Fintech-based financial inclusion and banks' risk-taking: the role of regulation in Sub-Saharan Africa

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Abstract

Purpose – The study examines the role of regulation in the fintech-based financial inclusion (FBFI)–risk-taking nexus in the Sub-Saharan African (SSA) region.

Design/methodology/approach – Using a sample of 10 countries in SSA over the period 2014 to 2021, the study employed the fixed-effect regression model and the two-step generalized method of moments (GMM) estimator.

Findings – The results show that FBFI mitigates commercial banks risk-taking in SSA. But as FBFI progresses, the association takes the shape of an inverted U, increasing risks initially and decreasing them later on. Effective supervision and regulatory quality, in particular, are essential in moderating this relationship by offsetting the adverse consequences of FBFI in its early stages.

Research limitations/implications – First, while our sample is limited to banks in ten SSA countries, future studies could extend the sample size, enabling more explicit generalization of the results. Second, the FBFI–bank risk nexus can be explored further by comparing diverse forms of fintech participation, such as fintech company investment, fintech technology investment, cooperation with specific fintech service providers and cooperation with Internet giants.

Practical implications – Policymakers, banks and fintech companies should collaborate to certify the sustainable utilization of fintech tools to ensure financial inclusion. Policymakers should craft policies that encourage effective supervision and regulatory quality of fintechs since they reduce banks' risk-taking practices, which usually have positive effect on the economy.

Originality/value – The study adds value to the debate on the role of regulation on the FBFI–risk-taking nexus, taking into account countries that are at different levels of development.

Keywords Fintech, Financial inclusion, Bank risk, Regulation, Sub-Saharan Africa

Paper type Research paper

1. Introduction

Digital financial services have for over two decades grown exponentially, thereby driving financial inclusion for billions of people and opening up spectacular opportunities for small businesses and entrepreneurs across the world. The 2024 Global System for Mobile Communications (GSMA) report reveals that 15 of the 17 Sustainable Development Goals (SGDs) can be reached when digital financial inclusion is effectively executed (The State of the Industrial Report on Mobile Money, 2024). In that regard, the concept of fintech-based financial inclusion (FBFI) (sometimes referred to as digital financial inclusion) has gained

recognition among academics, policymakers and other stakeholders, given its implications for augmenting shared prosperity. A number of development agencies have also taken significant steps to promote fintech-based financial inclusion, given its critical role in the development and state of economic development in emerging economies.

The financial technology revolution is being propelled by fintech, which has the potential to promote equitable finance, economic growth and decreased inequality. It describes creative financial solutions brought about by technology (which develops new goods, services or business models) to solve problems like expensive transaction fees and restricted banking accessibility. The development and growth of fintech have not only resulted in financial inclusion but also increased partnerships and interdependencies between banks and fintech companies (Shim and Shin, 2016). Consequently, this has competition and risk-taking implications (Mocetti *et al.*, 2017). On the one hand, fintech can reduce the cost of retrieving information, boost the speed and quality of acquiring information and enhance the level of risk management in banks. On the other hand, the emergence of new entrants to the bank's business can erode bank profits, which ultimately leads to an increase in the level of banks' risk-taking practices (Rakshit and Bardhan, 2022). Especially during the COVID-19 pandemic era, promoting financial inclusion through digital financial services became more vital as it contributed to the achievement of universal health and well-being (SDG 3) (Ahmad *et al.*, 2021; Allmen *et al.*, 2020). In addition to promoting sustainable economic growth and technological progress, contemporary researchers claim that financial inclusion has an equal impact on banks' risk-taking practices.

FBFI has increased over the last decade in Sub-Saharan Africa (SSA). The GSMA 2024 report revealed that there were approximately 435 million active mobile money accounts by the end of 2023 – an annual increase of 9%, compared to 13 and 15% in 2022 and 2021, respectively. These activities have accelerated due to the COVID-19 pandemic. As the digital economy grew, so did the activities driven by mobile money, which resulted in major advances in various SSA countries, such as Kenya (M-Pesa), South Africa (E-wallet) and Zimbabwe (Ecocash). West Africa has, however, emerged as a key player in the past decade, with mobile money accounts registering twice as many between 2013 and 2023, mostly driven by growth in Ghana, Senegal and Nigeria (The State of the Industrial Report on Mobile Money, 2024). Many users of mobile money are now capable of accessing productive services that were previously inaccessible. Bank balance sheets may be strained as a result of the rise in the value of mobile money transactions, which also tends to lower banks' liquidity and capital adequacy ratios and raise the ratio of nonperforming loans to total loans. This reduces banks' capacity to expand financial intermediation. In addition, extensive use of digital financial services is associated with dangers of digital risks such as payment system disruption and data theft. With an increasing proportion of the younger population embracing financial technology, SSA countries account for 18.2% of the world's population (1.5 billion), making them incredibly prone to risk.

The adoption of fintech by banks offers several opportunities for improved efficiency and cost reduction. Nonetheless, it introduces new challenges like regulatory compliance, cybersecurity threats and systemic risks. The dynamic nature of fintech innovations has raised concerns about their potential impact on banks' risk-taking practices. Furthermore, given the growing competition from fintech firms, there are concerns regarding the risks and benefits of traditional banks implementing technology. Previous research has largely ignored the relationship between risk-taking behaviors and FBFI, treating the two as distinct fields of study. Our study contributes to the debate on FBFI in several ways. First, the study developed an index to measure FBFI, which comprises the usage and access of fintech-based solutions. Second, we examined the role of regulation on the FBFI–risk-taking nexus, reducing the bias of our estimations by including a few controls such as bank-specific and macro-specific variables in contrast to existing literature. Third, we conducted a robustness test by replacing banks' risk-taking measure to validate our findings. Finally, our research

emphasizes how crucial fintech solutions are to helping banks in SSA reduce their risk-taking. The empirical results revealed that FBFI mitigates commercial banks risk-taking in SSA. But as FBFI progresses, the association takes the shape of an inverted U, increasing risks initially and decreasing them later on. Effective supervision and regulatory quality, in particular, is essential in moderating this relationship by offsetting the adverse consequences of FBFI in its early stages. The rest of the paper is organized as follows: following the introduction, Section 2 presents a review of relevant literature, Section 3 presents the data and methodology, Section 4 presents the data and discusses the results and Section 5 provides a conclusion to the study.

2. Literature review
To explore the potential and existing links among the two variables, we proposed examining the relationships between fintech and risk-taking, the effect of COVID-19 pandemic and the nexus between FBFI and risk-taking.

2.1 Fintech and risk-taking: what a linkage
The proliferation of fintech has ushered in a series of consequential changes in the financial ecosystem. One significant consequence is the rise of shadow banking and online lending, culminating in a visible reduction in traditional banks' lending activities and profitability (Li et al., 2022a, b; Thakor, 2020). Intense competition from fintech firms compels traditional banks to reconfigure their lending strategies. Banks, facing the threat of losing market share to agile fintech competitors, pivot toward sectors where they can retain a larger market share. This often leads to a concentration of lending in profitable yet captive sectors, potentially escalating banks' risk profiles (Agyemang-Badu et al., 2018).

According to existing theories, fintech has a dual effect on commercial bank risks. On the one hand, the rapid rise of fintech companies creates competitive pressure on commercial banks for payment services and demand deposits. To meet funding needs, commercial banks may increase interbank borrowing, thereby increasing risk exposure (Zhong and Jiang, 2021). On the other hand, fintech applications also bring positive effects, as commercial banks leverage advanced technologies to reduce operating costs, enhance data processing capabilities and improve operational efficiency, consequently reducing their risk exposure (Asongu and Salahodjaev, 2022; Wang et al., 2021).

Hu et al. (2024) and Li et al. (2022a, b) acknowledge the crucial role of fintech in reducing risk-taking by banks. According to Sajid et al. (2023), financial technologies are essential tools that contribute to reduced banks' risk-taking. In addition, Guo et al. (2024) discovered that fintech adoption reduces banks' risk-taking in high quantiles but increases it in low and middle quantiles of commercial banks in China. Ni et al. (2023) also examine the interplay between financial technology (fintech) and commercial bank risk, using 114 Chinese urban banks for the period 2014 to 2021. The findings reveal a relationship between fintech and banks' risk-taking. Follows an inverted U-shaped pattern, exacerbating risks in the early stages but reducing them as fintech develops. They also find that financial regulation moderates this relationship by counteracting the negative effects during the initial introduction of fintech.

Li et al. (2022a) examined the mechanisms and impact of banks' fintech innovation on risk-taking using panel data from 65 commercial banks over the period 2008 to 2020. According to the empirical findings, a bank's ability to innovate in the fintech space reduces its risk-taking dramatically. This effect is especially noticeable in larger, state-owned, joint-stock and highly competitive commercial banks. Banks rely on fintech innovation to lower their risk-taking by increasing their operating revenue, capital adequacy ratio and

operational performance, all of which improve their ability to regulate risk according to the mechanism analysis.

Zhao *et al.* (2023) utilized the system generalized method of moment modeling to examine the linkages between fintech and commercial banks' risk-taking of 114 commercial banks in China over the period 2013 to 2020. The results revealed functional differences in the impact of fintech on banks' risk-taking. The relationship between fintech adoption and risk-taking may not be linear but nuanced. Ochenge (2023) posit that heightened fintech adoption might initially reduce risk, only to see it rise again as fintech adoption intensifies further. These dynamics underscore the complexity of the fintech–risk nexus. Several studies (see Wang *et al.*, 2021; Banna *et al.*, 2021, 2022), have corroborated this notion of a U-shaped relationship between fintech and banks' risk-taking, indicating that risk exhibits a nonlinear response to heightened fintech entrants.

2.2 The effect of the COVID-19 pandemic on fintech-based financial inclusion

Due to the epidemic, there is now greater rivalry in the fintech sector as traditional financial institutions are starting to compete with fintech firms by offering digital financial services. The COVID-19 pandemic has created more opportunities for collaboration between banks and fintech firms. Financial institutions regularly adapt and use digital goods in order to stay competitive. In line with the competition-fragility theory, rivalry among fintechs and banks will reduce banks interest income, which will reduce their profitability. This will raise the likelihood of a bank default, which will ultimately cause the financial system as a whole to be disrupted. Numerous business models and economic sectors have had to adapt, as has consumer behavior in a variety of areas, including regular payment schedules. These changes are a result of the COVID-19 pandemic. Cashless payments have been made possible by numerous digital technologies. Pandemics, payments and technology are starting to make more sense, especially now that the COVID-19 pandemic has been linked to the digital shift (Huterska *et al.*, 2021). Due to the pandemic, contactless payment has become necessary, and as a result, the use of digital payments has expanded dramatically. Among the tools that have been used is the mobile wallet. Mobile payment methods have given a multifunctional network easy-to-use, convenient services. Gupta and Verma (2022) and Soni and Mangona (2024) demonstrate that fintech heightened financial inclusion in India during the COVID-19 era. A study by Zheng *et al.* (2024) revealed a U-shaped relationship between fintech and COVID-19. In addition, COVID-19 has caused the growth of fintech to accelerate the liberalization of interest rates, thus increasing the level of banks' price competition and risk-taking.

2.3 Fintech-based financial inclusion and risk-taking nexus

By assisting banks in determining the credit requirements of long-tail customers, FBFI successfully reduces the "hyper-normal" financial rationing brought on by financial exclusion. Fintech empowers banks to better predict the credit value of borrowers and reduce credit risk caused by information asymmetry, improve risk management capabilities through verification, post-event supervision, accurate customer profiling, control the level of bad debt rates, reduce bank transaction time and costs and improve bank resource allocation efficiency, which in turn reduces bank risk concentration and banks' risk-taking levels (Li *et al.*, 2022a, b).

A study by Ozili (2021) found that financial inclusion increases financial risk through high cost inefficiency and nonperforming loans, which differ across countries. In developing countries, the findings reveal that digital financial inclusion boosts financial sector efficiency and reduces risk. This result is supported by Chinoda and Kapingura, who find that digital financial inclusion reduces nonperforming loans in SSA. Asif *et al.* (2023) and Amnas *et al.*

(2024) emphasize the role of fintech in promoting financial inclusion in India, while Zhang and Chen (2023) establish a positive correlation between inclusive finance and risk-taking in China. In the same study, they also discovered that fintech can effectively weaken the facilitation impact of inclusive finance on banks' risk-taking.

Banna and Alam (2021) and Banna *et al.* (2022) employed the dynamic panel two-step generalized method of moments (GMM) estimators, panel-corrected standard errors and two-stage least squares instrumental variables to examine the impact of digital financial inclusion on risk-taking levels by commercial banks and microfinance institutions of Islamic and non-Islamic nations. The studies revealed that digital financial inclusion lowers the overall risk-taking level. The studies omitted the role of regulation.

Marcelin *et al.* (2022) establish that greater financial inclusion and information sharing reduce bank risk levels. This was consistent with Umar and Akhtar (2021), who discovered an inverse relationship between financial inclusion and risk-taking by banks in China. However, for large and unlisted banks, financial inclusion increased risk-taking and vice versa in China. The above reviewed literature shows conflicting results on the relationship between FBFI and economic growth.

Based on the discussions above, we present the following research hypotheses.

H1a. The degree of FBFI mitigates overall commercial bank risks.

H1b. There is an inverted U-shaped relationship between FBFI and commercial bank risks.

2.4 Regulation, fintech-based financial inclusion and risk-taking

Despite the claims of classical economics, market failure theory indicates that it is difficult for market forces to fully control the real economy. Fintech businesses and conventional financial institutions alike need financial regulation, according to the market failure theory (Pantielieieva *et al.*, 2020). Risk can arise from knowledge asymmetry and externalities, which might spread the risk to traditional commercial banks. In order to reduce banks' risk-taking, financial regulation is therefore essential. Sound financial regulation can avert fintech businesses' uncontrolled growth and the ensuing bitter rivalry with established financial institutions. Strengthening regulation can help to lessen the detrimental consequences of fintech development by preventing fintechs from invading conventional banks (Pentury, 2023).

Based on the discussions above, we present the following research hypotheses.

H2a. Regulatory quality positively moderates the FBFI–commercial banks' risk-taking nexus

H2b. The inflection point of the inverted U-shaped curve showing the relationship between commercial bank risks and FBFI moves to the left as regulatory quality intensity increases.

2.5 Research gap

The literature has paid little attention to the uneven digital financial inclusion developments in different regions of the world. de Sant'Anna and Figueiredo (2024) conducted a systematic literature review to chart some research directions for future research on the beneficial or detrimental effects of fintech innovation on financial inclusion and financial stability. The study concluded by presenting a conceptual framework in which regulatory frameworks and financial capabilities play moderating roles. The study also proposed an unprecedented empirical study to investigate the role of regulation in the fintech–financial inclusion–financial stability nexus among countries. In this sense, financial stability is related to

risk-taking. This was also supported by Ozili (2021), who recommended future research on how regulators can introduce soft-touch regulations to mitigate risks without restraining innovation in the digital financial inclusion space. This is crucial because introducing strict regulations can mitigate risks but can stifle innovation in the digital financial inclusion space, which could be a setback for digital financial inclusion. Our study seeks to bridge this gap in the literature (see Figure 1).

3. Methods

3.1 Data and data sources

The sample for our study is based on a balanced panel of 10 SSA countries, namely Botswana, Cameroon, Ghana, Guinea, Lesotho, Malawi, Namibia, Rwanda, Zambia and Zimbabwe over the period 2014 to 2021 based on data availability. The data used for the measurement of the variables were obtained from various sources, namely the World Governance Indicators (WGI), World Bank Global Findex (Findex) and International Monetary Fund (IMF) databases for the FBFI data.

3.1.1 Model specification. Following Fang *et al.* (2023), the following baseline equation has been used in the study:

$$RISK_{i,t} = \omega_0 RISK_{i,t-1} + \omega_1 FBFI_{i,t} + \omega_2 Reg_{i,t} + \omega_3 FBFI_{i,t} * Reg_{i,t} + \omega_4 \aleph_{i,t} + \varepsilon_{it} \qquad (1)$$

where $RISK_{i,t}$ denotes risk-taking activities proxied by the Z-score of country i at time t; $RISK_{i,t-1}$ denotes the lagged value of bank risk-taking activities; $FBFI_{i,t}$ denotes fintech-based financial inclusion; $Reg_{i,t}$ denotes regulatory quality; , $\aleph_{i,t}$ signifies the control variables, which include bank size, institutional quality, inflation and GDP growth; $FBFI*Reg_{i,t}$ denotes the interaction between fintech and regulation and subscripts t and i are the indices for time and country, respectively, while ε_{it} is the error term.

3.2 Variables definitions

3.2.1 Fintech-based financial inclusion (FBFI). In order to investigate how FBFI affects banks' risk-taking practices in SSA, this study has examined proxies using data from the World Bank Development Indicators database covering the years 2014–2021. Based on earlier research, we took into account the FBFI usage penetration and outreach indices (e.g. Banna and Alam, 2020; Banna *et al.*, 2020). We took into account the number of automated teller machines (ATMs) and mobile money agent locations per 100,000 adults and per 1,000 km2 as part of the demographic and geographic outreach penetration (also referred to as the "supply side") and the number of Internet and mobile banking transactions per 1,000 adults and the number of mobile money accounts per 1,000 adults as part of the usage of digital financial
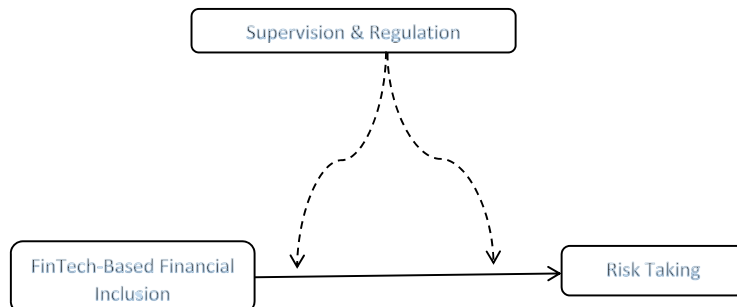

Figure 1.
Conceptual framework

services penetration (also referred to as the "demand side"). We used the principal component analysis method to create an inclusive index that captures the most common variation across the proxies, thereby avoiding multicollinearity and over-parameterization problems that could arise when computing the FBFI index. We then employed the softmax technique to transform the selected FBFI indicators into normalized variables before aggregating them to form a composite index. In contrast to Z-score and Min-Max normalization, the method reduces the impact of extreme values or outliers in the data without eliminating them from the dataset. Softmax normalization calculates the normalized score using the exponential function and mean and standard deviation as follows.

$$\text{Softmax} = \frac{1}{1 + exp^{-V}}$$

where, $V = \frac{X - \overline{X}}{\sigma}$

$\overline{X}$ = group average.

σ = standard deviation

Table 1 and Table 6 shows the variables used for constructing the FBFI index.

3.2.2 Risk. The study employed the bank z-score as the primary banks' risk-taking indicator not only because of its wide adoption in the literature (Sajid *et al.*, 2023; Banna *et al.*,

Variable definition	Obs	Mean	Std. Dev	Minimum	Maximum	Source
Panel A: Bank risk taking						
Z-Score	80	15.70	6.75	5.06	27.95	GFDI
NPLs	80	9.38	6.15	1.45	24.80	GFDI
Panel B: Bank characteristics						
Bank size- Log (Total assets)	80	8.98	0.814	7.43	10.74	GFDI
Panel C: fintech variables						
registered m-money accounts per 1,000 adults	80	486.70	310.75	5.53	1443.55	IMF
Mobile money agents per 100,000 adults	80	466.85	438.66	13.62	2145.51	IMF
Mobile money agents outlets per 1,000 km2	80	464.78	952.68	0.21	4725.38	IMF
Value of mobile and Internet banking transactions (% of GDP)	80	43.67	78.23	0.01	437.98	IMF
Number of mobile and Internet banking transactions per 1,000 adults	80	13421.54	41432.01	12.80	229940.5	IMF
ATMs per 100,000 adults	80	16.48	20.08	1.87	72.95	IMF
Fintech-based financial inclusion (FBFI)	80	0.481	0.184	0.255	0.984	Authors
Panel D: Macro-specific factors						
Inflation, consumer prices (annual %) (INF)	80	17.63	67.46	−2.43	557.20	GFDI
GDP growth (annual %) (GDPG)	80	3.05	4.17	−8.73	11.87	GFDI
Regulatory quality (reg)	80	−0.474	0.599	−1.893	0.765	WGI

Note(s): Where: GFDI denotes Global Financial Development Indicators and WDI denotes World Development Indicators
Source(s): Authors' own creation

Table 1.
Descriptive statistics

2021, 2022) but also because of its ability to reflect the overall bank risks. Higher (lower) bank Z-score denotes lower (higher) risk-taking level. For robustness testing, the study also employed nonperforming loans as a percentage of gross loans following Li *et al.* (2022a, b) and Zhang *et al.* (2023). Zhang *et al.* (2023) contend that credit risk (NPL) is the primary source of banking risk; banks inability to control the rise in NPL may lead to banking failures.

3.3 Macroeconomic and bank variables

The study controlled for various bank- and country-specific factors. To capture the size hypothesis, we used the logarithm of total assets to denote bank size (SIZE) following Ochenge (2023). A bank's risk references may be positively or negatively impacted by its size. For example, the "too-big-to-fail" concept suggests that giant banks can take on excessive risk, knowing full well that they would receive help when things go wrong because doing so puts the economy at risk (the moral hazard view). Large businesses, on the other hand, can lower their risk profiles by diversifying their assets. The study also employed inflation (INF) and economic development (annual gross domestic product (GDP) growth-GDPG) to address country-specific variation. Economic development, proxied by high level of GDP growth rate, affects the operations of commercial banks and other businesses. Generally, GDP growth rate is expected to negatively affect the commercial banks risk-taking. Inflation refers to the percentage change in the yearly average consumer price index. Inflation can affect banks' risk-taking in three possible ways. First, inflation can adversely affect banks through increased bank costs. Second, inflation can result in the overissuance of the central bank's currency, which is beneficial to the debtors (the bank). Third, countries employ tight monetary policy to curb inflation when the economy is prosperous, thus adversely affecting the banking system.

Regulatory quality significantly influences the behavior of the banking industry. Although numerous studies have determined the impact of institutional quality on the financial and economic development of a country, studies examining how regulatory quality and effective supervision affect risk-taking behavior of the banking industry are scarce. We employed regulatory quality variable following Chinoda and Kapingura (2023). Data were compiled from the World Bank's WGI, which consist of six indicators. We expect regulatory quality to reduce risk-taking by banks.

3.4 Estimation technique

Since the left tail of the data distribution abruptly shortens when fintechs lack external capital, we employ a Tobit regression analysis following Fang *et al.* (2023). Tobit models work better to handle this distributional aspect; in fact, Tobit models are used in several start-up finance studies (Nofsinger and Wang, 2011).

To test hypotheses H1a and H1b, we constructed the model as follows:

$$\ln Zscore_{i,t} = \omega_0 + \omega_1 FBFI_{i,t} + \omega_2 \aleph_{i,t} + \varepsilon_{it} \tag{1}$$

$$\ln Zscore_{i,t} = \varphi_0 + \varphi_1 FBFI_{i,t} + \varphi_2 FBFI2_{i,t} + \varphi_3 \aleph_{i,t} + \varepsilon_{it} \tag{2}$$

Where $\ln Zscore_{i,t}$ is the risk-taking proxy; FBFI denotes FBFI; $\aleph_{i,t}$ denotes the control variables, such as inflation, economic development and bank size (total assets) and ε_{it} is the disturbance term.

To test hypothesis H2a and H2b, we constructed the moderating effect model as follows:

$$\ln Zscore_{i,t} = \tau_0 + \tau_1 FBFI_{i,t} + \tau_2 FBFI2_{i,t} + \tau_3 FBFI_{i,t} * Reg + \tau_4 FBFI2_{i,t} * Reg + \tau_5 \aleph_{i,t} + \varepsilon_{it}$$

$$\tag{3}$$

In Eq. (3), Reg is the regulatory quality of country i in year t; $FBFI_{i,t} * Reg$ is the interaction of FBFI and regulatory quality, whilst $FBFI2_{i,t} * Reg$ is the interaction between $FBFI^2$ and regulatory quality. If τ_4 in the regression result of Eq. (3) passes the significance test and is negative, the higher the Reg, the flatter the inverted U-shaped curve of the relationship between FBFI and lnZscore and, vice versa, the steeper it is. If $\tau 1$, $\tau 2$, $\tau 4$ and $\tau 5$ all pass the significance test and $\tau 1 \tau 5 - \tau 2 \tau 4$ is negative, the higher the Reg, the more the inflection point of the curve shifts to the right and, vice versa, the more it shifts to the left.

4. Results
4.1 Descriptive statistics
Table 1 shows the descriptive statistics. The sampled banks' average bank z-score is 15.7, with a 6.75 standard deviation. This suggests that the banks in SSA are generally time-varying, less risk-taking and reasonably stable. For the sample years of 2014–2021, the GDP growth rate for the SSA countries was 3.1%, while the inflation rate was 17.6%. With a mean rating of −0.47, regulatory quality is generally low. Wide variances are indicated by the regulatory quality minimum and maximum values of −1.893 and 0.765, respectively. Bank size stood at 8.98 on average, with maximum and minimum values of 10.74 and 7.43 respectively, signifying a diverse array of bank sizes in SSA. In terms of FBFI, the mean mobile money agent outlets per 100,000 adults and 1,000 km^2 stood at 467 and 465, respectively. In addition, the number of mobile money accounts is 487 per 1,000 adults. The value and the number of mobile money and Internet banking transactions per 1,000 adults are approximately 44 and 13,422, respectively. These indicate that the extant mobile money and bank account holders are comfortable using mobile banking facilities. The notably high standard deviations, particularly for the mobile money agent outlets, mobile and Internet banking transactions and the number of mobile money transactions, signify significant disparities in the usage patterns and integration of fintech within the banking system in SSA. The overall fintech index stood at 0.48, which is fairly moderate. The results on correlation analysis in Table 2 show that all the independent variables do not violate the multicollinearity issue since the correlation values are less than 0.70.

4.2 Analysis of the result on baseline regression
The benchmark regression results are presented in Table 3. In this instance, control variables and fixed effects are taken into account in columns (2) and (4) but not in columns (1) and (3). The findings demonstrate that FBFI generally lowers the risks taken by commercial banks, with a coefficient of 0.018, which passes the 1% significance test. The coefficient is significant and positive, indicating a strong downfall in risk-taking as a result of FBFI by banks. Our results demonstrate strong support for the lion share of the existing studies exhibiting an

	gdpgr	Reg	infl	lnzscore	npls	lnTA	FBFI
gdpgr	1.00						
reg	0.115	1.00					
infl	−0.37*	−0.26*	1.00				
lnzscore	0.16	0.23*	−0.20	1.00			
npls	−0.04	−0.61*	0.36*	−0.55*	1.00		
lnTA	−0.40*	−0.22*	0.30*	−0.46*	0.54*	1.00	
FBFI	−0.26*	0.31*	0.33*	−0.08	0.29*	0.35*	1.00

Note(s): * denotes significance at 5% level
Source(s): Authors' own creation

Variable	(1) lnZscore		(2) lnZscore		(3) lnZscore		(4) lnZscore	
	Coeff	Std. Error	Coeff	Std. Error	Coeff	Std. Error	Coeff	Std. Error
L.lnZscore								
FBFI	0.021*	5.308	0.018*	4.206	−0.124*	−3.635	−0.0042	−1.361
$FBFI^2$					0.018*	6.142	0.006**	2.311
Control variables	NO		YES		NO		YES	
Fixed effects	YES		YES		YES		YES	
Constant	1.021*	46.154	1.648*	6.871	0.731*	6.863	3.430*	3.286
N	80		80		80		80	

Note(s): *$p < 0.01$; **$p < 0.05$; ***$p < 0.1$; parentheses
Source(s): Authors' own creation

Table 3.
Benchmark regression results table

inverse relationship with bank risk-taking (Ahamed and Mallick, 2019; Banna *et al.*, 2021; Li *et al.*, 2022a, b), which in turn translates into a positive connection with financial stability. The results are also consistent with Cheng and Qu (2020), Daud *et al.* (2021), Hu *et al.* (2024) and Pantielieieva *et al.* (2018), whose findings indicated that fintech development generally increases financial stability and thus can reduce bank risk. This outcome could be a result of various explanations. First, due to fintech development in recent years, banks would be lending more to businesses and individuals, leading to economies of scale and diversification benefits. This was also documented in the studies of Danisman and Tarazi (2020) and Banna *et al.* (2021). Second, to a greater extent, FBFI increases deposits, which reduces the pro-cyclicality risk of the banking sector (Ozili, 2018). Thus, with an inclusive fintech-based financial sector in SSA, banks are likely to enjoy lower (greater) risk-taking (financial stability) in the region through increased financial mobility.

At the 1% significance level, all of the $FBFI^2$ coefficients are statistically positive, suggesting that both Hypothesis 1a and Hypothesis 1b are true. The influence of FBFI on commercial bank risks shows an inverted U-shape pattern of increasing and then declining. One explanation could be that, given the early stage of FBFI's low level of development, the competition created by fintech companies to increase financial inclusion drives up bank funding costs, and since commercial banks are still experimenting with fintech, FBFI's positive effects on them outweigh its negative ones. While fintech adoption significantly boosts bank operating efficiency and reduces information asymmetry, the current impact of FBFI development is greater than its beneficial effects. This is because banks are becoming more developed.

4.3 The moderating effect of regulation on the FBFI–risk-taking nexus

The regression outcomes of the moderated effects model are shown in Table 4. Regulatory quality can effectively reduce the risks associated with commercial banks, as seen by Column (4), where the coefficient of Reg is 0.013, which is statistically significant at 10%. Furthermore, FBFI* Reg is significantly positive at the 1% level, which demonstrates that Reg can positively regulate the linkage between FBFI and lnZscore, thus confirming hypothesis H2a. The association between Reg and lnZscore has a flatter inverted U-shaped curve, as seen by the coefficient of $FBFI^2$* Reg of −0.004, which passes the 1% significance test. The study also shows that a unit increase in regulatory quality significantly increases bank stability, thus reducing banks risk-taking in SSA countries. This outcome is in line with Banna *et al.* (2021), who found a significant effect in Organization of Islamic Cooperation (OIC) countries. This implies that banks maintain a lower risk level in countries with better

	(1) lnZscore		(2) lnZscore		(3) lnZscore		(4) lnZscore	
Variable	Coeff	Std. Error	Coeff	Std. Error	Coeff	Std. Error	Coeff	Std. Error
FBFI	−0.123*	−3.628	−0.042	1.346	0.012	0.458	0.011	0.457
$FBFI^2$	0.017*	6.003	0.006**	2.186	0.019*	6.051	0.006**	2.421
Reg	0.018***	1.784	0.014***	1.928	0.012***	1.712	0.013***	1.936
FBFI*Reg					0.034**	2.468	0.033*	2.670
$FBFI^2$*Reg					−0.005*	−3.055	−0.004*	−2.957
Control variables	NO		YES		NO		YES	
Fixed effects	YES		YES		YES		YES	
Constant	0.662*	5.841	3.358*	3.229	0.920*	23.723	3.558*	3.436
N	80		80		80		80	

Note(s): $*p < 0.01$; $**p < 0.05$; $***p < 0.1$; parentheses
Source(s): Authors' own creation

Table 4.
Regression results of
the moderating effect

regulatory quality. Banks are very much affected by the country's government system and the rule of law. In addition, in countries with rampant corruption, bankers have higher chances of being influenced by unethical means and accept loans that have a high likelihood of default. Regulatory quality ensures checks and balances in the banking system, thus reducing risk-taking.

We next compute the equation's inflection point, and it is clear that the moderated effects model's inflection point is substantially moved to the left when compared to the baseline model, supporting hypothesis H2b. One plausible argument is that financial regulation can substantially reduce the detrimental impacts of financial branch failure (FBFI), which can significantly lessen the exacerbating effects of FBFI on the risks faced by commercial banks.

4.4 Robustness tests-endogenous treatment

Previous studies have discovered that bank risks are enduring, mostly because of relationship lending and industry competition, which could cause endogeneity issues within the model. As a result, the regression model contains lagged first- and second-order terms of the explanatory variables. Through the selection of instrumental variables, the system generalized method of moments (SYS-GMM) estimation approach not only addresses the endogeneity issue but also takes serial correlation and heteroskedasticity issues into account. In this work, we incorporate first-order explanatory variables into the regress model (2) using the SYS-GMM estimation approach. The results of the baseline regression are essentially consistent with Column (1) of Table 4, which indicates that the coefficient of lnFT2 is significantly negative at the 10% significance level. Both the Hansen test statistic and the p-value of the AR(2) test are greater than 0.1, passing both the instrumental variable overidentification test and the autocorrelation test. This suggests that the model's empirical findings are credible.

To validate our findings, we also conducted a robustness test using NPLs, a different proxy for risk-taking activities by banks. Column (2) of Table 4 shows that the coefficient on $FBFI^2$ is significantly negative at the 1% significance level, which is further evidence of the reliability of the results of the baseline model. To replace the estimation method, since the explanatory variable lnZscore is a restricted variable belonging to the range between 0 and 1, we used the Tobit model to regress the baseline equation again, and Column (3) in Table 4 shows that the coefficient of $FBFI^2$ is significantly positive.

As revealed, in Table 5, there is an inverse relationship between FBFI and nonperforming loans. This denotes that FBFI reduces banks' risk-taking in SSA, which is consistent with our main result when the bank Z-score was employed. The coefficients of the FBFI index on banks' risk-taking suggest that an increase in the FBFI index is associated with a decrease in problem loans, which translates into a reduction in risk-taking. The coefficient is significant and negative, indicating a strong downfall of NPLs (risk-taking) as a result of FBFI by banks, just like in the main results (Tables 3 and 4). In addition, regulatory quality reduces risk-taking. According to the study results, FBFI has implications for both the economy and policy. These implications include limiting banks' risk appetite, preventing crises from spreading to other financial services sectors and broadening the breadth of financial mobility in the area. FBFI also helps the banks reduce the pro-cyclicality risk by targeting a good mix of qualified and well deserved but financially disadvantageous groups (Ozili, 2018). Therefore, in future, banks are expected to enjoy lower (greater) risk-taking (financial stability), with an inclusive fintech-based financial sector. This result also complements the findings of Deng et al. (2021), who found that fintech activities reduce bank risk in China by fostering competitiveness and stability in financial markets. Fintech companies in SSA can help traditional banks improve their efficiency, profitability and asset quality by providing them with advanced technologies and customer insights (see Table 6).

5. Conclusion

This study examined the relationship between FBFI and bank risk-taking and the role of regulation for a sample of 10 SSA countries over the 2014–2021 period. This study sheds light on the impact of FBFI on commercial bank risks, yielding several key findings. Firstly, FBFI has a mitigating effect on commercial bank risks. Secondly, considering the temporal dynamics, there exists an inverted U-shaped relationship between FBFI and commercial bank risks. In the early stages, FBFI exacerbates commercial bank risk, whereas as FBFI progresses, it contributes to the reduction of commercial bank risks. Lastly, financial regulation plays a crucial moderating role in the relationship between FBFI and bank risks. Specifically, financial regulation positively moderates the effects of FBFI on commercial bank risks, effectively offsetting the negative impact during the initial stages of FBFI.

Variable	(1) lnZscore Coeff	Std. Error	(2) NPLs Coeff	Std. Error	(3) NPLs Coeff	Std. Error
L. lnZscore	0.716*	12.082			0.012	0.458
L.NPLs	–	–	0.584*	9.852		
FBFI	−0.367**	−2.077	0.046***	1.728	0.055	0.745
FBFI^2	0.069*	4.992	−0.006**	−1.746	−0.015***	−1.778
Control variables	YES		YES		YES	
Fixed effects	YES		YES		NO	
Constant	−15.255*	−2.541			4.467*	3.429
N	80		80		80	
Arellano–Bond test for AR(1) in first differences: z = −3.49 Prob > z = 0.000						
Arellano–Bond test for AR(2) in first differences: z = 0.18 Prob > z = 0.841						
Hansen test of overid. restrictions: $\chi^2(70)$ = 74.92 Prob > χ^2 = 0.275						
Source(s): Authors' own creation						

Table 5.
Results of robustness test

Variable definition	Measurement	Source	Reference literature
Panel A: Bank risk taking			
Z-Score	The Z-score measures the distance to default of the banking sector. The higher the ZSCORE, the better	Global Financial Development Indicators	Sajid *et al.* (2023), Banna *et al.* (2021) and Wang and Luo (2022)
NPLs	Bank NPLs to total gross loans (%)	Global Financial Development Indicators	Zhang *et al.* (2023) and Li *et al.* (2022a, b)
Panel B: Bank characteristics			
Bank size	Bank size = Log (Total assets)	Global Financial Development Indicators	Ochenge (2023) and Zhang *et al.* (2023)
Panel C: fintech variables			
Mobile Money Accounts	Registered m-money accounts per 1,000 adults	Global Financial Development Indicators	Banna *et al.* (2021)
Mobile Money Agents	Mobile money agents per 100,000 adults	Global Financial Development Indicators	Ahamed and Mallick (2019) and Banna *et al.* (2021)
Mobile money agents outlets	Mobile money agents outlets per 1 000 km2	Global Financial Development Indicators	Ahamed and Mallick (2019) and Banna *et al.* (2021)
Value of Mobile and Internet banking transactions	Value of mobile and Internet banking transactions (% of GDP)	Global Financial Development Indicators	Ahamed and Mallick (2019) and Banna *et al.* (2021)
Mobile and Internet banking transactions	Number of mobile and Internet banking transactions per 1,000 adults	Global Financial Development Indicators	Ahamed and Mallick (2019) and Banna *et al.* (2021)
Fintech-based financial inclusion (FBFI) – Overall	Fintech-based financial inclusion – Overall	Authors	
Fintech-based financial inclusion (FinUse)	Fintech-based financial inclusion (FinUse)	Authors	
Panel D: Macro-specific factors			
Inflation, consumer prices (annual %) (INF)	Consumer prices (annual %)	Global Financial Development Indicators	Chinoda and Kapingura (2023)
GDP growth	(annual %) (GDPG)	Global Financial Development Indicators	Chinoda and Kapingura (2023)
Institutional quality (IQ)	Control of corruption	World Governance Indicators	Chinoda and Kapingura (2023)

Source(s): Authors' own creation

5.1 Limitations and future work
While the results of this study demonstrate the intricacy and dynamics of the relationship between FBFI and bank risk, future research will be required to expand our knowledge of the bank risks associated with FBFI and commercial bank rivalry. This will require more nuanced and diverse data. Future studies are required to investigate the precise methods via

which FBFI influences the risks faced by commercial banks. This could entail looking into the underlying causes of the inverted U-shaped relationship that has been discovered as well as figuring out how FBFI influences various risk dimensions in commercial banks, such as credit risk, liquidity risk and operational risk. Although our sample is restricted to banks in 10 SSA nations, larger sample sizes may be possible in the future, allowing for more precise generalization of the findings. We also recommend that in the future, incorporating qualitative data through interviews or case studies with bank executives and fintech operators in the SSA region could provide deeper insights into the practical challenges and opportunities of implementing fintech solutions. This would add a practical perspective to the empirical findings.

References

Agyemang-Badu, A.A., Agyei, K. and Kwaku Duah, E. (2018), "Financial inclusion, poverty and income inequality: evidence from Africa", *Spiritan International Journal of Poverty Studies*, Vol. 2 No. 2, pp. 138-162.

Ahamed, M.M. and Mallick, S.K. (2019), "Is financial inclusion good for bank stability? International Evidence", *Journal of Economic Behavior and Organization*, Vol. 157, pp. 403-427.

Ahmad, N.W., Bahari, N. and Ripain, N. (2021), "Covid-19 outbreak: the influence on digital finance and financial inclusion", *International Conference On Syariah and Law*, pp. 160-166.

Allmen, U.E.V., Khera, P., Ogawa, S. and Sahay, R. (2020), *Digital Financial Inclusion in the Times of COVID-19*, IMF Blog, Washington, DC.

Amnas, M.B., Selvam, M. and Parayitam, S. (2024), "FinTech and financial inclusion: exploring the mediating role of digital financial literacy and the moderating influence of perceived regulatory support", *Journal of Risk and Financial Management*, Vol. 17 No. 3, p. 108, doi: 10.3390/jrfm17030108.

Asif, M., Khan, M.N., Tiwari, S., Wani, S.K. and Alam, F. (2023), "The impact of fintech and digital financial services on financial inclusion in India", *Journal of Risk and Financial Management*, Vol. 16 No. 2, p. 122, doi: 10.3390/jrfm16020122.

Asongu, S.A. and Salahodjaev, R. (2022), "Demand-side mobile money drivers of financial inclusion: minimum economic growth thresholds for mobile money innovations", *Journal of the Knowledge Economy*, Vol. 14 No. 4, pp. 1-18, doi: 10.1007/s13132-022-01042-6.

Banna, H. and Alam, M.R. (2020), "Islamic banking efficiency and inclusive sustainable growth: the role of financial inclusion", *Journal of Islamic Monetary Economics and Finance*, Vol. 6 No. 1, pp. 213-242, doi: 10.21098/jimf.v6i1.1089.

Banna, H., Hassan, M.K. and Alam, M.R. (2020), "Digital financial inclusion, Islamic banking stability and sustainable economic growth", *Islamic Perspective for Sustainable Financial System*, pp. 131-152.

Banna, H. and Alam, M.R. (2021), "Does digital financial inclusion matter for bank risk-taking? Evidence from the dual-banking system", *Journal of Islamic Monetary Economics and Finance*, Vol. 7 No. 2, pp. 401-430, doi: 10.21098/jimf.v7i2.1320.

Banna, H., Hassan, M.K. and Rashid, M. (2021), "Fintech-based financial inclusion and bank risk-taking: evidence from OIC countries", *Journal of International Financial Markets, Institutions and Money*, Vol. 75, 101447, doi: 10.1016/j.intfin.2021.101447.

Banna, H., Mia, M.A., Nourani, M. and Yarovaya, L. (2022), "Fintech-based financial inclusion and risk-taking of microfinance institutions (MFIs): evidence from Sub Saharan Africa", *Finance Research Letters*, Vol. 45, 102149, doi: 10.1016/j.frl.2021.102149.

Cheng, M. and Qu, Y. (2020), "Does bank Fintech reduce credit risk? Evidence from China", *Pacific-Basin Finance Journal*, Vol. 63, 101398, doi: 10.1016/j.pacfin.2020.101398.

Chinoda, T. and Kapingura, F.M. (2023), "The impact of digital financial inclusion and bank competition on bank stability in Sub-Saharan Africa", *Economies*, Vol. 11 No. 1, p. 15.

Danisman, G.O. and Tarazi, A. (2020), "Financial inclusion and bank stability: evidence from Europe", *The European Journal of Finance*, Vol. 26 No. 18, pp. 1842-1855.

Daud, S.N.M., Khalid, A. and Azman-Saini, W. (2021), "Fintech and financial stability: threat or opportunity?", *Finance Research Letters*, Vol. 47, 102667, doi: 10.1016/j.frl.2021.102667.

de Sant'Anna, D.M. and Figueiredo, P.N. (2024), "Fintech innovation: is it beneficial or detrimental to financial inclusion and financial stability? A systematic literature review and research directions", *Emerging Markets Review*, 101140.

Deng, L., Lv, Y., Liu, Y. and Zhao, Y. (2021), "Impact of fintech on bank risk-taking: evidence from China", *Risks*, Vol. 9 No. 5, p. 99, doi: 10.3390/risks9050099.

Fang, L., Li, X., Subrahmanyam, A. and Zhang, K. (2023), "Does FinTech innovation improve traditional banks' efficiency and risk measures? A new methodology and new machine-learning-based evidence from patent filings", *SSRN Electronic Journal*. doi: 10.2139/ssrn.4350734.

Guo, P., Cheng, M. and Shen, Y. (2024), "FinTech adoption and bank risk-taking: evidence from China", *Applied Economics Letters*, Vol. 31 No. 7, pp. 594-602, doi: 10.1080/13504851.2022.2140755.

Gupta, M. and Verma, S. (2022), "Impact of covid-19 pandemic on fintech and financial inclusion in India", *Indian Journal of Finance and Banking*, Vol. 11 No. 1, pp. 1-14.

Huterska, A., Piotrowska, A.I. and Szalacha-Jarmużek, J. (2021), "Fear of the COVID-19 pandemic and social distancing as factors determining the change in consumer payment behavior at retail and service outlets", *Energies*, Vol. 14 No. 14, 4191.

Hu, D., Zhao, S. and Yang, F. (2024), "Will fintech development increase commercial banks risk-taking? Evidence from China", *Electronic Commerce Research*, Vol. 24 No. 1, pp. 37-67, doi: 10.1007/s10660-022-09538-8.

Li, C., He, S., Tian, Y., Sun, S. and Ning, L. (2022a), "Does the bank's FinTech innovation reduce its risk-taking? Evidence from China's banking industry", *Journal of Innovation and Knowledge*, Vol. 7 No. 3, 100219, doi: 10.1016/j.jik.2022.100219.

Li, G., Elahi, E. and Zhao, L. (2022b), "FinTech, bank risk-taking, and risk-warning for commercial banks in the era of digital technology", *Frontiers in Psychology*, Vol. 13, 934053, doi: 10.3389/fpsyg.2022.934053.

Marcelin, I., Sun, W., Teclezion, M. and Junarsin, E. (2022), "Financial inclusion and bank risk-taking: the effect of information sharing", *Finance Research Letters*, Vol. 50, 103182, doi: 10.1016/j.frl.2022.103182.

Mocetti, S., Pagnini, M. and Sette, E. (2017), "Information technology and banking organization", *Journal of Financial Services Research*, Vol. 51 No. 3, pp. 313-338, doi: 10.1007/s10693-016-0244-3.

Ni, Q., Zhang, L. and Wu, C. (2023), "Fintech and commercial bank risks–the moderating effect of financial regulation", *Finance Research Letters*, Vol. 58, 104536.

Nofsinger, J.R. and Wang, W. (2011), "Determinants of start-up firm external financing worldwide", *Journal of Banking and Finance*, Vol. 35 No. 9, pp. 2282-2294, doi: 10.1016/j.jbankfin.2011.01.024.

Ochenge, R.O. (2023), "The effect of FinTech development on bank risk-taking: evidence from Kenya", KBA Centre for Research on Financial Markets and Policy Working Paper Series No. 72, Kenya Bankers Association (KBA), Nairobi.

Ozili, P.K. (2018), "Impact of digital finance on financial inclusion and stability", *Borsa Istanbul Review*, Vol. 18 No. 4, pp. 329-340, doi: 10.1016/j.bir.2017.12.003.

Ozili, P.K. (2021), "Financial inclusion research around the world: a review", *Forum for Social Economics*, Vol. 50 No. 4, pp. 457-479, doi: 10.1080/07360932.2020.1715238.

Pantielieieva, N., Khutorna, M., Lytvynenko, O. and Potapenko, L. (2020), "FinTech, RegTech and traditional financial intermediation: trends and threats for financial stability", *Data-Centric Business and Applications: Evolvements in Business Information Processing and Management (Volume 3)*, Springer International Publishing, Cham, pp. 1-21.

Pantielieieva, N., Krynytsia, S., Khutorna, M. and Potapenko, L. (2018), "FinTech, transformation of financial intermediation and financial stability", *2018 International Scientific-Practical Conference Problems of Infocommunications. Science and Technology (PIC S&T)*, IEEE, pp. 553-559.

Pentury, F. (2023), "The role of knowledge and penetration of Fintech services in improving MSMEs of fishermen and marine farmers in remote small islands region", *Jurnal Manajemen Teori Dan Terapan*, Vol. 16 No. 1.

Rakshit, B. and Bardhan, S. (2022), "An empirical investigation of the effects of competition, efficiency and risk-taking on profitability: an application in Indian banking", *Journal of Economics and Business*, Vol. 118, 106022.

Sajid, R., Ayub, H., Malik, B.F. and Ellahi, A. (2023), "The role of fintech on bank risk-taking: mediating role of Bank's operating efficiency", *Human Behavior and Emerging Technologies*, Vol. 2023, pp. 1-11, doi: 10.1155/2023/7059307.

Shim, Y. and Shin, D.H. (2016), "Analyzing China's fintech industry from the perspective of actor–network theory", *Telecommunications Policy*, Vol. 40 Nos 2-3, pp. 168-181, doi: 10.1016/j.telpol.2015.11.005.

Soni, S. and Mangona, R.L. (2024), "Financial inclusion in India amid covid-19 pandemic: recent trends and determinants", *Journal of the Knowledge Economy*, Vol. 12, pp. 1-19, doi: 10.1007/s13132-024-01992-z.

Thakor, A.V. (2020), "Fintech and banking: what do we know?", *Journal of Financial Intermediation*, Vol. 41, 100833, doi: 10.1016/j.jfi.2019.100833.

The State of the Industrial Report on Mobile Money (2024), *GSMA Association*, available at: https://www.gsma.com/mobile%20money (accessed 19 May 2024).

Umar, M. and Akhtar, M. (2021), "Financial inclusion and bank risk-taking nexus: evidence from China", *China Finance Review International*, Vol. 14 No. 2, pp. 352-362, doi: 10.1108/cfri-08-2021-0174.

Wang, R., Liu, J. and Luo, H. (2021), "Fintech development and bank risk taking in China", *The European Journal of Finance*, Vol. 27 Nos 4-5, pp. 397-418, doi: 10.1080/1351847x.2020.1805782.

Wang, R. and Luo, H.R. (2022), "How does financial inclusion affect bank stability in emerging economies?", *Emerging Markets Review*, Vol. 51, 100876.

Zhang, Y. and Chen, M. (2023), "Fintech, inclusive finance, and Bank's risk-taking", *Proceedings of the 3rd International Conference on Internet Finance and Digital Economy (ICIFDE 2023)*, Vol. 1, Springer Nature, pp. 302-307, doi: 10.2991/978-94-6463-270-5_33.

Zhang, Y., Ye, S., Liu, J. and Du, L. (2023), "Impact of the development of FinTech by commercial banks on bank credit risk", *Finance Research Letters*, Vol. 55, 103857, doi: 10.1016/j.frl.2023.103857.

Zhao, Y., Goodell, J.W., Wang, Y. and Abedin, M.Z. (2023), "Fintech, macroprudential policies and bank risk: evidence from China", *International Review of Financial Analysis*, Vol. 87, 102648, doi: 10.1016/j.irfa.2023.102648.

Zheng, Y., Dong, H. and Li, N. (2024), "Analysis of the impact of the COVID-19 lockdown on financial technology (FinTech), interest rate liberalization (IRL) and commercial banks' risk-taking: Chinese empirical evidence", *Applied Economics*, Vol. 32, pp. 1-17, doi: 10.1080/00036846.2024.2302934.

Zhong, W. and Jiang, T. (2021), "Can internet finance alleviate the exclusiveness of traditional finance? Evidence from Chinese P2P lending markets", *Finance Research Letters*, Vol. 40, 101731, doi: 10.1016/j.frl.2020.101731.

Further reading

Adedokun, M.W. and Ağa, M. (2023), "Financial inclusion: a pathway to economic growth in Sub-Saharan African economies", *International Journal of Finance and Economics*, Vol. 28 No. 3, pp. 2712-2728, doi: 10.1002/ijfe.2559.

Alexander, A.J., Shi, L. and Solomon, B. (2017), *How Fintech is Reaching the Poor in Africa and Asia*, World Bank Other Operational as Studies, Washington, DC, doi: 10.1596/30360.

Arellano, M. and Bond, S. (1991), "Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations", *The Review of Economic Studies*, Vol. 58 No. 2, pp. 277-297, doi: 10.2307/2297968.

Arellano, M. and Bover, O. (1995), "Another look at the instrumental variable estimation of error-components models", *Journal of Econometrics*, Vol. 68 No. 1, pp. 29-51, doi: 10.1016/0304-4076(94)01642-d.

Arner, D.W., Buckley, R.P., Zetzsche, D.A. and Veidt, R. (2020), "Sustainability, FinTech and financial inclusion", *European Business Organization Law Review*, Vol. 21 No. 1, pp. 7-35, doi: 10.1007/s40804-020-00183-y.

Ashraf, B.N. (2017), "Political institutions and bank risk-taking behaviour", *Journal of Financial Stability*, Vol. 29, pp. 13-35, doi: 10.1016/j.jfs.2017.01.004.

Ayadi, R. and de Groen, W.P. (2016), "Banks' business models in Europe", in *The Palgrave Handbook of European Banking*, pp. 81-102, doi: 10.1057/978-1-137-52144-6_4.

Banna, H. (2020), "The role of digital financial inclusion on promoting sustainable economic growth through banking stability: evidence from Bangladesh", *Development Review*, Vol. 29, pp. 19-36.

Barik, R. and Sharma, P. (2019), "Analyzing the progress and prospects of financial inclusion in India", *Journal of Public Affairs*, Vol. 19 No. 4, e1948, doi: 10.1002/pa.1948.

Beck, T. (2020), "Fintech and financial inclusion: opportunities and pitfalls", (No. 1165), ADBI Working Paper Series.

Bhandari, A.K. and Kundu, A. (2014), "Risk-taking behaviour in financial decision making: a village-level study", in Bhandari, A.K. and Kundu, A. (Eds), *Microfinance, Risk-Taking Behaviour and Rural Livelihood*, Springer, New Delhi, pp. 15-33.

Chitimira, H. (2023), *Warikandwa Financial Inclusion and Digital Transformation Regulatory Practices in Selected SADC Countries: South Africa, Namibia, Botswana and Zimbabwe*, Springer International Publishing, Cham, pp. 1-22.

Disrupt Africa (2021), "Finnovating for Africa 2021: reimagining the African financial services landscape", available at: https://disruptafrica.gumroad.com/l/razjs (accessed 2 September 2022).

Eyraud, L., Bunda, I., Jack, J., Jardak, M.T., Ouedraogo, R., Wang, Z. and Wezel, T. (2021), *Resolving Nonperforming Loans in Sub-Saharan Africa in the Aftermath of the COVID-19 Crisis*, International Monetary Fund, Washington, DC.

Financial Stability Board (2017), "Financial stability implications from fintech supervisory and regulatory issues that merit authorities' attention", available at: https://www.fsb.org/wp-content/uploads/R270617.pdf

He, M., Song, G. and Chen, Q. (2023), "Fintech adoption, internal control quality and bank risk taking: evidence from Chinese listed banks", *Finance Research Letters*, Vol. 57, 104235, doi: 10.1016/j.frl.2023.104235.

Hoang, T.G., Nguyen, G.N.T. and Le, D.A. (2022), "Developments in Financial Technologies for Achieving the sustainable development goals (SDGs): fintech and SDGs", in Akkucuk, U. (Ed.), *Disruptive Technologies and Eco-Innovation for Sustainable Development*, IGI Global, Hershey, PA, pp. 1-19.

Hussain, S., Gul, R., Ullah, S., Waheed, A. and Naeem, M. (2023), "Empirical nexus between financial inclusion and carbon emissions: evidence from heterogeneous financial economies and regions", *Heliyon*, Vol. 9 No. 3, e13164, doi: 10.1016/j.heliyon.2023.e13164.

Lee, C.C., Li, X., Yu, C.H. and Zhao, J. (2021), "Does fintech innovation improve bank efficiency? Evidence from China's banking industry", *International Review of Economics and Finance*, Vol. 74, pp. 468-483, doi: 10.1016/j.iref.2021.03.009.

Levine, M.R. (2021), *Finance, Growth, and Inequality*, International Monetary Fund, Washington, DC.

Ndung'u, N. and Oguso, A. (2023), "Digital technology and innovation in Africa: leapfrogging in finance", in *Technological Leapfrogging and Innovation in Africa: Digital Transformation and Opportunity for the Next Growth Continent*, Vol. 89, pp. 89-111, doi: 10.4337/9781800370395.00013.

Neaime, S. and Gaysset, I. (2018), "Financial inclusion and stability in MENA: evidence from poverty and inequality", *Finance Research Letters*, Vol. 24, pp. 230-237, doi: 10.1016/j.frl.2017.09.007.

Nkoa, B.E.O. and Song, J.S. (2020), "Does institutional quality affect financial inclusion in Africa? A panel data analysis", *Economic Systems*, Vol. 44 No. 4, 100836, doi: 10.1016/j.ecosys.2020.100836.

Petersen, M.A. and Rajan, R.G. (1995), "The effect of credit market competition on lending relationships", *The Quarterly Journal of Economics*, Vol. 110 No. 2, pp. 407-443, doi: 10.2307/2118445.

Senyo, P.K. and Osabutey, E.L. (2020), "Unearthing antecedents to financial inclusion through FinTech innovations", *Technovation*, Vol. 98, 102155, doi: 10.1016/j.technovation.2020.102155.

Smaoui, H., Mimouni, K., Miniaoui, H. and Temimi, A. (2020), "Funding liquidity risk and banks' risk-taking: evidence from Islamic and conventional banks", *Pacific-Basin Finance Journal*, Vol. 64, 101436, doi: 10.1016/j.pacfin.2020.101436.

Suhrab, M., Chen, P. and Ullah, A. (2024), "Digital financial inclusion and income inequality nexus: can technology innovation and infrastructure development help in achieving sustainable development goals?", *Technology in Society*, Vol. 76, 102411, doi: 10.1016/j.techsoc.2023.102411.

Tchamyou, V.S., Erreygers, G. and Cassimon, D. (2019), "Inequality, ICT and financial access in Africa", *Technological Forecasting and Social Change*, Vol. 139, pp. 169-184, doi: 10.1016/j.techfore.2018.11.004.

Telukdarie, A. and Mungar, A. (2023), "The impact of digital financial technology on accelerating financial inclusion in developing economies", *Procedia Computer Science*, Vol. 217, pp. 670-678, doi: 10.1016/j.procs.2022.12.263.

The State of the Industrial Report on Mobile Money (2024), "GSMA association", available at: www.gsma.com/mobilemoney (accessed 19 May 2024).

van Duuren, T., de Haan, J. and van Kerkhoff, H. (2020), "Does institutional quality condition the impact of financial stability transparency on financial stability?", *Applied Economics Letters*, Vol. 27 No. 20, pp. 1635-1638, doi: 10.1080/13504851.2019.1707762.

Vo, D.H., Nguyen, N.T. and Van, L.T.H. (2021), "Financial inclusion and stability in the Asian region using bank-level data", *Borsa Istanbul Review*, Vol. 21 No. 1, pp. 36-43, doi: 10.1016/j.bir.2020.06.003.

Von Fintel, D. and Orthofer, A. (2020), "Wealth inequality and financial inclusion: evidence from South African tax and survey records", *Economic Modelling*, Vol. 91, pp. 568-578, doi: 10.1016/j.econmod.2020.02.001.

Xie, R.Q., Li, S.Q. and Zhang, M.X. (2021), "Research on the impact of financial inclusion on commercial banks' profitability in the context of financial technology", *Quantitative Economic and Technical Economics Research*, Vol. 38 No. 08, pp. 145-163.

Zins, A. and Weill, L. (2016), "The determinants of financial inclusion in Africa", *Review of Development Finance*, Vol. 6 No. 1, pp. 46-57, doi: 10.1016/j.rdf.2016.05.001.

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