))			
H excluding group			0.278
Dif(null, H = exogenous)			0.443
Instruments			25
Countries			25
Observations			232
Wald Chi ²			0.000

** significant at 5%; *** significant at 1%.

5. Conclusions and policy implications

The study aimed at establishing the possible mediating role of financial inclusion in the relationship between financial innovation and economic growth in sub-Saharan Africa. To achieve this, a test of the four conditions required for mediation analysis (Baron & Kenny, 1986) was conducted. All the conditions were satisfied. First, a significant relationship was established between economic growth (the dependent variable) and financial innovation (the independent variable). Secondly, the relationship between financial innovation and financial inclusion (the mediating variable) was also significant. Thirdly, the analysis revealed a significant relationship between financial inclusion and economic growth. These three sets of results confirmed the existence of mediation in the innovation-growth relationship. To test for the exact nature of the mediation (whether partial or full mediation), the fourth test was conducted by introducing the mediating variable into the innovation-growth model. The results confirmed that financial inclusion plays a complete mediating role in the innovation-growth relationship.

This paper has thus contributed to the innovation-growth debate by first establishing that financial inclusion fully mediates the innovation-growth relationship. This was until now not known empirically. In other words, until the innovations so introduced by the financial sector lead to greater levels of inclusiveness, the potential to spur economic will be lost. In essence innovations are useless unless they lead to greater availability and access to financial services as well as usage of these services. This paper thus further helps us explain why previous studies on this subject have produced mixed findings.

This finding thus brings to the fore the need to rethink critically policy issues in relation to governments efforts to derive economic prosperity through harnessing the potential of technological innovations in the financial sector of the economies in SSA. First and foremost, as governments in the sub-region create the enabling environment for Financial Institutions to take advantage of technology in the delivery of their services. Furthermore, attention should be directed

at dealing with any potential barriers that could interfere with the mechanism via which innovations can transmit into economic growth. One such barrier is the high level of illiteracy in the subregion. Enhancing literacy level would pave the way for the adoption of innovations, promote financial inclusion and hence economic growth in the SSA region.

It is further recommended that governments and regulators pursue policies that will ensure stability in the financial sector. This will enhance confidence in the system and further the course of the financial inclusion agenda in SSA. In Africa today, there appears to be a strong emergence of technology usage especially by the youth. Sub-region can take advantage of this trend to actively pursue financial inclusion-related policies which in turn would translate this rising reliance on technology into economic prosperity.

The paper also confirmed that financial inclusion affects economic growth positively. Access to financial services could enhance deposit mobilisation, capital formation, access to credit which could amongst other things lead to greater investment, job creation, and economic growth. Therefore, any actions that may improve on the macroeconomic fundamentals especially lowering lending rates could enhance the financial inclusion agenda as lending to support the productive activities of the private sector increases.

Furthermore, the findings reveal that innovations in the financial sector enhance financial inclusion in the selected SSA countries. As governments pursue policies that will drastically reduce the proportion of adults that are financially excluded, attention should be given to investing in the requisite technological infrastructure. This will provide the enabling environment that will allow financial institutions to leverage on technology to conveniently deliver affordable services to the populace. This paper did not consider the possibility some other variables may play a moderating role in the innovation-growth nexus. It is thus recommended that future studies in this area should test for the possibility of moderation effect of some key economic variables on the relationship under study.

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