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Fintech-based Financial Inclusion and Risk-taking of Microfinance Institutions (MFIs): Evidence from Sub-Saharan Africa

Hasanul Banna [a], Md Aslam Mia [b,*], Mohammad Nourani [c], Larisa Yarovaya [d]

[a] *Ungku Aziz Centre for Development Studies, Faculty of Economics and Administration, Universiti Malaya, 50603 Kuala Lumpur, Malaysia*
[b] *School of Management, Universiti Sains Malaysia, 11800 Penang, Malaysia*
[c] *School of Management, Universiti Sains Malaysia, 11800 Penang, Malaysia; University of Waikato, The University of Waikato Joint Institute at Zhejiang University City College, Hangzhou, China*
[d] *Southampton Business School, University of Southampton, Highfield, Southampton SO17 1BJ, United Kingdom*

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ABSTRACT

Fintech innovations are rapidly transforming the global financial industry and easing the financial inclusion initiatives of microfinance institutions (MFIs). Such technological transformations are expected to promote stability in the financial system and in turn reduce the risk-taking behavior of its main actors. However, there is limited or no empirical evidence to confirm the impact of fintech-based financial inclusion (FinFI) on the risk-taking behavior of Sub-Saharan African MFIs. Thus, we have developed a new index to measure FinFI and empirically assess its role in reducing the risk-taking attitude of MFIs. The validity of our results was confirmed by using various robustness tests.

Introduction

Financial inclusion of the poor through microfinance institutions (MFIs), by all means, remains one of the global prime agendas (Bhandari and Kundu, 2014), and have become an important public policy priority in regions with limited access to financial services, particularly in Sub-Saharan Africa.[1] The technological advancements and the rising involvement of MFIs in financial technology (Fintech) solutions have provided market players with more cost-saving opportunities and reduced information asymmetries. Similar to the banking operation, comprehensive financial inclusion strategies are linked to healthy and stable political environment and legal rights (Allen et al., 2016). As greatly discussed by Ahamed and Mallick (2019), in an inclusive financial system, lenders operate with lower marginal costs, and thus, observe significant reduction in excessive risk-taking behaviors.

Fintech is considered one of the most promising innovations that can solve the problems of inequity, poverty and inaccessibility of financial services. While Western nations and East Asian countries are ahead in terms of fintech adoption, its utilization in Sub-Saharan

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[1] Authors acknowledge the ongoing debate surrounding the relevance of the term "Sub-Saharan," which is applied to the selected countries in this analysis. We have applied the title to align with the previous literature on these specific countries. We will continue to monitor developments on the debate of the term and apply any changes where necessary in the future work.

Africa is just gaining momentum in recent years as a technology enabler to improve financial inclusion and reach out to the poor. The emergence of fintech based financial inclusion (FinFI) has been made possible owing to the decade-long investment in information and communication technologies (ICT) in African countries, followed by the high penetration potential and acceptance of such technology-driven services among the end-consumers (Bollou, 2006; Tchamyou et al., 2019a,2019b). The ensuing effect of fintech solutions on the efficiency improvement and cost reduction in service delivery have primarily attracted the attention of many lending firms in Sub-Saharan Africa, given the region's shallow financial inclusion and low level of competitive banking system (Sy et al., 2019). For example, Wizzit, a provider of microfinance products to the unbanked and underbanked, has partnered with the World Bank Group in offering microloans to the users via their phones. Wizzit is certainly one of the many companies in Sub-Saharan Africa reaping the benefits of FinFI.

There are several studies discussing the drivers and barriers of financial inclusion (e.g., (Anarfo et al., 2020); Asongu et al., 2020; Fintel and Orthofer, 2020; Ongo Nkoa and Song, 2020; Zins and Weill, 2016); however, only a handful of studies focuses on the role of fintech as a financial inclusion enabler in African countries (e.g., (Makina and Makina, 2019); Senyo and Osabutey, 2020). As an instance, Senyo and Osabutey (2020) combined the Unified Theory of Acceptance and Use of Technology 2 (UTAUT2) and the prospect theory to investigate the antecedents to financial inclusion through mobile money services. Their results suggest that perceived risk negatively influences mobile money service, while growing trust in mobile money service promote the use of fintech innovation.

The literature on financial inclusion and stability, particularly in banking domain, confirms the importance of inclusive financial system on greater institutional stability and ultimately less risk-taking intention. However, little attention has been devoted to FinFI particularly among MFIs, which are the core providers of loans to the poor populations. This was probably due to the lack of accessible data on MFIs and the novelty of fintech solutions being made available to MFIs. The current advancement in technology inclusiveness in Sub-Saharan Africa[2] and the recent publicly available dataset of MFIs, thanks to the recent initiative by World Bank in releasing the extensive dataset, have made it possible to explore this important supposition. Specifically, we examined the question of whether FinFI could affect the risk-taking of MFIs in Sub-Saharan African countries.

This study fills the aforementioned gap and makes several contributions to the literature. First, we developed an index to measure FinFI, which comprises of two components, namely access and usage of fintech-based solutions. Second, given the recent availability of the data, we included a few controls, MFI-specific and macro-specific variables. This has substantially reduced the bias of our estimations as compared to existing literature. Third, we have confirmed our findings with a number of robustness tests, including the substitution of MFIs' risk-taking measure, the use of additional econometric tests such as instrumental variables (IV) and the separation of our sample based on size and economic status of the country. Fourth, the need for remote access to financial services has been felt ever than before due to the emergence of novel coronavirus (COVID-19) worldwide. Hence, this study is timely in suggesting fintech solutions as a mechanism for risk reduction of MFIs considering the ongoing pandemic. Finally, our study highlights the importance of fintech solutions for MFIs in Sub-Saharan African countries in reducing their risk taking. Such findings provide a guideline for policymakers in easing the regulations and creating a more secure environment for MFIs; consequently, the technological transformation of MFIs will be better managed and executed.

The rest of the paper is organized as follows: In Section 2, we provide discussion on data and methods, followed by results and discussions in Section 3. Lastly, a brief conclusion is presented in Section 4.

Data and methods

The risk-taking of MFIs and fintech-based financial inclusion

As the risk-taking of MFIs are not directly given in the dataset, we had to rely on a conventional technique to calculate it. In other words, we used Z score as a proxy to measure the risk-taking of MFIs (also used as a bank stability indicator), which is in line with the existing banking literature (Danisman and Tarazi, 2020). The following formula was used to calculate the z-score:

$$Z - score_{it} = \frac{ROA_{it} + CTA_{it}}{\sigma(ROA)_{it}} \tag{1}$$

where, ROA_{it}, CTA_{it} and $\sigma(ROA)_{it}$ are the return on assets, the capital to assets ratio, and the standard deviation (σ) of ROA of MFI 'i' in year 't' respectively. To calculate the $\sigma(ROA)$, we considered the 3-year rolling period windows to allow for the variation in the denominator, in accordance to the study of Danisman and Tarazi (2020). To overcome the issue of high skewness of z-score, we transformed the value into logarithmic form and subsequently multiplied it with '−1' for simpler analysis. Consequently, a higher (lower) value suggests a higher (lower) risk-taking of MFIs.

Since FinFI is the core independent variable, we employed three steps to create the index. First, we winsorized each indicator at the 5th and 95th percentile to reduce the effect of outlier at the lower and upper levels. Second, we normalised the value of each indicator between 0 and 1. Then, by deploying the Principal Component Analysis (PCA), we constructed the supply-side index (access), which is expressed as FINFI_A and was created using two indicators, namely mobile money agent outlets (ATK) as well as mobile money agent and point of sale (POS) terminals (ATD). Similarly, an index for the demand side (usage) was created (FinFI_U) using the number of
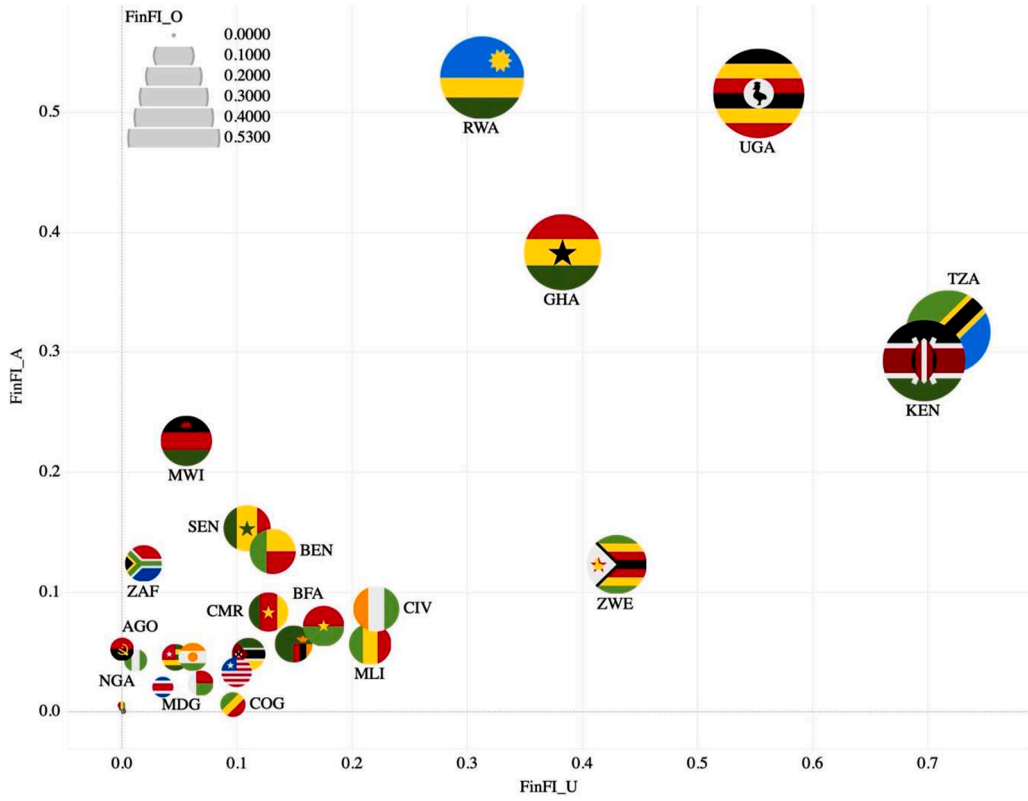

Fig. 1. Fintech-Based Financial Inclusion in Sub-Saharan African Countries.
Source: Authors' estimate based on the secondary data. The FinFI was calculated based on the average value between the year 2011 and 2018. Kindly refer to 'Appendix A' for the full name of each country. The figure displays the FinFI details of countries (represented by their flags) with values sufficient for visibility. The size of flags indicates the value of FinFI_O and their position in X and Y axes correspond to the values of FinFI_U and FinFI_A respectively. Among other countries, Uganda scored the highest in terms of overall FinFI (FinFI_O).

mobile and internet transactions (MITD), the value of mobile and internet transaction (MIVT), as well as the number of mobile money and e-money accounts (ACD). Lastly, combining these two indices (FinFI_A and FinFI_U), we constructed the overall (FinFI_O) index using the PCA technique. All these three indices were normalised using the minimum-maximum normalization technique. The results of the country-wise FinFI, descriptive statistics and correlation coefficients are reported in Fig. 1, Table 1 and Table 2 respectively.

Estimation technique

Given the effect of FinFI on MFIs' risk-taking, we considered the baseline regression as follows:

$$Y_{ijt} = \alpha + \beta FinFI_{jt} + \varnothing X_{ijt} + \omega Z_{jt} + \varepsilon_{ijt} \tag{2}$$

where, $Y_{ijt} = DRK$, which is termed as default risk and a proxy for the risk-taking of MFI *i* of country *j* in year *t*; $FinFI_{jt}$ = Fintech-based financial inclusion index (FinFI_O, FinFI_A and FinFI_U) of country *j* in year *t*; X_{ijt} = MFI-specific factors of MFI *i* of country *j* in year *t* (*such as* MFIS, LNS, DPS, AGT, MNQ and CAR); Z_{jt} = Macroeconomic factors of country *j* in year *t* (such as GDPG, INF and INQ); β, ∅, ω = Coefficients of the variables; and ε_{ijt} = error term. This study used clustered standard errors to control the problems of serial correlation and heteroskedasticity.

Data source

We have used several datasets in this study. For example, MFI-related variables were extracted from the MIX Market database, which is now incorporated into the World Bank Open Data Catalog for a more extensive and freely accessible data.[3] This is one of the reliable sources of MFIs' data used extensively by researchers (Mia, 2021). For the list of countries and sample used in the study, refer to 'Appendix A.' To construct FinFI, we utilized data from the Financial Access Survey (FAS) of International Monetary Fund (IMF) and

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[3] To access to the dataset, please see https://datacatalog.worldbank.org/dataset/mix-market.

Table 1
Descriptive statistics.

Variable	Obs.	Mean	Std. Dev.	Min	Max
MFI risk-taking					
Default Risk (DRK): −1* natural logarithm of [capital over assets (CTA) + return on assets (ROA) / standard deviation of ROA]	513	−2.824	1.214	−5.057	−0.478
Loan loss rate (LLR): −1*(Write-offs - value of loans recovered) / average gross loan portfolio)	853	0.012	0.024	−0.032	0.076
Control variables					
MFI-specific variables					
MFI size (MFIS) – Ln of total assets	1317	15.596	2.133	11.942	19.417
Loan share (LNS) - Gross loan portfolio / total assets	1246	0.642	0.172	0.279	0.905
Deposit share (DPS) – Deposit / total assets	1281	0.467	.254	0	0.861
Asset growth (AGT) – Annual growth of total assets	762	0.123	0.229	−0.241	0.658
Management quality (MNQ) – Other assets / total assets	1194	0.096	0.087	0.013	0.334
Capital Adequacy Ratio (CAR)-total equity/total assets	1304	0.273	0.189	−0.003	0.701
Macro-specific variables					
GDP growth (annual) GDP	29	5.211	2.042	1.223	8.889
Inflation (IFN)	29	5.592	4.798	−0.576	16.001
Institutional quality (INQ)	29	0.000	0.833	−2.378	1.7
Fintech-based financial inclusion (FinFI) componentsand index					
Access to digital financial services (Supply side)					
ATK - Mobile money agent outlets per 1000 km^2	29	137.126	205.619	0.408	796.878
ATD - Mobile money agent and POS (point of sale) terminals per 100,000 adults	29	240.078	254.682	2.063	877.989
Usage of digital financial services (Demand side)					
ACD – The number of mobile money and e-money accounts per 1000 adults	29	405.172	418.724	10.125	1322.499
MITD – The number of mobile and internet transaction per 1000 adults	29	9938.391	14,883.62	6.35	50,088.750
MIVT – The value of mobile and internet transaction (% of GDP)	29	11.52	16.239	0.01	49.405
FinFI index using PCA					
FinFI_O - Fintech-based financial inclusion (overall)	29	0.202	0.256	0	1
FinFI_A - Fintech-based financial inclusion (access)	29	0.185	0.254	0	1
FinFI_U - Fintech-based financial inclusion (usage)	29	0.233	0.297	0	1
Instrumental variables					
MBS – The proportion of mobile cellular subscriptions (per 100 people)	29	0.023	0.006	0.011	0.034
FF – The percentage of adults borrowing from friends and family during emergency funding	29	36.854	10.883	20.014	58.219

Source: Authors' estimation based on the secondary data. Definitions are based on the MIX Market, IMF and World Bank. To ensure that our results are unaffected by the extreme outliers, we have winsorized all the variables at 5% and 95% levels. Note: INQ index is standardized using six (6) components of good governance, namely control of corruption, government effectiveness, political stability and absence of violence/terrorism, regulatory quality, rule of law, as well as voice and accountability. Descriptive statistics of the macroeconomic variables are reported here based on the number of countries, which is why the number of observations is 29, in line with the number of countries for macroeconomic, FinFI and instrumental variables. For brevity, PCA results are not reported here but can be obtained from the corresponding author.

Table 2
Pairwise correlations among the independent variables.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1) FinFI_O	1.000											
(2) FinFI_A	0.968*	1.000										
(3) FinFI_U	0.918*	0.790*	1.000									
(4) MFIS	0.246*	0.179*	0.320*	1.000								
(5) CAR	−0.035	−0.016	−0.059*	−0.185*	1.000							
(6) LNS	−0.009	−0.039	0.040	0.166*	0.113*	1.000						
(7) DPS	0.037	0.051	0.009	0.137*	−0.585*	−0.237*	1.000					
(8) AGT	−0.021	−0.034	0.003	−0.054	−0.032	0.095*	−0.053	1.000				
(9) MNQ	−0.016	−0.034	0.016	−0.156*	−0.150*	−0.445*	0.039	−0.141*	1.000			
(10) GDP	0.156*	0.144*	0.154*	−0.032	−0.019	0.017	0.084*	0.149*	0.039	1.000		
(11) IFN	0.052*	0.039	0.065*	0.126*	0.147*	−0.018	−0.149*	−0.014	−0.030	−0.156*	1.000	
(12) INQ	0.302*	0.365*	0.163*	−0.168*	−0.061*	−0.050	0.018	−0.012	0.094*	0.198*	−0.125*	1.000

Source: Authors' computation based on the secondary data. Note: The reported pairwise correlation values are based on independent variables only, as we did not show the pairwise correlation with dependent variable. The FinFI_A and FinFI_U were used to measure the FinFI_O, which was found to be highly correlated. However, these variables were rather introduced separately in different models to avoid multicollinearity issue. The asterisk (*) shows significance at 5%.

World Bank Global Findex (Findex) databases. Since our study also included macroeconomic and institutional quality variables, these were collected from the World Development Indicators (WDI) and the World Governance Indicators (WGI) databases respectively.

Results and discussion

Baseline regression

Similar with the convention, Eq (2) was estimated by both Fixed effect (FE) and Random effect (RE) models. To identify which model fits better, we performed the Hausman test and the results supported the RE model. Hence, we have reported the RE results in Table 3. It is also noteworthy that we have clustered our model by country effect to minimize statistical bias. To further minimize the effect of outliers on the nexus, which may results from the higher FinFI exhibited by these countries, we also split our sample into two groups—A: full sample and B: sub-sample (All countries except Rwanda, Uganda, Tanzania, Kenya, Zimbabwe and Ghana). In terms of the overall fitness of the models reported in Table 3, Chi[2] is highly significant for all the models. However, it should be noted that the overall explanatory power of the models (e.g.: R^2) are relatively modest, which is often the case of many microfinance (different scope) researches (Rahman et al., 2018; Dahal and Fiala, 2020). Having said that, the coefficient sign of the main variable remains unchanged, which reiterate the overall stability of the models.

Our findings support the widely held argument that FinFI has a negative and statistically significant effect on the risk-taking of MFIs, as evidenced in the results of overall (FinFI_O) and access (FinFI_A) variables in our sample. However, our results failed to establish any statistically significant effect of FinFI_U on the risk-taking of MFIs, although the relationship is negative. This conclusion remains unchanged even after excluding the high-performing FinFI countries (see group B).

The results of FinFI support the extant studies exhibiting its positive connection with financial stability (Ahamed and Mallick, 2019), which in turn translates into a negative relationship with MFIs' risk-taking. There are a couple of explanations behind such outcome. First, due to the enhancement of fintech in recent years, MFIs would be lending more to businesses and individuals that will

Table 3
Fintech-based financial inclusion and MFIs' risk-taking (random effect).

| | Dependent Variable: DRK | | | | | |
| | Group A: Full Sample | | | Group B: Sub Sample | | |
	Model-(1)	Model-(2)	Model-(3)	Model-(4)	Model-(5)	Model-(6)
FinFI_O	−0.468**			−0.792**		
	(0.200)			(0.338)		
FinFI_A		−0.486**			−0.823***	
		(0.195)			(0.304)	
FinFI_U			−0.291*			−0.424
			(0.167)			(0.426)
MFIS	−0.224***	−0.227***	−0.225***	−0.250***	−0.248***	−0.257***
	(0.041)	(0.040)	(0.042)	(0.066)	(0.065)	(0.067)
CAR	−3.449***	−3.416***	−3.507***	−3.247***	−3.205***	−3.297***
	(0.410)	(0.405)	(0.419)	(0.483)	(0.476)	(0.494)
LNS	−0.216	−0.243	−0.146	0.006	−0.030	0.046
	(0.481)	(0.478)	(0.484)	(0.609)	(0.602)	(0.605)
DPS	−0.427	−0.417	−0.453	−0.420	−0.415	−0.411
	(0.289)	(0.288)	(0.287)	(0.358)	(0.352)	(0.370)
AGT	0.326	0.328	0.316	0.257	0.247	0.276
	(0.205)	(0.204)	(0.205)	(0.254)	(0.251)	(0.251)
MNQ	1.587**	1.550**	1.638**	1.167	1.146	1.101
	(0.741)	(0.744)	(0.750)	(0.874)	(0.866)	(0.888)
GDP	−0.022	−0.023	−0.026	−0.021	−0.021	−0.026
	(0.028)	(0.027)	(0.028)	(0.031)	(0.030)	(0.031)
IFN	0.018	0.018	0.017	0.040**	0.042**	0.041**
	(0.016)	(0.017)	(0.016)	(0.017)	(0.017)	(0.018)
INQ	0.186	0.199*	0.146	0.333***	0.349***	0.298**
	(0.115)	(0.117)	(0.111)	(0.114)	(0.112)	(0.116)
Constant	1.953**	1.992**	1.965**	2.093	2.053	2.214*
	(0.854)	(0.841)	(0.865)	(1.280)	(1.261)	(1.283)
Observations	459	459	459	331	331	331
R^2	0.2522	0.2555	0.2476	0.2571	0.2657	0.2521
Chi[2]	274.158***	298.504***	253.565***	146,822.028***	448,453.377***	344,768.9***
# of groups/MFIs	164	164	164	119	119	119
Year effect	yes	yes	yes	yes	yes	yes
Clustered by country	yes	yes	yes	yes	yes	yes
Hausman test	RE	RE	RE	RE	RE	RE

Source: Authors' computation based on secondary data. Robust standard errors are in parenthesis. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

bring diversification benefits. A similar findings has been documented in the study of Khan (2011) and Danisman and Tarazi (2020). Second, FinFI also substantially increase deposits and decrease the procyclicality risk of the banking sector (Han and Melecky, 2013; Hannig and Jansen, 2010). Thus, with an inclusive fintech-based financial sector, MFIs are likely to enjoy lower (greater) risk-taking (financial stability) in the Sub-Saharan region.

Concerning the control variables, our study documented that size and capital adequacy ratio (CAR) have a negative effect on the default risk of MFIs. These significant results obtained for CAR variable are similar to Harkati et al. (2020) who suggest that CAR reduces the risk-taking behavior of financial institutions and reduces overall financial performance of MFIs (Afrifa et al., 2019). However, our result for size variable contradict the earlier findings by Bokpin (2016). Furthermore, increasing *other assets* over *total assets* (MNQ) signifies the deterioration in the management quality and hence, a positive effect on the risk-taking of MFIs. We also observed that INQ have a positive effect on the MFIs' risk-taking. Our results reiterate that high-growth MFIs will be carrying more default risk, as AGT was found to be positive and statistically significant, in line with the findings of Danisman and Tarazi (2020). Another interesting result observed from group-B sample is that increasing inflationary environment will raise the risk-taking behavior of MFIs, as the coefficient value is positive and remain significant at 5% and 10% for models 4 to 6.

Additional/Robustness test

We have also conducted a series of robustness test to examine the reliability of the result by observing the changes in coefficient sign and values following the use of different proxies or estimator. In doing so, we initially employed two-step Least Square Instrumental Variables (LS-IV) by considering mobile cellular subscriptions (MBS) and borrowing from friends and family (FF) as instrumental variables following the previous studies (e.g., Ahamed and Mallick, 2019; Banna, 2020), to re-estimate Eq (2) and the results are reported in Table 4. Again, we found a statistically significant effect of FinFI_O and FinFI_A, which is consistent with the RE results reported earlier except for a slight variation in the coefficient values (but the sign of the coefficient remains unchanged).

Table 4
Fintech-based financial inclusion and MFIs' risk-taking (two-step LS-IV regression).

	Dependent Variable: DRK		
	Model- (7)	Model- (8)	Model- (9)
FinFI_O	−0.450**		
	(0.204)		
FinFI_A		−0.476**	
		(0.200)	
FinFI_U			−0.264
			(0.166)
MFIS	−0.216***	−0.219***	−0.217***
	(0.041)	(0.040)	(0.043)
CAR	−3.424***	−3.394***	−3.475***
	(0.429)	(0.423)	(0.437)
LNS	−0.154	−0.185	−0.084
	(0.477)	(0.474)	(0.480)
DPS	−0.470	−0.459	−0.494
	(0.305)	(0.304)	(0.304)
AGT	0.387*	0.390*	0.378*
	(0.208)	(0.206)	(0.207)
MNQ	1.819**	1.778**	1.872**
	(0.722)	(0.727)	(0.733)
GDP	−0.024	−0.024	−0.028
	(0.028)	(0.028)	(0.028)
IFN	0.017	0.017	0.016
	(0.017)	(0.018)	(0.017)
INQ	0.189*	0.204*	0.149
	(0.111)	(0.114)	(0.106)
Constant	1.760**	1.803**	1.774**
	(0.871)	(0.857)	(0.884)
Observations	450	450	450
R^2	0.2548	0.2581	0.2504
Chi^2	257.507***	282.069***	243.177***
Number of groups	161	161	161
Year fixed effect	yes	yes	yes
Clustered by country	yes	yes	yes

Source: Authors' computation based on secondary data. Robust standard errors are in parenthesis. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 5

Fintech-based financial inclusion and MFIs' risk-taking (split sample based on size).

	Dependent Variable: DRK					
	Small	Big	Small	Big	Small	Big
	FinFI_O		FinFI_A		FinFI_U	
	Model- (10)	Model- (11)	Model- (12)	Model- (13)	Model- (14)	Model- (15)
FinFI	−0.607**	−0.145	−0.611***	−0.132	−0.424	−0.112
	(0.246)	(0.452)	(0.212)	(0.486)	(0.280)	(0.297)
Constant	−1.830***	−0.956	−1.829***	−0.959	−1.832***	−0.962
	(0.494)	(1.183)	(0.487)	(1.187)	(0.506)	(1.175)
Obs.	284	175	284	175	284	175
R^2	0.2221	0.1696	0.2236	0.1688	0.2156	0.1710
Chi^2	410.051***	423.802***	585.916***	418.267***	233.375***	494.202***
Number of groups	118	60	118	60	118	60
Year fixed effect	yes	yes	yes	yes	yes	yes
Clustered by country	yes	yes	yes	yes	yes	yes
Control variables (except size of MFIs)	yes	yes	yes	yes	yes	yes
Hausman test	RE	RE	RE	RE	RE	RE

Source: Authors' computation based on secondary data. Robust standard errors are in parenthesis. Random effect with heteroskedastic-corrected robust standard errors are used here. For brevity, coefficient and standard errors for control variables are not reported here. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Apart from the above estimation, we also split our sample into two groups based on the size of MFIs: small and big. Based on the intuition and arbitrary decision, top 25% MFIs are considered 'big,' while the remaining are regarded as 'small.' Subsequently, Eq (2) was re-estimated by RE and the results, which are interesting, are reported in Table 5. For example, we found that FinFI_O and FinFI_A are statistically significant only for small-scale MFIs and remain insignificant for big MFIs. This indicates that FinFI will bring more benefits (e.g., risks' reduction) to small MFIs compared to their counterpart. As usual, in line with the results reported earlier, FinFI_U remain insignificant for both small and big MFIs. This finding reiterates that small-scale MFIs will be more cautious in managing/minimizing default risk, which is indeed necessary for them to survive and grow in the market (Table 6).

Then, we divide our sample again based on the economic status of the country and excluded the upper middle-income countries before re-estimating Eq (2). Again, we observed a very consistent result that FinFI_O and FinFI_A have a negative and statistically significant effect on the risk-taking of MFIs in the Sub-Saharan African countries.

Lastly, to further ascertain the consistency of our results, we used a different proxy for the risk-taking of MFIs, known as loan loss rate (LLR). A similar type of variable (e.g., loan loss provision) has also been used as a proxy in the banking literature to capture the risk-taking of banks (Khan et al., 2020). In addition to FinFI_O and FinFI_A, we also found that FinFI_U now exhibits a negative and statistically significant relationship (Table 7). This implies that enhancing FinFI (access, usage and overall) will considerably reduce the risk-taking of MFIs.

Table 6

Fintech-based financial inclusion and MFIs' risk-taking (without upper middle-income countries).

| | Dependent Variable: DRK | | |
	Model-(16)	Model-(17)	Model-(18)
FinFI_O	−0.452**		
	(0.202)		
FinFI_A		−0.470**	
		(0.197)	
FinFI_U			−0.278*
			(0.166)
Constant	1.964**	2.002**	1.979**
	(0.854)	(0.842)	(0.863)
Obs.	454	454	454
R^2	0.2543	0.2575	0.2498
Chi^2	346.884***	366.623***	311.183***
Number of groups	163	163	163
Year fixed effect	yes	yes	yes
Clustered by country	yes	yes	yes
Control variables	yes	yes	yes
Hausman test	RE	RE	RE

Source: Authors' computation based on secondary data. Robust standard errors are in parenthesis. The random effect with heteroskedastic-corrected robust standard errors are used here. For brevity, the coefficient and standard errors for control variables are not reported here *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 7
Fintech-based financial inclusion and MFI's risk-taking (alternative proxy of risk taking).

	Dependent Variable: LLR		
	Model-(19)	Model-(20)	Model-(21)
FinFI_O	−0.013**		
	(0.005)		
FinFI_A		−0.012**	
		(0.005)	
FinFI_U			−0.013***
			(0.004)
Constant	0.014	0.016	0.012
	(0.019)	(0.019)	(0.019)
Obs.	540	540	540
R^2	0.0678	0.0616	0.0768
Chi^2	33.346***	30.714***	36.380***
Number of groups	209	209	209
Year fixed effect	yes	yes	yes
Clustered by country	yes	yes	yes
Control variables	yes	yes	yes
Hausman test	RE	RE	RE

Source: Authors' computation based on secondary data. Robust standard errors are in parenthesis. The random effect with heteroskedastic-corrected robust standard errors are used here. For brevity, the coefficient and standard errors for control variables are not reported here. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Conclusion

The economic benefits of financial inclusion are well-evidenced and include, but not limited to economic growth, poverty reduction and financial stability. However, with the ever advancement of fintech solutions, it is still unclear how exactly FinFI attracts more value in terms of risk reduction for firms operating particularly in less developed countries, such as the Sub-Saharan African countries. In this paper, we focused on MFIs as the preferred development tool in poverty reduction, which are gaining momentum in the Sub-Saharan Africa and are increasingly utilizing technological capabilities in their businesses. This has motivated us to develop a new FinFI index to quantify fintech-based financial inclusion and explore its effect on the risk-taking of 512 MFIs in 29 Sub-Saharan African countries.

Our econometric analysis concluded the importance of fintech solutions in reducing the risk-taking of MFIs. We performed a number of robustness tests to confirm our findings. As a result, we emphasized the importance of overall and accessibility of fintech solution in minimizing MFIs' risk. Additionally, we concluded that fintech solutions are more relevant to small-scale MFIs. These outcomes can be used as a reference for policymakers and MFI managers to support fintech solutions as part of the financial inclusion strategies and a means to attain operational stability. We recommend future scholars to re-examine the developed index in other financial institutions or MFIs of other regions to confirm the generalizability of our results. Nonetheless, a different set of financial variables (if available) to construct FinFI can also significantly contribute to the existing Fintech literature.

CRediT author statement

Hasanul Banna: Conceptualization, Software, Formal Analysis, Data Curation, Writing - Review & Editing **Md Aslam Mia:** Conceptualization, Writing - Original Draft, Review & Editing, Methodology, Project administration, Investigation **Mohammad Nourani:** Conceptualization, Writing - Original Draft, Review & Editing, Visualization, Software **Larisa Yarovaya:** Supervision, Validation, Writing - Original Draft, Review & Editing

Appendix A: list of countries, MFIs and observations

Country	Country code	Number of MFIs	Observations
Angola	AGO	1	8
Benin	BEN	28	107
Burkina Faso	BFA	30	97
Cameroon	CMR	17	66
Central African Republic	CAF	2	2
Chad	TCD	2	4
Congo, Republic of the	COG	3	12
Cote d'Ivoire (Ivory Coast)	CIV	24	59
Ghana	GHA	32	93
Guinea	GIN	3	3
Kenya	KEN	37	120
Liberia	LBR	4	14
Madagascar	MDG	12	61

(*continued*)

Malawi	MWI	5	29
Mali	MLI	11	36
Mozambique	MOZ	9	33
Namibia	NAM	1	2
Niger	NER	20	60
Nigeria	NGA	60	136
Rwanda	RWA	49	115
Senegal	SEN	72	167
South Africa	ZAF	5	15
Sudan	SDN	2	5
Swaziland	SWZ	1	2
Tanzania	TZA	18	62
Togo	TGO	32	81
Uganda	UGA	24	74
Zambia	ZMB	5	24
Zimbabwe	ZWE	3	8
Total		512	1495

Source: Authors' estimate based on the MIX market data. These countries were chosen based on the availability of the required MFIs-related data.

Declaration of Competing Interest

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