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A dynamic panel threshold regression on financial inclusion-financial stability nexus: Evidence from developing countries

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Abstract

This paper investigates the relationship between financial inclusion and financial stability in 24 developing countries during the period 2004-2020. In light of inconclusive findings in prior research regarding this association, this study employs a dynamic panel threshold model. This approach incorporates time-varying threshold effects and lagged variables to identify distinct regimes, enabling a comprehensive analysis of nonlinear interactions between variables. The empirical findings reveal a nonlinear relationship between financial inclusion and financial stability. Financial inclusion significantly reinforces financial stability, especially in its lower regime, while the upper regime of financial inclusion exacerbates financial instability. This research makes new evidence on the financial inclusion-financial stability nexus.

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1. Introduction

In prior research, the pivotal role of banks in promoting economic activities within developing countries has been extensively discussed and affirmed (Amidu and Wolfe, 2013). However, the perceived invulnerability of the banking system's resilience faced a significant challenge during the 2008 global financial crisis, revealing persistent solvency concerns and triggering a contraction in deposit expansion. This sequence of events deeply exposed the intrinsic fragility inherent within the structure of the banking sector (Han and Melecky, 2017). The era spanning the 1980s and 1990s witnessed financial deregulation that led to the liberalization of financial markets, paving the way for the emergence of modern finance in the early 2000s. Despite this evolution, economists hold differing views on the importance of developing the banking system in these countries. While the evolution of the banking system plays a crucial role in catalyzing industrialization, it unfortunately tends to exclude marginalized populations, particularly those in poverty (Nkoa and Song, 2020). As a response to the challenges encountered by these marginalized populations, a novel financial paradigm known as “financial inclusion” has emerged as a central developmental consideration. Particularly within developing economies, the significance of financial inclusion has become pronounced, emphasized by a substantial annual decline in deposits by over 12 percentage points between 2006 and 2009 (Global Financial Index Database, 2011).

The foundation of financial inclusion rests upon the extensive offering of diverse financial services to a growing demographic, aimed at alleviating individuals from prevailing financial constraints. Through an augmented accessibility of requisite financial services, an increasing not only in capital influx becomes feasible, but also a bolstering of the corporate capital chain network ensues (Chen et al., 2018). The scarcity of financial resources within developing economies has left a substantial portion of the population struggling with challenges. Based on the Global Financial Index Database (2011), in 2011, around half of the population in developing nations remains devoid of banking privileges. Even among those possessing accounts, a mere 43% employ them for savings accumulation. In addition, women contend with considerable disadvantages, including poverty rates that are 38%. Meanwhile, access to banking facilities is also skewed, with only 58% of men in developing countries possessing a bank account. This insufficiency has further reverberated to impede the endeavors of small and medium-sized enterprises. For instance, nearly 200 million SMEs lacked access to economical credit and financial services (Chen and Divanbeigi, 2019). In response, financial regulators have recognized financial exclusion as a pivotal impediment obstructing sustainable economic advancement within developing nations (Ahamed and Mallick, 2019). Hence, the study of the implications for financial stability arising from inclusive financial practices holds substantial political and academic significance, deserving exploration.

Theoretical literature presents divergent predictions regarding the intricate relationship between financial inclusion and banking stability. A spectrum of perspectives has emerged. The initial stance posits that financial inclusion serves as a potent instrument, offering numerous advantages to individuals. Researchers such as Hawkins (2006), Hannig and Jansen (2010), Prasad (2010), Cull et al. (2012), and Han and Melecky (2017) underscore that even smaller clients have the capacity to yield significant opportunities for stable deposit mobilization. A banking framework focused on cultivating retail deposits can provide a diversified and stable source of funding that is less susceptible to market volatility and strengthens the bank's financial health, thereby mitigating liquidity risk. Moreover, diversifying banking assets through increased lending to small and medium-sized enterprises

(SMEs) holds promise for reducing overall loan portfolio risk and borrower volatility (Khan, 2011). Furthermore, emphasizing diversification strengthens financial institutions' resilience and their ability to withstand financial crises (Mehrotra and Yetman, 2015).

An alternative theoretical perspective proposed by Khan (2011), Josè and Garcia (2016), Allen et al. (2016) argues that the ultimate effects of financial inclusion on financial stability attribute to information asymmetry, the extent and effectiveness of regulatory oversight, and a country's financial inclusion level. The development of financial inclusion can lead to credit excess, where allocated funds exceed the actual needs of borrowers. This can result from multiple loans granted by different financial institutions to circumvent evaluation criteria. This phenomenon causes negative externalities and can generate a vicious cycle of ongoing decline, inducing instability in the financial system (Jia et al., 2021). Moreover, banks that are highly liquid and hold dominant market positions may be incentivized to undertake riskier ventures, thereby heightening the potential for bank defaults (Smaoui et al., 2020). On the other hand, excessive innovation in financial inclusion, particularly through Fintech, can enhance accessibility but also introduces risks such as maturity mismatches, liquidity mismatches, and asset price volatility in the absence of robust regulation (Liu et al., 2017).

Empirically, a significant corpus of research has investigated the impact of financial inclusion on financial stability. Early studies have identified a positive relationship between financial inclusion and financial stability (Morgan and Pontines, 2014; Siddik and Kabiraj, 2018; Al-Smadi, 2018; Ahamed and Mallick, 2019; Alvi et al., 2020; Vo et al., 2020; Risman et al., 2021; Hakimi et al., 2022). Additionally, Ahamed et al. (2021) and Banna et al. (2022) establish a robust and favorable impact of financial inclusion on banking efficiency. Other studies, including those by Amatus and Alireza (2015), Feghali et al. (2021), and Barik and Pradhan (2021), have found a negative association between financial inclusion and financial stability. More recently, Ofoeda et al. (2023), and Hua et al. (2023), Antwi et al. (2024) underscore a nonlinear relationship between financial inclusion and financial stability. This suggests that the initial stages of financial inclusion development reinforce financial stability, after which increasing the level of financial inclusion may undermine financial stability. Nonetheless, their research emphasizes that this adverse effect can be moderated by considering factors such as financial regulation, institutional quality and market structure. Ghosh (2022) further elucidates the positive link between financial inclusion and financial stability, even in the presence of interest rate repression[1].

Based on the discussion above, the relationship between financial inclusion and financial stability remains a subject of ambiguity and uncertainty. Although previous empirical studies have predominantly focused on the positive implications of financial inclusion for financial stability, the potential negative impact has often been overlooked or inadequately examined. Our analysis emphasizes key theoretical studies, notably those by Khan (2011), and Josè and Garcia (2016), which suggest a non-monotonic association between financial inclusion and the stability of the financial system. These studies underscore that a moderate level of financial inclusion serves as a stabilizer for the financial sector by diversifying funding sources, expanding the deposit base, and enhancing credit access. Nevertheless, as financial inclusion progresses excessively, it can transform into 'bad finance,' characterized by inefficient resource allocation, excessive and disorderly lending, thereby undermining financial stability. This dynamic implies the existence of a 'critical threshold' in the development of inclusive finance. If so, it is crucial to determine at what level this weakening begins and to understand how to reduce or eliminate the negative impacts. In this vein, this article aims to examine the potential

[1] For a more detailed insight, a selection of empirical studies is presented in Table I.

of a nonlinear relationship between financial inclusion and financial stability in a sample of 24 developing countries over the period 2004-2020.

By doing so, this paper contributes to the existing literature in several ways: (1) To our knowledge, this study is among the few that examine the nonlinear effect between financial inclusion and financial stability, particularly in developing countries. These nations merit special attention due to the precarious supervisory framework of their banking institutions in the early stages of financial evolution (Barik and Pradhan, 2021). (2) In contrast to current studies, this paper utilizes a dynamic panel threshold model (DPTR), as proposed by Seo and Shin (2016). This method offers several advantages compared to traditional approaches prevalent in the existing literature. Firstly, the dynamic panel threshold regression identifies the threshold value capable of capturing nonlinearity, where shifts in the direction of the relationship between financial inclusion and financial stability are pronounced. Linear regression models may fail to detect such nonlinearity and may introduce downward bias in estimating the relationship between financial inclusion and financial stability. Additionally, the inclusion of polynomial expressions to investigate threshold effects, which can cause multicollinearity problems, renders the dynamic panel threshold regression a suitable approach. Secondly, this method quantifies the threshold value, thereby providing precise values and their level of significance, thus enriching our understanding of the dynamics of this relationship. Thirdly, this approach addresses endogeneity issues that may arise when unobserved or omitted variables affect the dependent variable. By incorporating lagged values of the dependent variable as regressors, dynamic panel data analysis controls for unobserved heterogeneity (Xue, 2020). To the best of our knowledge, no study employs this approach in this specific context.

The remaining sections of the paper are organized as follows. Section 2 presents a description of the data. Section 3 explains the dynamic panel threshold analysis. Section 4 discusses the main empirical results. Section 5 concludes with a summary of findings and implications for policymakers.

2. Data set and variables measures

This paper aims to examine the impact of financial inclusion on financial stability, employing data from 24 developing countries[2] over the period 2004-2020. The relevant data on variables of interest are collected from World Bank World Development Indicators (WDI), International Monetary Fund (IMF) and Refinitiv Eikon DataStream-Financial Data. List of banks can be found in the appendix[3].

Building upon the study of Barik and Pradhan (2021), the present paper employs the Principal Component Analysis (PCA) technique to construct a financial inclusion index. This index is formed by amalgamating six distinct sub-indices, aligning with their dimensions. Specifically, for the accessibility dimension, the analysis incorporates: the density of commercial bank branches and Automated Teller Machines (ATMs) per 1000 km² (BB_Km² and ATM_Km², respectively) and the density of commercial bank branches and ATMs per 100,000 adult

[2] In accordance with the classifications by Standard & Poor's and MSCI, the scope encompassing developing nations comprises the following countries: Argentina, Brazil, Chile, China, Croatia, the Czech Republic, Egypt, Hong Kong, India, Indonesia, Kenya, Malaysia, Mexico, Pakistan, Peru, the Philippines, the Federation of Russia, Saudi Arabia, Tunisia, South Africa, Thailand, Turkey, Hungary, Poland.

[3] Refer to Table X.

inhabitants (BB_POP and ATM_POP, respectively). Regarding the usage dimension, the study integrates variables such as the percentage of GDP represented by the volume of credits and current deposits in the private sector (OLC and ODC, respectively).

Following Ahamed and Mallick (2019), the financial inclusion indices for each country have undergone normalization on a scale ranging from 0 to 1. A value of 0 indicates a state of financial exclusion, whereas a value of 1 signifies the achievement of full financial inclusion. The findings of the Principal Component Analysis applied to each financial inclusion indicator are presented in Table II.

(Insert Table II about here)

Financial stability, represented by the Z-score, is assessed using the Banks Z-score ratio. This measure has been widely used in previous studies (Fang et al., 2014; Ahamed and Mallick, 2019). In accordance to the literature, a set of control variables is incorporated, including: logarithm of total assets (Bank size), ratio of banking performance (ROE), and inflation rate (Inflation). The definitions and data sources of all variables are outlined in Table III. Descriptive statistics for all variables are presented in Table IV.

(Insert Table III about here)

(Insert Table IV about here)

3. Methodology: Dynamic Panel Threshold Regression

To investigate the nonlinear effect of financial inclusion on financial stability, models that fail to capture non-linearity may introduce a downward bias in estimating the relationship between these variables (Arcand et al., 2015). Furthermore, including a quadratic term can exacerbate multicollinearity issues, potentially leading to misleading outcomes (Zouaoui et al., 2018). This study employs the dynamic panel threshold regression (DPTR) method, introduced by Seo and Shin (2016). The DPTR method allows for the detection of non-linearity and the determination of the precise threshold value at which the effect of financial inclusion on financial stability changes direction, while also accounting for potential endogeneity. This approach extends the panel transition model (PTR) proposed by Hansen (1999) by establishing an empirical model with a one-year lag for the variable of interest (financial inclusion). Formally, the dynamic panel threshold model is presented as follows:

$$\begin{aligned}\mathbf{Z\_score_{it}} = (&\beta_1 \mathrm{Z\_score_{it-1}} + \beta_2 \mathrm{Financial\_Inclusion_{it}} + \beta_3 \mathrm{SIZE_{it}} + \beta_4 \mathrm{ROE_{it}} + \\ &\beta_5 \mathrm{INFLATION_{it}})\, \mathrm{I}\{q_{it} \le \gamma\}\, (\lambda_1 \mathrm{Z\_score_{it-1}} + \lambda_2 \mathrm{Financial\_Inclusion_{it}} + \lambda_3 \mathrm{SIZE_{it}} + \\ &\lambda_4 \mathrm{ROE_{it}} + \lambda_5 \mathrm{INFLATION_{it}})\, \mathrm{I}\{q_{it} > \gamma\} + \varepsilon_{it} \qquad (1)\end{aligned}$$

Where $\mathbf{Z\_score_{it}}$: implies the financial stability measure, $\mathbf{Z\_score_{it-1}}$: presents lagged term of financial stability. $\mathbf{Financial\_Inclusion_{it}}$: measure of financial inclusion of the country (i) at year (t). Banking size ($\mathbf{SIZE_{it}}$), banking performance ($\mathbf{ROE_{it}}$), inflation rate ($\mathbf{INFLATION_{it}}$) as a vector of control variables. I{.} is the indicator function used to specify the regime. q_{it} : represents the threshold variable (Financial inclusion), γ: is the threshold parameter. β and λ respectively denote the coefficients of all independent variables for the

lower and upper regimes. The $\varepsilon_{it}(\varepsilon_{it} = \mu_{it} + v_{it})$ represent an error component, where v_{it} : is the idiosyncratic random disturbance. μ_{it}: denotes the individual fixed effects. For more detailed model information, please refer to Seo and Shin's (2016) study. The definitions and data sources of all variables are outlined in Table III.

(Insert Table III about here)

4. Empirical Results and discussion

4.1 Panel Unit root test results

In order to ascertain the suitability of the variables for panel threshold estimation, an initial stationarity test is conducted. This involves employing three panel unit root tests: the augmented Dickey-Fuller (ADF) test, the Phillips-Perron (PP) Fisher-Type unit root test, and the Im, Pesaran, and Shin (2003) test (IPS). The results of these tests indicate the stationarity of the variables at a significance level of 1%. Detailed results of the panel unit root tests can be found in Tables VI and VII.

(Insert Table VI about here)

(Insert Table VII about here)

4.2 Results of the Dynamic Panel Threshold Regression Model

The impact of financial inclusion on financial stability in developing countries, as evident from the findings presented in Table VIII (Eq. (1)), demonstrates a nonlinear relationship. The estimated threshold value is calculated to be 0.146, accompanied by a 95% confidence interval of (0.099, 0.193). The coefficient exhibits a positive and statistically significant association at the 1% significance level. This implies that an inclusive banking sector enhances financial stability by increasing the proportion of customer deposits used for funding and by mitigating the operational expenses linked with delivering banking services. Indeed, financial institutions view the incorporation of more people into the financial system as a strategy to accumulate substantial and secure deposits, primarily those that are low in risk and cost-effective. This offers them a considerable opportunity to decrease their dependence on unstable and frequently expensive funds from the money market. The enhancement of financial inclusivity also serves as a tool to curtail the incremental expenses associated with generating various yields. This, in turn, adds to the enhanced capacity of banks to set prices competitively and fortify their overall stability.

Nonetheless, surpassing the threshold of 0.146 results in a significant reversal of the influence of financial inclusion on banking stability, with statistical significance at the 1% level. This inflection point suggests that excessively high levels of financial inclusion might exert pressure on financial stability, potentially resulting in overleveraging or misallocation of resources. In particular, financial inclusiveness amplifies the scope for heightened lending, which, in turn, triggers complexities like moral hazard post-lending and intricacies related to asset substitution (Barik and Pradhan, 2021). However, the surge in credit provisioning by banks over time stems directly from the implementation of extensive financial inclusion policies. Consequently, the rise in the number of borrowers is correlated with a heightened likelihood of defaults. As a

result, the proliferation of inclusivity measures within the financial system poses a risk to its stability.

Moreover, developing nations grapple with insufficient or absent oversight within the banking sector. With inadequate strides in technology and a dearth of proficient bank personnel, the act of monitoring and regulating banking activities becomes intricate. Additionally, in developing nations, individuals inhabiting the realm of extreme poverty frequently lack a consistent income structure, introducing complexities when it comes to repaying bank loans at computed interest rates. As a result, governments in these countries frequently introduce loan forgiveness programs specifically designed for agriculturalists, recognizing their difficulties in meeting repayment obligations. Besides, the rapid credit expansion driven by heightened financial inclusion can create bubbles in asset markets, leading to price volatility and potentially financial crises. These bubbles can pose significant risks to the stability of the overall financial system. In effect, within developing countries, the financial framework becomes vulnerable when rapid credit expansion unfolds amongst economically disadvantaged and marginalized sectors of society, further exacerbated by the fragility of banking oversight. This underscores the critical significance of maintaining a balanced degree of financial inclusion to ensure sustainable financial stability in developing economies. Our findings substantiate the theoretical predictions put forth by Khan (2011) and Josè and Garcia (2016). Furthermore, the results demonstrate that all control variables considered in this analysis exhibit statistical significance, particularly within the upper regime, at the 1% level.

(Insert Table VIII about here)

4.3 Robustness test

In the subsequent phase of analysis, a robustness assessment is performed to investigate the sensitivity of the initial findings. This evaluation involves the adoption of an alternative measure of financial stability to ensure the reliability and consistency of our results.

Building upon the works of Sufian and Noor (2009), Mustafa et al., (2012), the current study employs the Loan Loss Provision index (LLP) to capture the degree of bank credit risk. The LLP index serves as a proxy for the prospective financial burden that banks might face due to forthcoming defaults in payments. This measure is calculated as a quotient between provisions set aside for potential loan losses and the aggregate sum of loans extended by the banks. The findings of the dynamic panel threshold model, as presented in Table IX, robustly reaffirm the presence of nonlinear relationship between financial inclusion and financial stability. This supportive evidence consistently aligns with previous scholarly investigations, exemplified by the studies of Khan (2011), Hua et al., (2023). Remarkably, the computationally derived threshold point is precisely situated at 0.025. This pivotal value signifies that financial inclusion initially mitigates the credit risk faced by banks, until an optimal threshold is reached. Beyond this threshold, the increase in the degree of financial inclusion corresponds to a marked elevation in the associated level of banking credit risk. Indeed, financial institutions may extend credit to borrowers with higher risk profiles, increasing the probability of loan defaults. This requires banks to allocate greater provisions for loan loss reserves to accommodate the anticipated rise in defaulted loans, which can pose adverse consequences for their financial stability.

(Insert Table IX about here)

5. Conclusion

Using a broad sample of 131 banks operating in 24 developing countries over the period 2004-2020, the present study examines the dynamic relationship between financial inclusion and financial stability. To overcome identified limitations in the existing literature, an advanced analytical approach is applied, specifically the dynamic panel threshold model (DPTR). Our empirical results reveal an inverted U-shaped relationship between financial inclusion and financial stability. Specifically, an increase in the level of financial inclusion reinforce financial stability, particularly within the lower regime. Nonetheless, at higher levels of financial inclusion, a significant decrease in financial stability is observed. The inverse relationship associated with financial inclusion is underscored by escalated levels of outstanding credit to the private sector relative to GDP, increased risk-taking behavior, inefficient resource allocation, credit default risks, and regulatory oversight deficiencies prevalent in developing economies. This research contributes empirical validation to the theoretical frameworks proposed by Khan (2011), and Josè and Garcia (2016), emphasizing the presence of a nonlinear effect of financial inclusion on financial stability. Overall, our findings remain robust to alternative measure of financial stability. This research advances novel perspectives on the nexus between financial inclusion and financial stability, presenting empirical evidence that this relationship defies simplistic linearity.

The conclusions of our study offer crucial guidance to financial regulatory authorities operating in developing economies. The identified critical thresholds can serve as key benchmarks for policymakers aiming to establish a robust financial infrastructure. Urgent measures are required to strengthen regulations, particularly concerning credit distribution across sectors to mitigate concentration risks and promote equitable credit allocation. Initial loans should be granted in small amounts, with regular monitoring of financial reports to assess the impact of financial inclusion on financial health. Furthermore, it is imperative to explore innovative approaches that balance financial inclusion with stability. This includes implementing responsive policies, fostering self-regulation within financial institutions, and providing comprehensive training and supervision to enhance market regulation. Policymakers should also consider incentivizing secure sharing of client data within regulated frameworks to address information asymmetry issues. Establishing collaborative platforms among regulatory bodies is crucial for coherent oversight and understanding local financial dynamics. Sharing financial data enhances monitoring capabilities and facilitates early risk detection, which is essential for maintaining stability. Implementing risk detection programs based on identified thresholds is vital for proactive monitoring of the financial system, enabling regulators to intervene as risks approach critical levels. Such preventive measures are crucial for mitigating default risks, particularly in developing countries. Finally, emphasizing financial education as a fundamental pillar is essential. This involves not only improving financial literacy among citizens but also increasing awareness of responsible financial practices. A well-informed public is better prepared to make informed decisions, thereby enhancing financial stability. In future research endeavors, it is imperative to prioritize the exploration of supplementary strategies, particularly focusing on measures of digital financial inclusion.

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Appendix

Table I. Empirical investigations into the relationship between financial inclusion and financial stability

Authors	Years of work	Approches	Key findings
Morgan and Pontines (2014)	Panel data 2005-2011	System (GMM) dynamic panel Model	By increasing lending to MSEs, financial inclusion contributes positively to financial stability.
Han and Melecky (2017)	Sample of 95 countries for the period of 2007-2010	System dynamic panel Estimation (GMM model)	Financial inclusion reinforce financial stability.
Al-Samadi (2018)	The Central Bank of Jordan from 2006 to 2017	Fully Modified Least Squares (FMOLS) method	Financial inclusion has a positive impact on financial stability.
Chen, Feng and Wang (2018)	31 Chinese provinces from 2005 to 2016	Panel fixed effect model	Financial inclusion has a negative impact on the non-performing loans of commercial banks.
Siddik and Kabiraj (2018)	Panel data 2001-2013	System (GMM) dynamic panel Estimation	Promoting financial inclusion through MSE borrowers and loans yields a beneficial impact on financial stability.
Ahamed and Mallick (2019)	2635 banks were sampled across 86 countries from 2004 to 2012	OLS, quantile regression and System (GMM) dynamic panel method	Financial inclusion exhibits a positive relationship with financial stability especially in countries with robust institutional quality.
Vo, Nguyen and Hang-Van (2020)	Sample of 3071 banks in all Asian countries for the period 2008-2017	OLS and GMM estimation	Financial inclusion contributes positively to financial stability.
Alvi, Rafique, and Shehzad (2020)	Sample of 88 banks form South Asian over the period 2012-2018.	Two-step system GMM	Positive impact of financial inclusion on financial stability.
Barik and Pradhan (2021)	BRICS countries, during the period 2005-2015	System (GMM) dynamic panel estimation	Financial inclusion has a detrimental impact on banking stability.
Risman, Mutyana, Silvatika and Sulaeman (2021)	Sample of 120 banks from Indonesia spanning the period 2010 and 2019	Multiple Linear regression model and Moderating regression analysis (MRA)	Digital finance, through increased financing, has a positive impact on financial stability.
Feghali, Morra and Nassif (2021)	International scale for three years (2011, 2014, 2017)	Panel regression with fixed effects, 2SLS	Financial inclusion exerts a neutral or positive influence through improved access to payment and savings accounts, while it exerts a negative impact through increased access to credit on financial stability. Moreover, a competitive market structure amplifies the detrimental effects of credit inclusion on financial stability.
Hua, Bi and Shi (2023)	Sample of 115 countries, over the period 2004-2019	OLS, Tobit, Instrumental variables.	An inverted U-shaped relationship between financial inclusion and systematic risk. Efficient macro-regulation can alleviate the adverse effect of financial inclusion on financial stability.

Source: The table has been prepared by the authors.

Table II. Principal component analysis: Financial Inclusion index of developing countries

	PC_1	PC_2	PC_3	PC_4	PC_5	PC_6
Eigen values	3.729	1.481	0.438	0.321	0.023	0.007
Percentage of variance	0.622	0.247	0.073	0.053	0.004	0.001
Cumulative percentage	0.622	0.869	0.942	0.995	0.999	1.000
Variables	**Comp_1**	**Comp_2**	**Comp_3**	**Comp_4**	**Comp_5**	**Comp_6**
OLC	0.473	0.025	-0.040	-0.699	0.522	0.115
ODC	0.504	-0.082	0.050	-0.280	-0.807	-0.083
BB_Km²	0.486	-0.154	0.065	0.494	0.080	0.697
BB_POP	0.195	0.650	-0.714	0.161	-0.041	-0.035
ATM_Km²	0.493	-0.144	0.114	0.403	0.262	-0.702
ATM_POP	0.067	0.725	0.684	0.033	-0.004	0.027

Note. All variables are presented in Table III.

Table III. Definitions and sources of variables

Variables	Definition	Sources
Z_score	The Z-score index is an inverse proxy for the probability of a bank's failure. A high index implies a low probability of insolvency. $$\text{Z\_score}_{it} = \frac{\text{ROA}_{it} + \text{EQA}_{it}}{\sigma(\text{ROA})_{it}}$$ Where ROA_{it} : represents the return on assets, EQA_{it}: signifies the equity-to-assets ratio, $\sigma(\text{ROA})_{it}$: denotes the standard deviation of the return-on-assets, calculated using a three-year rolling window.	DataStream, Authors' calculation
BB_Km²	Number of commercial bank branches per 1000 Km².	IMF
BB_POP	Number of commercial bank branches per 100.000 adults.	IMF
ATM_Km²	Number of ATMs per 1000 Km².	IMF
ATM_POP	Number of ATMs per 100.000 adults.	IMF
OLC	Outstanding Credits to private sector as a % of GDP.	IMF
ODC	Outstanding Deposit in private sector as a % of GDP.	IMF
SIZE	Logarithm of total assets.	DataStream, Authors' calculation
ROE	Return on Equity.	DataStream
INFLATION	Inflation rate index.	WDI

Note. WDI: denotes the World Bank's World Development Indicators database. IMF: International Monetary Fund. DataStream: Refinitiv Eikon DataStream-Financial Data. A list of banks can be found in appendix.

Table IV. Summary statistics

Variables	Obs	Mean	ST.D	Min	Max	Q1	Q3
Z_SCORE	1973	0.126	0.222	-0.258	3.445	0.033	0.132
Financial_Inclusion	2087	0.095	0.132	0	1	0.034	0.102
SIZE	2193	8.644	1.079	5.664	12.177	7.937	9.269
ROE	2157	0.168	0.206	-0.828	2.34	0.093	0.205
INFLATION	2142	0.052	0.040	-0.021	0.295	0.025	0.074

Note. The analysis reveals that the average financial stability stands at 12.6%, with a range spanning from -2.58% to 34.45%. Similarly, the financial inclusion variable exhibits a positive mean of 9.5%, characterized by a relatively higher volatility level at 13.2%. Among the control variables, the average banking size is recorded at 86.44%. The mean banking performance is calculated to be 16.8%. Meanwhile, the inflation rate demonstrates an average of 5.2%. All the variables can be found in Table III.

Table V. Correlation coefficients

	Z_score	Financial_Inclusion	SIZE	ROE	INFLATION
Z_score	**1.000**				
Financial_Inclusion	0.035	**1.000**			
SIZE	0.100	0.050	**1.000**		
ROE	0.089	-0.021	0.024	**1.000**	
INFLATION	-0.039	-0.255	-0.097	-0.102	**1.000**

Note. The following table presents the correlation matrix of all variables spanning the period 2004 to 2020 in developing countries. The results indicate that all correlation coefficients are below 0.5, suggesting the absence of multicollinearity issues and confirming the appropriateness of utilizing the dynamic panel threshold model. All variables are presented in table III.

Table VI. Unit root tests (Without trend)

	Levels			First Difference		
	ADF	PP	IPS	ADF	PP	IPS
Z_SCORE	-12.524***	-16.566***	-8.209***	-28.049***	-37.790***	
Financial_Inclusion	0.582	0.761	0.484	-7.536***	-16.150***	-6.432***
SIZE	-1.479	-6.380***	-0.386	-12.510***	-23.859***	-10.898***
ROE	-3.765***	-6.999***	-4.063***		-40.511***	-19.833***
INFLATION	-7.130***	-13.967***	-6.411***	-32.033***	-48.797***	-27.493***

Note. (***) denotes statistical significance at the 1% level. The Fisher (ADF) and Fisher (PP) panel unit root tests were suggested by Maddala and Wu (1999) and developed by Choi (2001), respectively. The IPS test was proposed by Im, Pesaran, and Shin (2003). This table reports the results of unit root tests conducted on all variables from developing countries over the period 2004-2020. The maximum number of lags is one. All variables are showcased in Table III.

Table VII. Unit root tests (With trend)

	Levels			First Difference		
	ADF	PP	IPS	ADF	PP	IPS
Z_SCORE	-10.709***	-11.262***	-6.787***	-20.777***	-31.864***	
Financial_Inclusion	1.814	6.709	3.776	-4.992***	-12.350***	-3.533***
SIZE	0.525	3.919	0.341	-12.438***	-23.964***	-9.680***
ROE	-5.965***	-9.372***	-6.261***	-17.683***	-35.198***	-14.277***
INFLATION	-8.396***	-15.571***	-6.869***	-24.237***	-41.056***	-19.898***

Note. (***) indicates statistical significance at the 1% level. The Fisher (ADF) and Fisher (PP) panel unit root tests were suggested by Maddala and Wu (1999) and developed by Choi (2001), respectively. The IPS test was proposed by Im, Pesaran, and Shin (2003). This table reports the results of unit root tests conducted on all variables from developing countries over the period 2004-2020. The maximum number of lags is limited to one. All variables are detailed in Table III.

Table VIII. The effect of financial inclusion on financial stability (Z_SCORE): A dynamic panel threshold regression

Variables	Lower regime	Upper regime
$\mathbf{Z\_SCORE_{t-1}}$	-0.055*** (0.000)	0.156*** (0.000)
Financial_Inclusion	**1.145***** (0.000)	**-0.258***** (0.000)
SIZE	-0.081*** (0.000)	-0.107*** (0.000)
ROE	0.049 (0.139)	0.149*** (0.000)
INFLATION	-0.286*** (0.000)	-0.551*** (0.006)
Constant	1.241*** (0.000)	
Threshold	**0.146***** (0.000)	
Confidence interval	[0.099 , 0.193]	
LR	0.000	
N-T	51-16	
Number of countries	24	
Number of Banks	131	

Note. This table reports the result of a dynamic panel threshold regression, as shown in Eq. (1). The LR test applied in this study yields a test statistic with an approximate p-value of 0.000. Furthermore, the distinct results of the threshold test, depicted in Figure 1, affirm the suitability of adopting the dynamic panel threshold model. The definitions of all variables are provided in Table III. *** indicates variable significance at the 1% level. The values within parentheses represent the corresponding p-values.

Table IX. Dynamic panel threshold analysis using alternative measure of financial stability (LLP)

Variables	Lower regime	Upper regime
LLP_{t-1}	-0.133** (0.040)	0.749*** (0.000)
Financial_Inclusion	**-0.201***** (0.000)	**0.142***** (0.003)
SIZE	0.004* (0.058)	0.004 (0.197)
ROE	-0.026*** (0.001)	0.071*** (0.000)
INFLATION	0.0008 (0.989)	-0.835*** (0.000)
Constant	0.024 (0.392)	
Threshold	**0.025**** (0.031)	
Confidence interval	[0.002, 0.05]	
LR	0.000	

Note. This table presents the result of a dynamic panel threshold model, Eq. (1). Table III provides the definitions for all variables. **LLP**: Loan Loss Provision index. The non-linear test result is presented in Figure 2. ***, ** denote variable significance at the 1% and 5% levels, respectively. The values in parentheses correspond to the associated p-values.

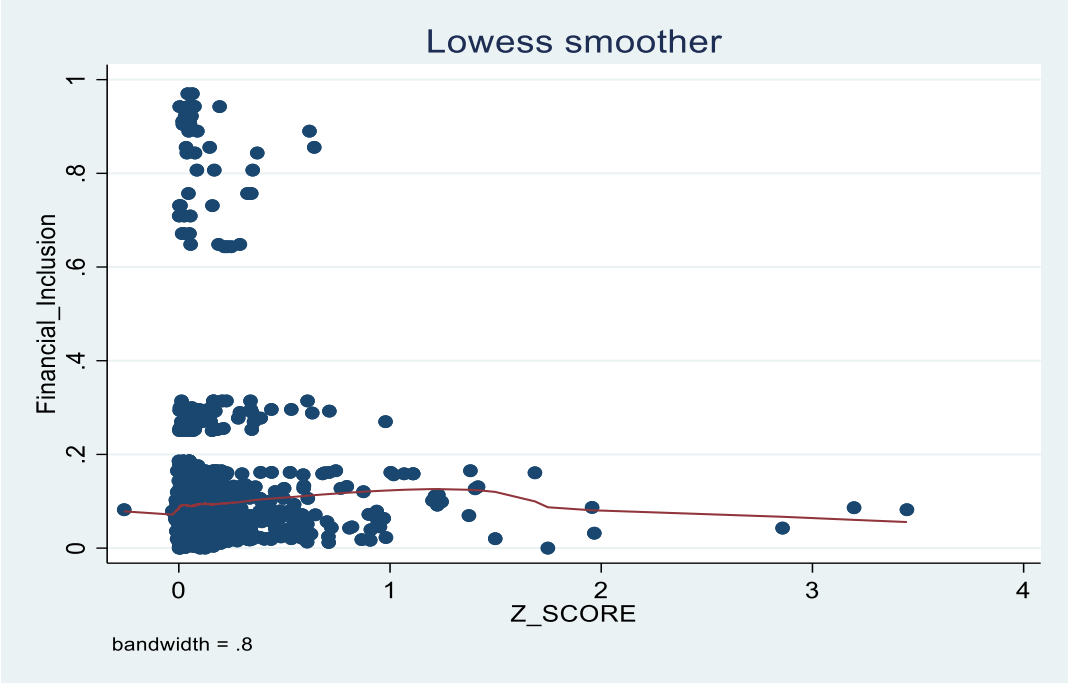

Figure 1. Nonlinear test of financial inclusion and financial stability (Z_SCORE)

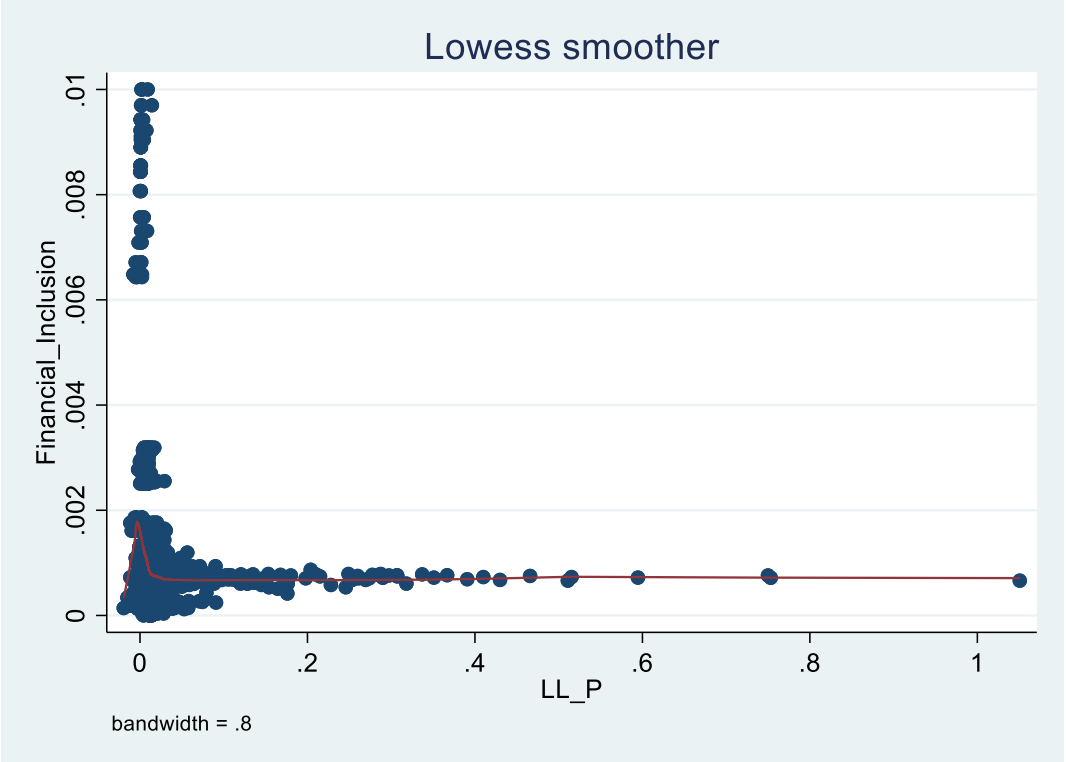

Figure 2. Nonlinear test of financial inclusion and financial stability (LLP)

Table X. List of Banks

ABSA BANK - ABSA GROUP LTD - AKBANK TAS - AL RAJHI BANK - ALLIED BANK LTD - ARAB NATIONAL BANK - ASKARI BANK LIMITED - AXIS BANK - BAJ BANK - BANCO BBVA ARGE - BANCO BBVA PERU - BANCO DA AMAZONIA SA - BANCO DE CHILE - BANCO DE CREDITO - BANCO DO NORDE - BANCO HIPOTECARIO SA - BANCO MACRO - BANCO PAN SA - BANCO PATAGONIA S.A. - BANCO PINE SA - BANCO SANTANDER - BANCO SANTANDER MEX - BANGKOK BANK LIMITED - BANK ALFALAH LTD - BANK DANAMON INDO - BANK HANDLOWY - BANK MAYBANK - BANK MILLENNIUM SA - BANK NEGARA - BANK OCHRONY - BANK OF AYUDHYA PCL - BANK OF BARODA - BANK OF CHINA LTD - BANK OF COMMN - BANK OF EAST ASIA - BANK OF INDIA LTD - BANK OF MAHARASHTRA - BANK PAN INDONESIA - BANK PEKAO - BANK QNB - BANK RAKYAT INDO - BANK RAYA - BANK SANKT - BANK URALSIB - BANK VTB PAO - BANK ATTIJARI - BANK INTERNAT - BANK SAUDI FRANSI - BDO UNIBANK - BOC HONG KONG - CANARA BANK - CAPITEC BANK - CENTRAL BANK - CHINA CONSN - CHINA MERCHANTS BANK - CHINA MINSHENG BANK - CHINA ZHESHAN - CIMB GROUP HOLDIN - CIMB THAI BANK PCL - CITIC BANK - COMMERCIAL INTL BANK - CREDITO E INVERSION - DIAMOND TRUST BANK - EGYPTIAN GULF BANK - FAYSAL BANK LIMITED - FIRSTRAND LIMITED - GRUPO FINANCIERO ARG - GRUPO FINANCIERO MEXICO - HABIB BANK LTD - HANG SENG BANK LTD - HDFC BANK LIMITED - HONG LEONG BANK BHD - HONG LEONG FIN - ICICI BANK LIMITED - INDUSTRIAL AND COMM - ING BANK SLASKI SA - ITAU CORPBANCA - ITAU UNIBANCO - KASIKORNBANK PLC - KCB GROUP PLC - KIATNAKIN BANK - KOMERCNI BANKA, A.S - KOTAK MAHINDRA BANK - KRUNG THAI BANK PCL - MALAYAN BANKING BHD – MBANK - MCB BANK LTD - METROPOLITAN BANK - NATIONAL BANK - NATL BK OF PAKISTAN - NEDBANK GROUP LTD - OTP BANK NYRT - PHIL BANK OF COM - PHILIPPINE NAT'L BK - PHILIPPINE SAVINGS - PHILTRUST BANK - PING AN BANK - PUBLIC BANK BHD - QATAR NATIONAL BANK - QNB FINANSBANK AS - REGIONAL SAB DE - RHB BANK BHD - ROSBANK PAO - SANTANDER BANK - SAUDI BRITISH BANK - SBERBANK ROSSII – SCOTIABANK - SCOTIABANK CHILE - SECURITY BANK – SEKERBANK - SONERI BANK LTD - STANBIC HOLDINGS - STANDARD BANK GRP - STANDARD CHARTERED - STANDARD CHARTERED PAKISTAN - STATE BANK OF INDIA - THANACHART CAPITAL - TISCO FINANCIAL - TMB BANK PCL - TURKIYE GARANTI BANK - TURKIYE HALK BANKASI - TURKIYE IS BANKASI - TURKIYE KALKINMA - TURKIYE SINAI KALK - TURKIYE VAKIFLAR –UNION BANK OF TUNISIA - UNION BANK OF PHILIPPINE - UNION BANK OF INDIA - UNITED BANK LIMITED - YAPI VE KREDI - ZAGREBACKA BANKA.

Source. The list of banks is collected from Datastream.