The Relationship Between Inclusion, Financial Innovation and Economic Growth in Sub-Saharan African Countries: A PVAR Approach

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Abstract: The objective of this paper is to examine the relationship between inclusion, financial innovation, and economic growth. The goal is to verify the existence of a bidirectional relationship between the three variables. For this purpose, we use the Panel Vector Autoregressive (PVAR) model in the Generalized Method of Moments (GMM) on data from 46 Sub-Saharan African countries. The results confirm the existence of a positive and unidirectional relationship between economic growth and financial innovation and the existence of a unidirectional relationship between financial inclusion and economic growth. Additionally, our results show that there is a bidirectional relationship between economic growth and investment. Regarding practical implications, this study jointly analyzes three current and interrelated topics that pose a problem for the African continent and expands the scarce literature on financial development and economic growth. As for originality, this study considers the possibility of a bidirectional relationship between inclusion, financial innovation, and economic growth using a sample of 46 sub-Saharan African countries covering the period 2005-2018, a fact that was ignored in previous studies when they examined only unidirectional causality.

Keywords: Financial Innovation, Financial Inclusion, Economic Growth, Panel Vector Autoregressive model (PVAR), Sub-Saharan Africa.
JEL classification: C33, C38, E21, E22, E26, G20.

1. INTRODUCTION

The instability of the financial system, the poor access to financial products and services, as well as the heterogeneity of economic growth in the African region, poses strong challenges for policymakers and financial institutions in the search for alternative solutions for the development and implementation of strategies that expand access to and use of financial services. Some studies suggest that one of these measures, for example, is financial innovation and financial inclusion (Beck et al., 2015; Chinoda & Kwenda, 2019), as a way to promote economic development (Mukherjee & Sood, 2020; Qamruzzaman & Wei, 2019). On the other hand, World Bank (2016) reports that about 50.7% of the poor population in the world belongs to Sub-Saharan African countries. However, evidence is growing on the significant effect of financial inclusion on poverty reduction (Amponsah et al., 2021; Boateng et al., 2019; Huang & Zhang, 2020; Ojo, 2021; Omar & Inaba, 2020; Zins & Weill, 2016). In addition, poor access to financial products and services inhibits financial development and impedes poverty alleviation (Ojo, 2021).

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The accumulation of capital has direct implications for economic growth, but to sustain growth, technological progress is also required, which is the element capable of doubling production without increasing capital or labor (Blanchard, 1999; Li & Chu, 2022; Nejjari & Aamoum, 2022). Technological progress is characterized by the research and development (R&D) of the entities. For example, spending on research and development in the United States, France, Germany, Japan, and the United Kingdom accounted for about 2% to 3% of the GDP of each country (Blanchard, 1999, p.451). There is a positive correlation between technological innovation and financial innovation, and the combination of the two will produce the sustainability of economic growth (Laeven et al., 2015).

Regarding the financial sector, technological innovation allowed the expansion and diversification of the use and access of financial services, increasing transactions and liquidity, eliminating barriers of spatial differentiation between users and financial institutions (Freitas, 2013; Sdiri & Ayadi, 2021). Technological innovation enables the use of financial services in an easy, safe, and fast way, such as buying investment products, insurance, and credits online, as well as, it is a great opportunity for the execution of financial inclusion and microcredit programs (Beck et al., 2016; Demirgüç-Kunt et al., 2018; Sharmila, 2019). A similar argument is found in Beck (2011), stating that financial innovation allows the expansion of financing, facilitates domestic and international commercial transactions, and reduces the bu-

reaucracy of financial institutions in terms of customer satisfaction. Likewise, the author states that the combination of these processes promotes economic growth. Ouma et al. (2017) and later Chinoda and Kwenda (2019), stated that the use of mobile phones in the financial sector has become vital to promote financial inclusion, mainly because it reduces the cost of infrastructure for banks and the cost of use for customers.

The increase in financial innovation in Sub-Saharan Africa was notable in the 1980s and 1990s, characterized by a period of major financial reforms and there were also increases in financial innovation after 2008, specifically in the East African region, added by the emergence of mobile banking technology (Dunne & Kasekende, 2018). In terms of leadership in financial innovation, Dunne and Kasekende (2018) highlight the South African Development Community (SADC), which has shown strong growth in the field of financial innovation, with countries like Mauritius registering the highest rate of innovative financial services (about 7.3% higher than the average of 1.88% in Sub-Saharan Africa), although other regions also showed an increase in the availability of ATMs (automatic teller machines) in 2012 as compared to 2004.

In the study on financial innovation and endogenous growth carried out by Laeven et al. (2015), it is mentioned that financial innovation represents any change in the financial system, which improves the access and use of financial services. They support this idea by stating that financial innovation is not limited to the invention of new financial instruments, but includes techniques that allow banks to increase the control and evaluation of borrowers. This fact reinforced the argument presented by Cagnin (2009) when he mentioned that financial innovation allows the adaptation of financing to economic and structural conditions. In addition, financial inclusion facilitates access to finance, encourages bank deposits and savings, and thus contributes to bank stability and poverty reduction (Huang & Zhang, 2020; Ouechtati, 2020, 2022; Qamruzzaman & Wei, 2019). Therefore, more stable banks conform to the financing needs of the economy (Musau et al., 2018). Additionally, financial innovation improves the control of bad debt customers and can significantly contribute to reducing the amount of money outside the financial system and facilitate the control of corruption (Beck et al., 2015; Grennan & Michaely, 2021; Peterson Kitakogelu Ozili, 2021; Setor et al., 2021; Sharmila, 2019). However, we can easily understand that the combination of the advantages provided by inclusion and financial innovation can contribute to the promotion of economic growth.

Macroeconomic conditions, particularly economic growth can affect banks' ability to provide products and services as well as their ability to innovate (Allen et al., 2016; Grohmann et al., 2018; Omar & Inaba, 2020). The purpose of the present study is to examine the relationship between inclusion, financial innovation, and economic growth, specifically to see if there is a bidirectional or reverse relationship between inclusion, financial innovation, and economic growth.

Based on the literature review presented in this section, we can gauge that the relationship between inclusion, financial innovation, and economic growth is inconclusive. Moreover, we are unaware of any study that analyzes these variables simultaneously and in a sample of Sub-Saharan African countries.

The present study contributes in various ways to the literature on financial innovation. First, analyzing jointly three current and interrelated topics that constitute a problem for the African continent (financial innovation, financial inclusion, and economic growth). Second, by expanding the scarce literature on the study of financial development and economic growth, which until then has been quite inconclusive, on the relationship between financial inclusion, financial innovation, and economic growth. Third, we used principal component analysis (PCA) to construct the inclusion and financial innovation indexes. Fourth, by awakening in policymakers in Africa the need to know the behavior and the relationship of the variables financial innovation, financial inclusion, and economic growth, for better handling and decision making. Finally, as the literature review will show, the previous studies ignore the possibility of economic growth influencing inclusion and financial innovation, considering solely the effect of inclusion and financial innovation on economic growth. In addition, the previous studies very often employ the autoregressive vector model (VAR) and Granger causality to gauge the effect of self-feeding or reverse causality, however, these models do not consider the effect of endogeneity on the estimates. We employ the Generalized Method of Moments (GMM) of the Panel Vector Autoregressive (PVAR) model, which outperforms the VAR estimation, removing any bias (Chia et al., 2021; Usman et al., 2022). We also note that few studies analyze the possible existence of bidirectional causality between financial inclusion, financial innovation, and economic growth simultaneously for sub-Saharan African countries.

The rest of the article is structured in a literature review in section 2. In the third section, we present the description of the data and the study methodology implemented, whereas in the fourth section we describe the results and discuss them. Finally, in section 5, we present the conclusions of the study.

2. LITERATURE REVIEW

Developing countries are generally characterized by high population growth rates, high corruption rates, heterogeneity in economic growth, and dualistic economic systems, characterized by a large portion of the population in the informal sector and without access to formal financial services. However, it is by no accident that Beck et al. (2015) allude that economic growth on the African continent is not inclusive. Thus, the study of economic growth, financial inclusion, and financial innovation in developing countries has received attention from policymakers and academics.

Financial system development is a very relevant factor in sustaining economic growth (Chia et al., 2021). In this perspective, Ozili (2021) states that financial inclusion influences and is influenced by countries' levels of financial innovation, poverty levels, financial sector stability, financial literacy levels, and financial regulatory structure. Emara and El Said (2021) found that financial inclusion positively impacts economic growth in the countries of the Middle East and North African (MENA) region. Similarly, Singh and

Stakic (2021) evidenced a long-term relationship between financial inclusion and economic growth in South Asian Association for Regional Cooperation (SAARC) countries. Nazir et al. (2021) showed that financial innovation produces a positive and statistically significant impact on economic growth. Qamruzzaman et al. (2021) certify the existence of a long-term relationship between financial innovation, human capital development, and economic growth.

Bilan et al. (2019) showed that online financial services are positively and significantly influenced by the country's financial development, financial inclusion, and innovation levels. Igharo et al. (2020) use the vector autoregressive (VAR) and autoregressive lag distribution (ARDL) models and concluded that the high informality of the financial system and the strong intervention of the authorities in the banking sector weaken the monetary policy transmission mechanism in Nigeria. Furthermore, they found that financial innovation increases economic growth. Ouma et al. (2017), showed that the availability and use of a cell phone to provide financial services increases the likelihood of users saving and significantly increases the volume (quantity) of the amount to be saved. The authors allude that the growth and deepening of mobile phone financial services is a way to promote saving, especially for low-income groups.

Valverde et al. (2007) analyze the effect of credit expansion and financial innovation on economic growth in Spain and found that there is a positive and significant correlation between financial deepening and regional growth. Additionally, they showed that innovation of financial products and services contributes positively to economic growth. Qamruzzaman and Wei (2019) examine the relationship between financial inclusion and financial innovation in six countries in South Asia (Bangladesh, India, Pakistan, Nepal, Bhutan, and Sri Lanka), using monthly data for the period 1990-2018. The result confirms the existence of a bidirectional relationship between financial inclusion and financial innovation, as was also evidenced by Bara and Mudzingiri (2016) in Zimbabwe. In contrast, Lumpkin (2010) did not confirm causality between financial innovation and economic growth.

Idun and Aboagye (2014) used ARDL estimation to assess the short-run and long-run relationship between competitiveness, financial innovation, and economic growth in Ghana and found that in the long run financial innovation is negatively related to economic growth. In terms of Granger causality, they found that there is bidirectional causality between financial innovation and economic growth. Low levels of financial inclusion and the serious gaps in financial inclusion were the main motivations of Chinoda and Kwenda (2019), analyzing the impact of mobile phones, economic growth, competitiveness, and stability of banks on financial inclusion. To this end, they used data from 49 African countries for the period 2004-2016. The result of the autoregressive structural vector model showed that financial inclusion responds positively and significantly to shocks in bank competitiveness, economic growth, and the use of mobile phones. These variables were also evidenced to be also positively impacted by financial inclusion.

The macroeconomic structure and in particular the gross domestic product can condition the ability of financial institutions to offer financial services and products (Grohmann et al., 2018). Thus, Omar and Inaba (2020) use the fixed effects model and evidenced that developing countries with higher per capita income experienced greater financial inclusion. Otekunrin et al. (2021) investigate the link between growth, financial development, financial inclusion in Africa using the error correction model and the Granger causality test, to find that there is bidirectional causality between innovation and financial inclusion as well as a causal relationship between economic growth, innovation, and financial inclusion. Bara et al. (2016) investigate the link between financial innovation and economic growth in SADC countries and showed that financial innovation has a positive link with economic growth. Furthermore, the Granger causality test indicated that there is no bidirectional causality between financial innovation and economic growth in the short and long run. Based on the literature review presented in this section, we can gauge that the relationship between financial inclusion, financial innovation, and economic growth is inconclusive. Moreover, we are unaware of any study that analyzes these variables simultaneously and in a sample of Sub-Saharan African countries, as noticed previously in the introduction.

3. METHODOLOGY

3.1. Data and Descriptive Statistics

The theoretical and empirical literature on endogenous economic growth highlights positive impacts of the variables' financial development, financial innovation, financial inclusion, real interest rate, and investment on economic growth (Idun and Aboagye, 2014). To conduct our study, we collected information from the World Bank's World Development Indicators (WDI) and International Monetary Fund databases, using financial access statistics (FAS). Data on an annual basis was collected for 46 countries in Sub-Saharan Africa (see annex 1), for the period 2005-2018[1], in line with studies on the same approach conducted by Chinoda and Kwenda (2019), Dunne and Kasekende (2018), and Idun and Aboagye (2014), although they used different periods. Due to the great scarcity of data, we used an unbalanced panel to obtain a considerable number of annual data to be used in the sample, which is why there is a difference in the number of observations for the variables under study, shown in Table 1, similarly to the study conducted by Dunne and Kasekende (2018).

Unlike the study of Dunne and Kasekende (2018), who used the inflation rate to represent the opportunity cost of holding money at the expense of investing it in the financial system, in this study we used the real interest rate, as did Idun and Aboagye (2014). Well-developed financial markets promote investment and economic growth, channeling financial resources to the most productive uses (Qamruzzaman & Jianguo, 2017; Qamruzzaman & Wei, 2019; Qamruzzaman

[1] The need to include a considerable number of Sub-Saharan African countries in the sample, as well as due to the unavailability of data on some variables, lead us to be compelled to merge information extracted from two different databases (World Bank and International Monetary Fund) and to limit the study period to 2005-2018, where there is a set of considerable informations that satisfies our study interest and avoid the lack of data for many years.

Table 1. Descriptive Statistics and Data Sources

Variables	Source	Obs	Average	S.D.	Min	Max
GDP	World Bank	644	1.356	0.825	-2.490	3.031
Investment		644	2.947	0.743	1.523	11.852
Interest		642	1.629	1.353	-3.725	7.055
Inovf	IMF and World Bank	634	0.018	1.000	-3.490	2.130
Ifi		644	-0.100	1.000	-1.479	1.676

& Jianguo, 2017; Qamruzzaman & Wei, 2019)[2]. For this reason, we used investment and interest rate as control variables in the study (Chen & Creamer, 2019).

To measure financial inclusion, we created the index that represents the multidimensionality of financial inclusion, using the multivariate technique of principal component analysis (PCA), according to the approach of Sarma (2008), instead of depending on a single simple indicator. This technique is suitable in this situation as revealed in the studies carried out by Anarfo et al. (2019), Elsherif (2019), and Jungo et al. (2021). Thus, the basic variables used to create this index are the number of banks per 1,000Km2, the number of banks per 100,000 adults, credit provided to the private sector as a percentage of gross domestic product, number of depositors in commercial banks, accounts demand deposits in commercial banks per 100,000 adults, and number of borrowers in commercial banks per 100,000 adults.

Regarding financial innovation, several empirical studies have used a series of different indicators as a proxy for financial innovation. For example, Dunne and Kasekende (2018), used the ratio of M2/M1 monetary aggregates and bank concentration, ATMs, and private sector credit as a percentage of GDP, as proxies for financial innovation. Authors such as Abor et al. (2018), Chinoda and Kwenda (2019), Ouma et al. (2017), and Shaughnessy (2015), used the mobile phone as a proxy for financial innovation, through the use and access of/to bank accounts on this device. Valverde et al. (2007) considered as a proxy for financial innovation in their study, the existence of mutual funds, and commitments for loans, debit and credit cards, and ATMs. The fact that motivated us to also use the principal component analysis (PCA), to build a financial innovation index, coinciding with the measure used by Qamruzzaman and Wei (2019). Thus, our financial innovation index is composed of the variables debit and credit cards, the number of mobile money accounts registered by 1,000 adults (internet banking), numbers of ATMs per 1000 km2, numbers of ATMs per 100,000 adults, and the ratio (M2/M1)[3].

Given that each of the variables had different dimensions according to the country under analysis, for example, gross domestic product and investment are calculated based on national currencies of each country, consequently, to avoid spurious regressions by different variables measurement, we apply the natural logarithm in all variables. Table **1** shows the variables under study, their sources, and the respective descriptive statistics.

Based on the descriptive statistics we can verify that the average economic growth rate in the period under analysis is 1.36%, and the maximum rate is 3.03%. We also verify that the average investment spending is 2.95% of gross product, the average real interest rate was 1.63%, and concerning financial innovation and financial inclusion, we note that the average financial innovation index is 0.018% and on average 0.10% of individuals are included in the financial system.

3.2. Model Specification

According to Anarfo et al. (2019), the construction technique of the inclusion index and the innovation index can be specified according to equations (1) and (2).

$$IFI_j V = W_{j1}X_1 + W_{j2}X_2 + \cdots + W_{jp}X_p \quad (1)$$

$$INOVF = W_{k1}X_1 + W_{k2}X_2 + \cdots + W_{kP}X_p \quad (2)$$

Where *IFI* is the financial inclusion index and *INOVF* financial innovation index, W_j and W_k represent the weights of the respective coefficients for country j or k (considered in IFI and INOVF, respectively, being j = k). *X* represents the variables which constitute each variable included in the financial inclusion index (number of banks per 1,000Km2, number of banks per 100,000 adults, credit provided to the private sector as a percentage of gross domestic product, number of depositors at commercial banks, demand deposit accounts at commercial banks per 100,000 adults, number of borrowers in commercial banks per 100,000 adults) and the financial innovation index (number of debit and credit cards per 1000 adults, number of mobile money accounts registered per 1,000 adults, number of ATMs per 1000 km2, numbers of ATMs per 100,000 adults, M2/M1 ratio). $P = 1,2,\ldots,P$ represents the number of variables in the equation.

To test the adequacy of the financial innovation and financial inclusion indexes we will use the Kaiser-Meyer-Olkin (KMO) test, which compares the simple correlations with the partial correlations. Therefore, the values of this statistic vary from 0 to 1, being that, values close to 0 (zero) indicate that the use of the index may not be adequate and values close to 1 (one), indicate better adequacy in the use of the index (Carillo et al., 2019; Carvalho, 2013). The KMO statistic is specified according to equation (3).

[2] The real interest rate is the main instrument used in the financial system for financial intermediation activity, representing the cost of loans and remuneration for savings, taking out the inflation rate effect.

[3] Corroborating the exposure presented by Dunne and Kasekende (2018), about the use of this proxy, the use of this variable is justified as a measure of financial innovation, because when the ratio evolves, it means that people abdicate of assets with greater liquidity (M1) and opt for less liquid assets (M2).

$$KMO = \frac{\sum\sum_{j\neq k} r_{jk}^2}{\sum\sum_{j\neq k} r_{jk}^2 + \sum\sum_{j\neq k} q_{jk}^2} \quad (3)$$

where r_{jk}^2 represents the square of the correlation matrix of the original variables outside the diagonal and q_{jk}^2 is the square of the partial correlation matrices among variables.

Knowing the relationship between the variables' financial innovation, financial inclusion, and economic growth is essential for the implementation of economic policies, as well as their effectiveness. Thus, our objective is to examine the effect of financial innovation on financial inclusion and economic growth and vice versa, that is, to verify the existence of bidirectional causality between the three variables (financial innovation, financial inclusion, and economic growth). For this purpose, we use the panel vector autoregressive (PVAR) model, with the generalized method of moments (GMM), specifying the endogenous behavior between financial innovation, financial inclusion, and economic growth. Thus, our model is specified following equation (4) (Abrigo & Love, 2015; Anarfo et al., 2019):

$$Y_{it} = \beta_{0\,it} + \sum_{k=1}^{p} \propto_{it} Y_{it-k} + u_{it} \quad (4)$$

Where Y_{it} is the vector of the k endogenous variables for each country, specifically, financial innovation, financial inclusion, economic growth, investment, real interest rate; β_{0it} captures the effect of deterministic components, Y_{it-k} represents the number of lags of endogenous variables and u_{it} is the vector of random errors; *i* is the country subscript and *t* is the time subscript.

4. RESULTS AND DISCUSSION

4.1. Adequacy Test of Kaiser Factors

By the application adequacy test of the Kaiser factorial model, shown in Table **2**, it is acceptable to use the financial innovation and financial inclusion indexes created by the PCA method in the estimation of the model, with KMO values greater than 60%, that is, equal to 62% and 72.4%, respectively (Carillo et al., 2019; Carvalho, 2013).

Table 2. Factor Tests for Financial Innovation and Financial Inclusion Indexes.

	Inovf	Ifi
Determinant of correlation matrix	0.309	0.065
Chi2	739.38***	1746.85***
KMO	0.620	0.724

Notes: ***, **, * significance levels of 1%, 5% and 10% respectively.

4.2. Correlation Matrix

The results presented in Table **3** suggest that there is a weak, positive, and significant correlation between investment and economic growth and a weak, negative, and significant correlation between financial innovation and economic growth. However, there is nothing to be said about the correlation between financial inclusion and economic growth.

Table 3. Correlation Matrix.

	GDP	Investment	Interest	Inovf	Ifi
GDP	1.000				
Investment	0.1446*** (0.000)	1.000			
Interest	0.0617 (0.1178)	0.0009 (0.9816)	1.0000		
Inovf	-0.0950** (0.0167)	0.0368 (0.3549)	0.0039 (0.9226)	1.0000	
Ifi	0.0323 (0.4131)	0.0227 (0.5646)	0.0627 (0.1121)	0.3714*** (0.0000)	1.0000

Notes: ***, **, * significance levels of 1%, 5% and 10% respectively; Values in parenthesis refer to p-values.

Regarding the variables financial inclusion and financial innovation, Table **3** shows the existence of a weak, positive, and significant correlation between both. Therefore, the result of the correlation matrix suggests that there is no evidence of multicollinearity problems since there is no correlation above strong between the variables included in the study[4].

4.3. Selection and Estimation of Lag Order

Table **4** presents the procedure for selecting the number of lags to be implemented in the estimation, based on the selection criteria of the three models (MBIC, MAIC, and MQIC)[5]. By the determination coefficient, we selected the first order PVAR, because it presents the minimum values of MBIC, MAIC, and MQIC (Abrigo and Love, 2015; Andrews and Lu, 2001).

4.4. Unit Root Tests

The result of the stationarity test is presented in Table **5**, having been estimated using the technique of Levin Lin Chu (LLC), whose null hypothesis assumes that the panel has a unit root and the alternative hypothesis, regards the panel being stationary (Levin *et al.*, 2002). The results of this test show that all variables are integrated of order zero I (0).

4.5. Results from the Panel Vector Autoregressive Estimation

The results of the PVAR estimation are shown in Table **6**. It can be seen that economic growth in Sub-Saharan Africa is positively influenced by investment, that is, a 1% variation in investment causes an increase of 52.65% in economic growth, coincident with the results found by Ibrahim et al. (2015), Jalles (2016), Qamruzzaman and Jianguo (2017) and Qamruzzaman and Wei (2019). Additionally, our results show that there is a bidirectional relationship between economic growth and investment, that is, increases in invest-

[4] Results were confirmed through VIF (variance inflation factors) as well.
[5] MBIC = Modified Bayesian Criteria; MAIC = Modified Akaike Information Criteria; MQIC = Modified Hannan-Quinn Information Criteria.

Table 4. Lag Order Selection.

Lag	CD	J	J p-value	MBIC	MAIC	MQIC
1	0.9996	80.6454	0.3071	-369.6461	-69.35457	-188.2156
2	0.9993	52.0341	0.3947	-248.1603	-47.96593	-127.2066
3	0.9985	17.9446	0.8447	-132.1525	-32.05536	-71.67572

Notes: MBIC = Modified Bayesian Criteria; MAIC = Modified Akaike Information Criteria; MQIC = Modified Hannan-Quinn Information Criteria.

ment improve economic growth and economic growth expands investment.

Table 5. Panel Unit Root Test.

	GDP	Investment	Interest	Inovf	Ifi
LCC	-6.974***	-8.974***	-1.696**	-17.98***	-16.77***

Notes: ***, **, * significance levels of 1%, 5% and 10% respectively.

Interestingly, we note that financial inclusion has negative impacts on economic growth, namely, increases in the level of financial inclusion cause a reduction of 27.99% in economic growth, in opposition to the results found by Chinoda and Kwenda (2019).

The results also seem to show that increases in financial innovation expand investment, just as financial innovation induces a reduction in interest rates, making the cost of bank credits less onerous. In dimensional terms, a 1% variation in financial innovation produces a 19.94% increase in investment and a 29.70% reduction in the real interest rate, similarly to the result obtained by Qamruzzaman and Jianguo (2017).

Unlike the study carried out for Ghana by Idun and Aboagye (2014), where the authors proved the existence of a negative relationship between financial innovation and economic growth, in the short and long term, our results suggest that there is no bidirectional relationship between economic growth and financial innovation, but rather, a unidirectional relationship that goes from economic growth to financial innovation. That is, economic growth improves financial innovation, while we cannot infer anything about the opposite relationship. It is based on this result that an increase in economic growth causes an improvement in the provision of services such as education, access to electricity, and the internet, factors that facilitate the use and access to financial innovation. This result strengthens the exposure of Bilan *et al.* (2019) when the authors mentioned that financial innovation is greatly influenced by the country's economic development. As in our study, Lumpkin (2010), found no evidence about the influence of innovation on economic growth. In contrast, Valverde *et al.* (2007) show positive impacts of financial innovation on economic growth. Although financial innovation is related to wealth creation, our results motivate us to agree with the presentation by Igharo *et al.* (2020), when he affirms that the informality of the financial system (population outside the financial system) and the excessive state intervention in the financial system in Nigeria weakens the impact of financial innovation on economic growth. Another explanatory reason for the results obtained is the level of corruption observed in the countries included in the sample or even the flight of capital that can occur more easily in international terms, facilitated by the existence of financial innovation, as we measured it in this work.

Studies carried out by Bara and Mudzingiri (2016) and Qamruzzaman and Wei (2019), confirm the bidirectional relationship between financial innovation and financial inclusion. Likewise, our results confirm the existence of a bidirectional relationship between financial innovation and fi-

Table 6. Panel Vector Autoregressive Model Estimation Results.

	GDP	Investment	Interest	Inovf	Ifi
GDP	0.3543***	0.0227	0.1436**	0.0238**	0.0599
	(0.000)	(0.469)	(0.021)	(0.035)	(0.116)
Investment	0.5265**	0.4234***	0.2469	0.0346	0.3760***
	(0.014)	(0.001)	(0.147)	(0.248)	(0.005)
Interest	0.0454	0.0142	0.2025***	0.0022	0.0279
	(0.425)	(0.652)	(0.005)	(0.830)	(0.389)
Inovf	-0.1502	0.1994***	-0.2970**	0.6869***	-0.3397***
	(0.269)	(0.007)	(0.011)	(0.000)	(0.000)
Ifi	-0.2799**	0.0739	-0.1216	0.0600**	0.9448**
	(0.043)	(0.406)	(0.380)	(0.020)	(0.000)
Nº Obs.	414	414	414	414	414
Nº Panel	46	46	46	46	46

Notes: ***, **, * significance levels of 1%, 5% and 10%, respectively. Values in parenthesis are the coefficient p-values

nancial inclusion. Paradoxically, we find that financial innovation reduces financial inclusion, while financial inclusion positively drives financial innovation. This result leads us to conclude that financial innovation only produces good results when complemented with other components such as electricity and internet service supplies and fundamentally due to the level of education of users. In contrast, Ouma et al. (2017) found that there is a positive relationship between financial innovation and financial inclusion.

4.6. Conditions of Model Stability

The interpretation of the variance decomposition function and impulse response functions are most interesting when the model satisfies stability conditions (Abrigo & Love, 2015; Abrigo & Love, 2016; Chia et al., 2021). An estimative is considered stable when the eigenvalues are within the unit cycle (Fig. **1**), or when the modulus values are no greater than 1 (Table 7) (Abrigo & Love, 2016; Chia et al., 2021). From the results presented in Fig. (**1**) and Table **7**, we can conclude that our model satisfies the stability conditions.

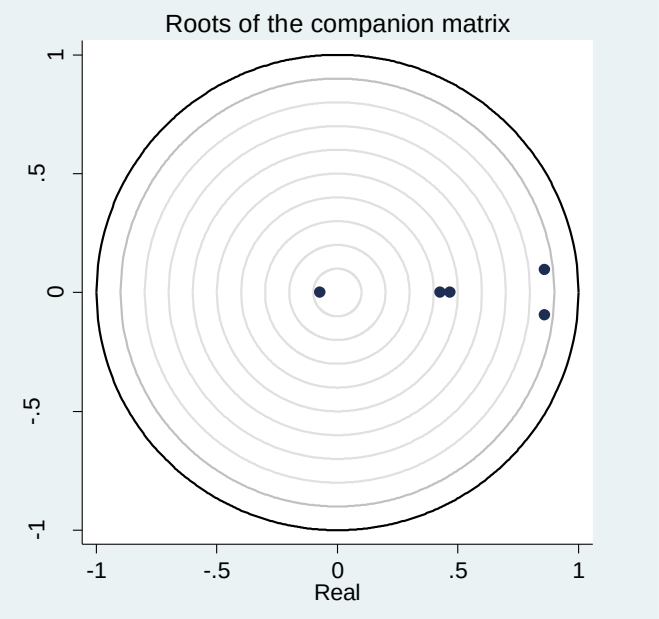

Fig. (1). Model stability conditions.

Table 7. Model Stability Conditions

Eigenvalue		
Real	**Imaginary**	**Modulus**
0.8612472	-0.0948372	0.866453
0.8612472	0.0948372	0.866453
0.4674684	0	0.4674684
0.4271643	0	0.4271643
-0.0726578	0	0.0726578

4.7. Results from the Variance Decomposition (FEVD[6])

Based on the variance decomposition estimate, the results of which are shown in Table **8**, we can see that about 24.77% of the variance decomposition of economic growth errors is explained by short-term (3-year) and long-term investment (10 years). The investment explains only 22.44%. We found that the variables real interest rate, financial innovation, and financial inclusion, do not have great explanatory power on the variation of economic growth in Africa, that is, they explain only 1.80%, 1.05%, and 10.6%, respectively. We emphasize that after the investment, the other variable with strong explanatory power for the decomposition of errors in the variance of economic growth, in the long run, is financial inclusion.

Table 8. Variance Decomposition of GDP.

Time	GDP	Investment	Interest	Inovf	Ifi
1	1.00000	0.00000	0.00000	0.00000	0.00000
2	0.75024	0.23257	0.01287	0.00056	0.00375
3	0.71793	0.24771	0.01215	0.00072	0.02149
4	0.69877	0.24381	0.01277	0.00070	0.04395
5	0.68266	0.23793	0.01409	0.00094	0.06437
6	0.66936	0.23333	0.01540	0.00177	0.08014
7	0.65898	0.23004	0.01645	0.00327	0.09127
8	0.65114	0.22764	0.01721	0.00535	0.09865
9	0.64529	0.22583	0.01773	0.00784	0.10331
10	0.64091	0.22444	0.01807	0.01051	0.10607

Note: Time/horizon is measured in years.

Regarding the investment behavior in the long term (10 years), the results presented in Table **9**, suggest that about 12.85%, 3.68%, 0.17%, and 1.28% of the investment variation are explained by economic growth, real interest rate, financial innovation, and financial inclusion, respectively.

Table 9. Variance Decomposition of Investment.

Time	GDP	Investment	Interest	Inovf	Ifi
1	0.12485	0.87515	0.00000	0.00000	0.00000
2	0.12404	0.83622	0.03174	0.00011	0.00788
3	0.12724	0.82597	0.03576	0.90002	0.01079
4	0.12827	0.82265	0.03661	0.00043	0.01204
5	0.12858	0.82141	0.03679	0.00068	0.01254
6	0.12864	0.82085	0.03683	0.00094	0.01273
7	0.12863	0.82053	0.03684	0.00119	0.01280
8	0.12861	0.82032	0.03684	0.00141	0.01282
9	0.12858	0.82016	0.03683	0.00160	0.01282
10	0.12857	0.82004	0.03683	0.00175	0.01282

Note: Time/horizon is measured in years.

[6] Forecast-error variance decomposition (FEVD).

The results which are shown in Table **10** evidence the behavior of the real interest rate. We can still verify that financial inclusion and financial innovation are the variables with less explanatory power over the real interest rate in the long term (10 years), explaining only 0.3% and 1.86%, respectively. On the other hand, economic growth and investment explain about 9.40% and 9.12%, respectively, of the variance of the decomposition of errors in the real interest rate in the long term (10 years).

Table 10. Variance Decomposition of the Real Interest Rate.

Time	GDP	Investment	Interest	Inovf	Ifi
1	0.05577	0.04359	0.90064	0.00000	0.00000
2	0.07994	0.06569	0.85135	0.00219	0.00080
3	0.09107	0.08235	0.82072	0.00509	0.00077
4	0.09426	0.00893	0.80763	0.00784	0.00096
5	0.09478	0.09132	0.80210	0.01030	0.00149
6	0.09465	0.09167	0.79912	0.01247	0.00208
7	0.09443	0.09159	0.79705	0.01436	0.00256
8	0.09424	0.09145	0.79544	0.01601	0.00286
9	0.09409	0.09131	0.79417	0.01741	0.00302
10	0.09396	0.09120	0.79316	0.01858	0.00309

Note: Time/horizon is measured in years.

Concerning financial innovation, we found that the variable with the greatest explanatory power over its variability is financial inclusion, which explains about 8.24% of the variation in financial innovation in the long term (10 years). The remaining variables such as economic growth, investment, and the real interest rate explain about 5.06%, 5.5%, and 0.55%, respectively (see Table **11**).

Table 11. Variance Decomposition of Financial Innovation.

Time	GDP	Investment	Interest	Inovf	Ifi
1	0.02698	0.00465	0.00495	0.96342	0.00000
2	0.02843	0.02330	0.00475	0.93737	0.00615
3	0.03214	0.03183	0.00395	0.91746	0.01462
4	0.03561	0.03785	0.00363	0.89832	0.02460
5	0.03884	0.04240	0.00361	0.87984	0.03530
6	0.04182	0.04604	0.00383	0.86217	0.04613
7	0.04452	0.04905	0.00419	0.84568	0.05655
8	0.04691	0.05153	0.00463	0.83071	0.06623
9	0.04895	0.05356	0.00510	0.81748	0.07489
10	0.05067	0.05520	0.00557	0.80614	0.08242

Note: Time/horizon is measured in years.

We can see in Table **12** that the variables economic growth, investment, real interest rate, and financial innovation, do not have great explanatory power in the variation of financial inclusion. Specifically, about 9.52%, 7.28%, 5.65%, and 6.97% of the decomposition of the variance of errors of financial inclusion in the long term (10 years) is explained by economic growth, investment, the real interest rate, and financial innovation, respectively.

Table 12. Variance Decomposition of Financial Inclusion.

Time	GDP	Investment	Interest	Inovf	Ifi
1	0.07393	0.08552	0.01180	0.05516	0.77359
2	0.08835	0.07033	0.03912	0.03408	0.77865
3	0.03214	0.03183	0.04749	0.02431	0.76952
4	0.09425	0.07344	0.05175	0.02178	0.75878
5	0.09722	0.07532	0.05552	0.02446	0.74885
6	0. 09826	0.07590	0.00383	0.03079	0.73952
7	0.09813	0.07559	0.05627	0.03948	0.73052
8	0.09736	0.07479	0.05660	0.04942	0.72182
9	0.09630	0.07378	0.05665	0.05972	0.71353
10	0.09527	0.07277	0.05652	0.06969	0.70584

Note: Time/horizon is measured in years.

6. CONCLUSIONS

To fill the gap in the study on the relationship between financial innovation, financial inclusion, and economic growth, we extracted data from the World Bank database and the International Monetary Fund, for the period 2005-2018. Methodologically, we applied the panel vector autoregressive model under the GMM specification, to examine the causal relationship or self-feeding effect between the variables inclusion, financial innovation, and economic growth. The result found by Qamruzzaman and Wei (2019) for six countries in South Asia, showed the bidirectional relationship between financial innovation and financial inclusion, emphasizing a positive relationship in the short and long term. Our study also highlights a bidirectional relationship between financial innovation and financial inclusion and differs in that the relationship found is positive between inclusion and financial innovation and negative between financial innovation and financial inclusion, that is, financial inclusion improves financial innovation and financial innovation facilitates financial exclusion given our sample.

Regarding economic growth, we found the existence of a positive and unidirectional relationship between economic growth and financial innovation, showing that increases in economic growth lead to increases in financial innovation, just as a negative and unidirectional relationship was detected between financial inclusion and economic growth, leading us to conclude that increases in financial inclusion reduce economic growth. The result about the negative relationship between financial inclusion and economic growth, are in line with the results found by Bara et al. (2016) when they found that there is a negative relationship between financial development and economic growth. However, the authors justify the negative relationship by the strong heterogeneity in economic growth and financial system of countries, underdeveloped financial systems, strong default lending rates, and poor credit allocation structures.

We believe that the negative relationship between financial inclusion and economic growth in Sub-Saharan African

countries can also be justified by high corruption rates, which affect the efficient allocation of credit. It may also be justified by high numbers of the population outside the financial system, factors that may underpin income inequality, poor savings and investment, and difficulties in economic growth. Our results also show that there is a bidirectional relationship between economic growth and investment, that is, increased investment enhances economic growth and economic growth expands investment.

Our study did not allow us to assess the impact of financial innovation on economic growth, as this relationship was not statistically significant. But it made it possible to verify the impact of financial innovation in reducing the real interest rate, thus reducing the costs of financial loans and concluding for the positive impact on investment. Thus, we conclude that financial innovation is a fundamental variable to take into account when analyzing economic growth in Sub-Saharan Africa. For this reason, we suggest to policymakers in this region, that measures aimed at promoting financial inclusion and innovation, should be complemented by other measures of a social scope, such as education in general and financial education, post-credit assistance, and improvement in the provision of services such as electricity and internet access, to facilitate the use and access of financial services and mitigate credit risks. It is also suggested that greater control should be taken in terms of financial corruption and the level of departure of funds to international tax havens. These may result from the financial innovation already existing in the country, given that the levels of the informal economy are still very high in this region of the globe.

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CONFLICT OF INTEREST

The authors reported no potential conflict of interest.

Appendix 1. Countries within the Sample.

Order No	Country	Order No	Country
1	Angola	24	Liberia
2	Benin	25	Madagascar
3	Botswana	26	Malawi
4	Burkina Faso	27	Mali
5	Burundi	28	Mauritania
6	Cape Verde	29	Mauritius
7	Cameroon	30	Mozambique
8	Central African Republic	31	Namibia
9	Chad	32	Niger
10	Comoros	33	Nigeria
11	Congo, Dem. Rep.	34	Rwanda
12	Congo, Rep.	35	Sao Tome and Principe
13	Cote d'Ivoire	36	Senegal
14	Equatorial Guinea	37	Seychelles
15	Eswatini	38	Sierra Leone
16	Ethiopia	39	South Africa
17	Gabon	40	South Sudan
18	Gambia, The	41	Sudan
19	Ghana	42	Tanzania
20	Guinea	43	Togo
21	Guinea-Bissau	44	Uganda
22	Kenya	45	Zambia
23	Lesotho	46	Zimbabwe

REFERENCES

Abor, J. Y., Amidu, M., & Issahaku, H. (2018). Mobile Telephony, Financial Inclusion and Inclusive Growth. *Journal of African Business*, *19*(3). https://doi.org/10.1080/15228916.2017.1419332

Abrigo, M. R. ., & Love, I. (2015). *Estimation of Panel Vector Autoregression in Stata: a Package of Programs*. http://paneldataconference2015.ceu.hu/Program/Michael-Abrigo.pdf

Allen, F., Demirguc-Kunt, A., Klapper, L., & Martinez Peria, M. S. (2016). The foundations of financial inclusion: Understanding ownership and use of formal accounts. *Journal of Financial Intermediation*, *27*. https://doi.org/10.1016/j.jfi.2015.12.003

Amponsah, M., Agbola, F. W., & Mahmood, A. (2021). The impact of informality on inclusive growth in Sub-Saharan Africa: Does financial inclusion matter? *Journal of Policy Modeling*, *43*(6), 1259–1286. https://doi.org/10.1016/j.jpolmod.2021.03.009

Anarfo, E. B., Abor, J. Y., Osei, K. A., & Gyeke-Dako, A. (2019). Monetary Policy and Financial Inclusion in Sub-Sahara Africa: A Panel VAR Approach. *Journal of African Business*, *20*(4), 549–572. https://doi.org/10.1080/15228916.2019.1580998

Bara, A., & Mudzingiri, C. (2016). Financial innovation and economic growth: Evidence from Zimbabwe. *Investment Management and Financial Innovations*, *13*(2), 65–75. https://doi.org/10.21511/imfi.13(2).2016.07

Bara, A., Mugano, G., & Le Roux, P. (2016). Financial innovation and economic growth in the SADC. *African Journal of Science, Technology, Innovation and Development*, *8*(5–6), 483–495. https://doi.org/10.1080/20421338.2016.1226705

Beck, T. (2011). *The Role of Finance in Economic Development : Benefits, Risks, and Politics By Thorsten Beck December 2011 European Banking Center Discussion Paper No. 8 This is also a CentER Discussion Paper No. 201*. 2011-03.

Beck, T., Chen, T., Lin, C., & Song, F. M. (2016). Financial innovation: The bright and the dark sides. *Journal of Banking and Finance*, *72*, 28–51. https://doi.org/10.1016/j.jbankfin.2016.06.012

Beck, T., Senbet, L., & Simbanegavi, W. (2015). Financial Inclusion and Innovation in Africa: An Overview. *Journal of African Economies*, *24*(June), i3–i11. https://doi.org/10.1093/jae/eju031

Bilan, Y., Rubanov, P., Vasylieva, T., & Lyeonov, S. (2019). The influence of industry 4.0 on financial services: Determinants of alternative finance development. *Polish Journal of Management Studies*, *19*(1), 70–93. https://doi.org/10.17512/pjms.2019.19.1.06

Blanchard, O. (1999). *Macroeconomia: Teoria e Política Económica* (3rd ed.). Campus Ltda.

Boateng, E., Agbola, F. W., & Mahmood, A. (2019). Does the quality of institutions enhance savings? The case of Sub-Saharan Africa. *Applied Economics*, *51*(58), 6235–6263. https://doi.org/10.1080/00036846.2019.1616066

Cagnin, R. F. (2009). Inovações financeiras e institucionais do sistema de financiamento residencial Americano. *Revista de Economia Politica*, *29*(3), 256–273. https://doi.org/10.1590/S0101-31572009000300016

Carillo, M., Largo, F. F., & Ceballos, R. F. (2019). Principal Component Analysis on the Philippine Health Data. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3339627

Carvalho, F. D. (2013). *Análise Fatorial* [Coimbra]. https://ap1-dev.uc.pt/cris/rp/rp01923

Chen, W., & Creamer, K. (2019). An empirical analysis on the effects of the inflation targeting framework on monetary policy in South Africa. *South African Journal of Economics*, *87*(4), 450–463. https://doi.org/10.1111/saje.12234

Chia, P. S., Law, S. H., Trinugroho, I., Wiwoho, J., Damayanti, S. M., & Sergi, B. S. (2021). Dynamic Linkages among Transparency, Income Inequality and Economic Growth in Developing Countries: Evidence from Panel Vector Autoregressive (PVAR) Model. *Research in International Business and Finance*, *60*(July 2021), 101599. https://doi.org/10.1016/j.ribaf.2021.101599

Chinoda, T., & Kwenda, F. (2019). Do mobile phones, economic growth, bank competition and stability matter for financial inclusion in Africa? *Cogent Economics and Finance*, *7*(1). https://doi.org/10.1080/23322039.2019.1622180

Demirgüç-Kunt, A., Klapper, L., Singer, D., Ansar, S., & Hess, J. (2018). The Global Findex Database 2017: Measuring Financial Inclusion and Fintech Revolution. In *World Bank Publications*. https://doi.org/doi: 10.1596/978-1-4648-1259-0.

Dunne, J. P., & Kasekende, E. (2018). Financial Innovation and Money Demand: Evidence from Sub-Saharan Africa. *South African Journal of Economics*, *86*(4), 428–448. https://doi.org/10.1111/saje.12205

Elsherif, M. (2019). *the Relationship Between Financial Inclusion and Monetary Policy Transmission: the Case of Egypt*. *May*, 63–87. https://doi.org/10.20472/iac.2019.045.014

Emara, N., & El Said, A. (2021). Financial inclusion and economic growth: The role of governance in selected MENA countries. *International Review of Economics and Finance*, *75*(February), 34–54. https://doi.org/10.1016/j.iref.2021.03.014

Freitas, A. F. de. (2013). Organizações de microfinanças: inovações e desafios para a inclusão financeira. *Revista de Administração Da UFSM*, *6*(1), 39–54. https://doi.org/10.5902/198346593826

Grennan, J., & Michaely, R. (2021). FinTechs and the Market for Financial Analysis. *Journal of Financial and Quantitative Analysis*, *56*(6), 1877–1907. https://doi.org/10.1017/S0022109020000721

Grohmann, A., Klühs, T., & Menkhoff, L. (2018). Does financial literacy improve financial inclusion? Cross country evidence. *World Development*, *111*. https://doi.org/10.1016/j.worlddev.2018.06.020

Huang, Y., & Zhang, Y. (2020). Financial Inclusion and Urban–Rural Income Inequality: Long-Run and Short-Run Relationships. *Emerging Markets Finance and Trade*, *56*(2). https://doi.org/10.1080/1540496X.2018.1562896

Ibrahim, M., Kumi, E., & Yeboah, T. (2015). Greasing or sanding the wheels? Effect of corruption on economic growth in sub-Saharan Africa. *African J. of Economic and Sustainable Development*, *4*(2), 157. https://doi.org/10.1504/ajesd.2015.069858

Idun, A. A. A., & Aboagye, A. Q. Q. (2014). Bank competition, financial innovations and economic growth in Ghana. *African Journal of Economic and Management Studies*, *5*(1), 30–51. https://doi.org/10.1108/AJEMS-09-2012-0057

Igharo, A. E., Osabohien, R., Onyemariechi, G. O., & Ibidapo, D. T. (2020). Monetary policy transmission mechanism, innovative banking system and economic growth dynamics in Nigeria. *International Journal of Business Innovation and Research*, *21*(1), 1–22. https://doi.org/10.1504/IJBIR.2020.104032

Jalles, J. T. (2016). *A new theory of innovation and growth : the role of banking intermediation and corruption*. *33*(4), 488–500. https://doi.org/10.1108/SEF-01-2016-0017

Jungo, J., Madaleno, M., & Botelho, A. (2021). The Relationship between Financial Inclusion and Monetary Policy: A Comparative Study of Countries' in Sub-Saharan Africa and Latin America and the Caribbean. *Journal of African Business*, *00*(00), 1–22. https://doi.org/10.1080/15228916.2021.1930810

Laeven, L., Levine, R., & Michalopoulos, S. (2015). Financial innovation and endogenous growth. *Journal of Financial Intermediation*, *24*(1), 1–24. https://doi.org/10.1016/j.jfi.2014.04.001

Li, Z., & Chu, Y. (2022). Is Hierarchical Education Investment Synergistic ? Evidence from China's s Investment in General and Advanced. *Journal of the Knowledge Economy*, *0123456789*. https://doi.org/10.1007/s13132-022-00960-9

Lumpkin, S. (2010). Regulatory issues related to financial innovation. *OECD Journal: Financial Market Trends*, *2009*(2), 1–31. https://doi.org/10.1787/fmt-v2009-art14-en

Mukherjee, S., & Sood, K. (2020). Triggers and barriers of financial inclusion: A country-wise analysis. *Asian Economic and Financial Review*, *10*(9), 970–988. https://doi.org/10.18488/journal.aefr.2020.109.970.988

Nazir, M. R., Tan, Y., & Nazir, M. I. (2021). Financial innovation and economic growth: Empirical evidence from China, India, and Pakistan. *International Journal of Finance and Economics*, *26*(4), 6036–6059. https://doi.org/10.1002/ijfe.2107

Nejjari, Z., & Aamoum, H. (2022). The Impact of Intellectual Capital on Profitability, Market Value, Productivity, and Return on Equity : Empirical Evidence from Moroccan ICT Firms. *Journal of the Knowledge Economy*, *0123456789*. https://doi.org/10.1007/s13132-022-00956-5

Ojo, T. A. (2021). Gendered Finance and Economic Opportunities in SADC Communities: An Overview of Challenges and Prospects. *International Journal of African Renaissance Studies*. https://doi.org/10.1080/18186874.2021.1982649

Omar, M. A., & Inaba, K. (2020). Does financial inclusion reduce poverty and income inequality in developing countries? A panel data analysis. *Journal of Economic Structures*, *9*(1). https://doi.org/10.1186/s40008-020-00214-4

Otekunrin, A. O., Chinoda, T., & Matowanyika, K. (2021). The nexus between economic growth, financial development, financial inclusion and financial innovation in Africa. *Asian Economic and Financial Review*, *11*(8), 672–681. https://doi.org/10.18488/JOURNAL.AEFR.2021.118.672.681

Ouechtati, I. (2020). The contribution of financial inclusion in reducing poverty and income inequality in developing countries. *Asian Economic and Financial Review*, *10*(9), 1051–1061. https://doi.org/10.18488/JOURNAL.AEFR.2020.109.1051.1061

Ouechtati, I. (2022). Financial Inclusion, Institutional Quality, and Inequality: an Empirical Analysis. *Journal of the Knowledge Economy*, *0123456789*. https://doi.org/10.1007/s13132-022-00909-y

Ouma, S. A., Odongo, T. M., & Were, M. (2017). Mobile financial services and financial inclusion: Is it a boon for savings mobilization? *Review of Development Finance*, *7*(1), 29–35. https://doi.org/10.1016/j.rdf.2017.01.001

Ozili, Peterson K. (2021). Financial inclusion research around the world: A review. *Forum for Social Economics*, *50*(4), 457–479. https://doi.org/10.1080/07360932.2020.1715238

Ozili, Peterson Kitakogelu. (2021). Has financial inclusion made the financial sector riskier? *Journal of Financial Regulation and Compliance*, *29*(3), 237–255. https://doi.org/10.1108/JFRC-08-2020-0074

Qamruzzaman, M., & Jianguo, W. (2017). Financial innovation and economic growth in Bangladesh. *Financial Innovation*, *3*(1), 0–24. https://doi.org/10.1186/s40854-017-0070-0

Qamruzzaman, M., Jianguo, W., Jahan, S., & Yingjun, Z. (2021). Financial innovation, human capital development, and economic growth of selected South Asian countries: An application of ARDL approach. *International Journal of Finance and Economics*, *26*(3), 4032–4053. https://doi.org/10.1002/ijfe.2003

Qamruzzaman, M., & Wei, J. (2019). Financial innovation and financial inclusion nexus in south Asian countries: Evidence from symmetric and asymmetric panel investigation. *International Journal of Financial Studies*, *7*(4). https://doi.org/10.3390/ijfs7040061

Sdiri, H., & Ayadi, M. (2021). Does Innovation Foster or Mitigate the Corruption Obstacle? Firm-Level Evidence from Tunisia. *Journal of the Knowledge Economy*. https://doi.org/10.1007/s13132-020-00707-4

Setor, T. K., Senyo, P. K., & Addo, A. (2021). Do Digital Payment Transactions Reduce Corruption? Evidence from Developing Countries. *Telematics and Informatics*, *60*(November 2020), 101577. https://doi.org/10.1016/j.tele.2021.101577

Sharmila, S. (2019). Digital finance with respect to financial inclusion. *International Journal of Recent Technology and Engineering*, *8*(3), 6321–6326. https://doi.org/10.35940/ijrte.C6013.098319

Shaughnessy, H. (2015). *Innovation in Financial Services: The Elastic Innovation Index Report*. *January*.

Singh, D., & Stakic, N. (2021). Financial inclusion and economic growth nexus: Evidence from SAARC countries. *South Asia Research*, *41*(2), 238–258. https://doi.org/10.1177/0262728020964605

Usman, O., Adewale, A., & Saint, S. (2022). Effects of domestic material consumption , renewable energy , and fi nancial development on environmental sustainability in the EU-28 : Evidence from a GMM panel-VAR. *Renewable Energy*, *184*, 239–251. https://doi.org/10.1016/j.renene.2021.11.086

Valverde, S. C., Del Paso, R. L., & Fernández, F. R. (2007). Financial innovations in banking: Impact on regional growth. *Regional Studies*, *41*(3), 311–326. https://doi.org/10.1080/00343400600928350

WORLD BANK. (2016). Poverty And Shared Prosperity: Taking On Inequality. In *Open Knowledge. World bank*. https://doi.org/10.1596/978-1-4648-0958-3

Zins, A., & Weill, L. (2016). The determinants of financial inclusion in Africa. *Review of Development Finance*, *6*(1), 46–57. https://doi.org/10.1016/j.rdf.2016.05.001

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